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# The role of civic amenities in the residential satisfaction in apartment-housing localities of Prague

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**ABSTRACT**
This article employs the quantitative research of residential satisfaction in two localities in Prague with different civic amenities. The results show that the presence of civic amenities in the neighbourhood has a significant effect on residential satisfaction, which is comparable to the importance of the quality of housing and the perceived quality of the neighbourhood. The relationship between the presence of civic amenities and residential satisfaction is affected by differences in the perceived importance of amenities between the residents of housing estates and suburbs, and by the position of households in the household life cycle.

**KEYWORDS**
residential satisfaction; civic amenities; Prague; housing estate; suburb

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## 1. Introduction

Accessibility and quality of civic amenities in neighbourhoods are often pinpointed as an important component of residential satisfaction in general (Lovrich, Taylor 1976; Lu 1999; Dekker et al. 2011). Nevertheless, it is essential to be aware that dissimilar households demand different service utilisation, or they put diverse weights to civic amenities as such. Swindell and Kelly (2005: 709) are properly asking: "What, then, is the relationship between service outputs (distributions) and service outcomes (citizen satisfaction)? No one fully knows the answer to this deceptively simple question." Therefore, the aim of this paper is to scrutinise so far neglected relations of residential satisfaction components whereas the emphasis is given to the meaning of civic amenities.

– Nowadays, migration attractiveness of Czech capital is reflected in growing densification of housing development as well as its sprawl to the surrounding landscape. While in the urban areas the inhabitants of new residential quarters often enjoy a variety of existing infrastructure such as groceries, social services, or public transport, in Prague's suburbs, their presence is rather insufficient for the daily use. Therefore, for investigation of the relationship between residential satisfaction and the presence of civic amenities, two new apartment-housing projects of an unequal position towards the compact city have been chosen. To sum up, this paper pursues to answer these questions: How the evaluation of various components of residential satisfaction, mainly with civic amenities, differs according to the different types of households, inhabiting the dissimilarly situated localities of new apartments houses?

– How is satisfaction with civic amenities reflected in overall residential satisfaction in comparison with its other components?

This paper is structured as follows. At first, the concept of residential satisfaction is defined and divided. Attention is mainly paid to relationships between various components of residential satisfaction, civic amenities and residential environment of housing estates and suburbs. Next parts introduce both research localities and explain chosen methods of research and the process of data gathering. The quantitatively focused research rests on the statistical analysis of data from the questionnaire survey. Subsequently, the empirical part is dedicated to the data analysis and interpretation of results, followed by the discussion of the theoretical embedding of the paper. Finally, the above-mentioned research questions are answered in the conclusion.

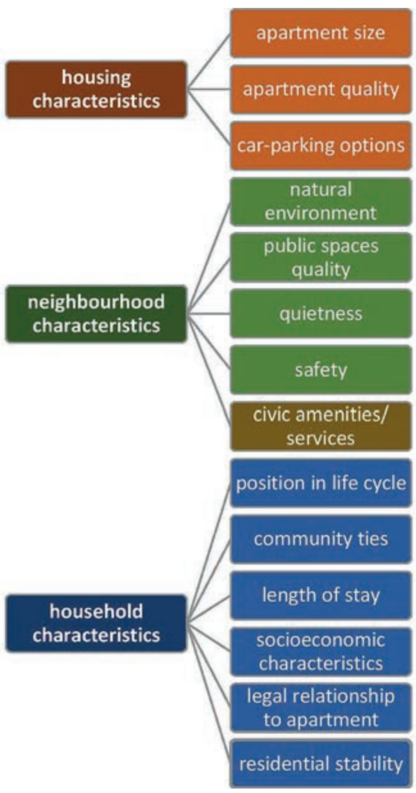


**Fig. 1** The division of residential satisfaction components. Sources: Galster (1987); Lu (1999); own elaboration

## 2. Residential satisfaction as theoretical concept

Residential satisfaction is one of the most important elements influencing the satisfaction of human beings with life (Lu 1999; Parkes et al. 2002). It is usually defined as one's own evaluation of the place of residence and its surroundings that alters according to the unique set of characteristics of households (e.g. Amérigo, Aragones 1997). However, amongst the authors who deal with this concept, there is neither consensus regarding the components which form residential satisfaction nor on the degree of their impact. It might be the consequence of the fact that residential satisfaction is always partly nurtured by the unique character of a territory (De Hoog et al. 1990; Parkes et al. 2002; Ren, Folmer 2017), differences in population samples, various definitions of used variables or statistical methods of their analysis (Lu 1999; Basolo, Strong 2002).

Residential satisfaction can be perceived as the intersection of many housing or neighbourhood features and individual characteristics of households which unequally influence the satisfaction of inhabitants with their place of residence. Galster (1987) and Lu (1999) distinguish the components of residential satisfaction between (1) *housing characteristics*, i.e. features of inhabited flat, (2) *neighbourhood characteristics*, i.e. features of adjoining surroundings and (3) *household characteristics*, i.e. features of households and their members (Fig. 1).

No less of importance is the division of components between objective and subjective dimension

(Amérigo, Aragonés 1997). While the objective components may be quantitatively measured, according to Campbell et al. (1976), residential satisfaction is rather the reflection of subjective perception of living environment that is created by objective characteristics along with features of households and their unique preferences and needs (also Weidemann, Anderson 1985; Lu 1999). Therefore, the relationship between objective reality and subjective evaluation is often weak (e.g. Stipak 1979; Marans 2003; Swindell, Kelly 2005; Dekker et al. 2011).

Hero, Durand (1985) or De Hoog et al. (1990) introduced calculation models of residential satisfaction based on objective components. In these models, for example, satisfaction with safety is substituted by the quantity of offenses that, however, as the objective components does not have to correspond to subjective perception (Basolo, Strong 2002). Similarly, Lu (1999: 268) emphasises that "objective measures of housing and neighborhood attributes alone do not provide an adequate explanation of satisfaction."

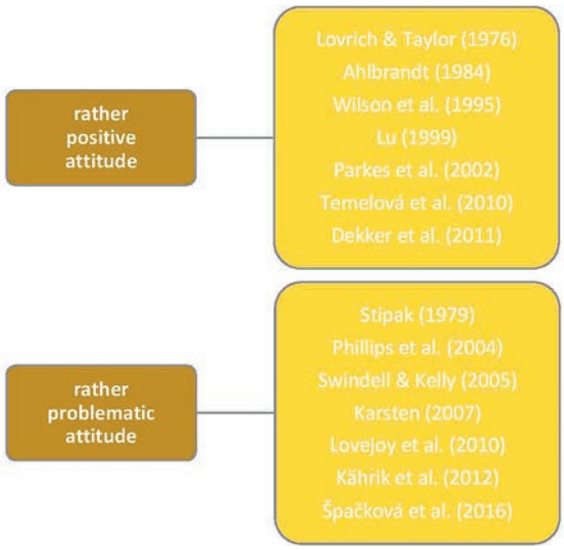


**Fig. 2** Authors' attitudes to the relationship between civic amenities and residential satisfaction.
Source: own elaboration

## 3. Civic amenities in residential satisfaction studies

According to the Czech law, civic amenities are defined as facilities for education, social and health care, culture, administration, retail, sport and spa, accommodation, dining, science and research or transport and technical infrastructure (similarly Musil 1985). However, in a lot of both Czech and foreign papers that deal with residential satisfaction, civic amenities are considered as services and aim for those that are used frequently and by larger groups of population (e.g. Gruber, Shelton 1987; Phillips et al. 2004; Kährik et al. 2012 or Špačková et al. 2016). Therefore, in residential satisfaction research, civic amenities and services may be considered as synonyms.

Accessibility and quality of civic amenities (or services) play a fundamental role in the urban way of life (Parkes et al. 2002) and are often pinpointed as an important component of residential satisfaction in general (Lovrich, Taylor 1976; Ahlbrandt 1984, in Basolo, Strong 2002; Lu 1999; Dekker et al. 2011). Parkes et al. (2002) assert that appropriate services might also contribute indirectly, for instance, by providing a platform for social interaction between inhabitants and, thus, lead to higher satisfaction with social relationships in neighbourhood (see also Hero, Durand 1985; Temelová et al. 2010). However, Swindell and Kelly (2005) asserts that civic amenities as a component of *residential quality of the environment* is not always clearly reflected in residential satisfaction even though in other views it may have a positive effect (see Fig. 2).

Firstly, Stipak (1979) emphasises that dissimilar groups of inhabitants may have as for civic amenities different demands and expectations which influence the evaluation of their quality. Secondly, different services might contribute to residential satisfaction diversely. For example, Wilson et al. (1995, in Dekker et al. 2011) and Temelová et al. (2010) attribute significance to grocery stores. Thirdly, Phillips et al. (2004) assert that the quality of services plays only a marginal role besides the more significant degree of importance. Forthly, amongst the clinchers of residential satisfaction also belongs awareness about that service inside a neighbourhood (Swindell, Kelly 2005) or one's own experiences with its utilisation (Gruber, Shelton 1987; Dekker et al. 2011).

Further on, Vackářová (2014: 19) emphasises that "it depends not only on the existence of that facility … but also on its allocation, quality of transportation network, size of a buffer zone or its capacity." The connexion between accessibility of civic amenities and residential satisfaction is often further limited by *the concept of marginal utility* when the occurrence of each additional service in a neighbourhood does not bring the same benefit as the first of them (Vackářová 2014). Similarly, Stipak (1979) notes that higher quality of services may not entail the proportional growth of residential satisfaction.

## 4. Residential environment of post-socialist housing estates

Regarding housing estates neighbourhoods in post-socialist cities, residential satisfaction is, according to Wilson (1995, in Dekker et al. 2011) or Temelová et al. (2010), connected to the accessibility of services, mainly grocery stores or adequate public transport. Similarly, the residential environment of housing estates is enhanced by the accessibility of nature (Musterd, van Kempen 2005; Temelová et al. 2010). Although in the quality of public spaces are the post-socialist housing estates usually behind those in Western Europe, in the domain regarding residential satisfaction with civic amenities get on usually better (Musterd, van Kempen 2005).

However, the physical proximity of various kinds of civic amenities often relates to certain drawbacks such as anonymity (Wirth 1938, in Parkes et al. 2002), noise (Musterd, van Kempen 2005; Karsten 2007), the occurrence of untrustworthy individuals (Temelová et al. 2010) or inappropriate environment for children's leisure in general (Newman, Duncan 1979; Swindell, Kelly 2005). Furthermore, former spaces of retail are sometimes commercially misused (Maier 2003). Karsten (2007) adds that the physical proximity of services might not imply their simple accessibility for the less mobile population.

Housing estates in Prague may presently profit from good accessibility of basic services albeit they became often available after the construction of panel houses had been already finished (Musil 1985). During the last three decades, newly emerged market forces have further contributed to the improvement of civic amenities therein (Temelová et al. 2010; Dekker et al. 2011). Nevertheless, the local housing estates even presently often lack civic amenities related to cultural life and leisure in general (Musil 1985; Havlíčková 2015) or the sufficient capacity of kindergartens or primary schools (Maier 2003).

## 5. Residential environment of post-socialist suburbs

The intensive process of suburbanisation of Prague which has taken place since the second half of the 1990s brings besides movements of the population also several problems with local infrastructures (Kährik et al. 2012; Špačková et al. 2016). This usually entails the insufficient capacity of educational facilities, poor public transport or the lack of grocery stores, healthcare facilities or restaurants in suburban localities (e.g. Špačková, Ouředníček 2012; Kostelecký 2016). While less mobile population might create demand for civic amenities inside the locality (Klápště et al. 2012), other residents are reconciled with commuting on daily basis (Morrow-Jones et al. 2004; Kährik et al. 2012).

According to Kährik et al. (2012), the accessibility of civic amenities is, however, only a minor factor when households make their choice for a suburban locality. Amongst inhabitants who had been accustomed to the better-served environment of a city, however, at least some discrepancy between their expectations and the reality has been observed (Kährik et al. 2012; Špačková et al. 2016). Both Kährik et al. (2012) and Špačková et al. (2016) emphasise that despite the above-mentioned drawbacks, new suburbanites are usually satisfied with the quality of their residential environment.

Residential satisfaction in suburban localities is rather linked to a tranquil living environment, safety perception or accessibility of parking lots albeit usual comfortless condition of public spaces (Cook 1988, in Parkes et al. 2002; Havlíčková 2012). Newman and Duncan (1997) find the similar connexion only for family-house inhabitants who are likely more resistant to drawbacks of their neighbourhood. Finally, Lovejoy et al. (2010) point the mild influence of neighbourhood characteristics to residential satisfaction in a suburban environment in general and, on the contrary, emphasise the role of housing characteristics and the quality of educational facilities (see also Morrow-Jones et al. 2004).

## 6. Influence of life-cycle position and other characteristics of households

The different position of households in a life cycle is projected to their demands and needs which is consequently reflected in overall residential satisfaction (Hourihan 1984; Lu 1999; Phillips et al. 2004; Temelová et al. 2010; Grinstein-Weiss et al. 2011). The presence of children often helps to make social relationships within the neighbourhood which might be reflected in higher residential satisfaction of the household (e.g. Parkes et al. 2002). Conversely, the presence of children usually raises requirements of households for the optimal flat size (Dekker et al. 2011) and the quality of residential environment such as safety (Newman, Duncan 1979), educational facilities (Karsten 2007; Kostelecký 2016), grocery stores (Vackářová 2015) or playgrounds (Dekker et al. 2011).

Ren and Folmer (2017) add that the above-mentioned requirements are usually moderated by the perpetual presence of a woman at home who has an opportunity, owing to the higher amount of time spent in a locality, to become more socially integrated. On the other hand, the lack of time in households in which both parents work may, especially in the conditions of suburban areas, lead to commuting problems for children's activities (Karsten 2007). Therefore, it is understandable that while some authors have come to conclusion ascribing higher satisfaction to households with children in comparison to young childless households (Spain 1988, in Grinstein-Weiss et al. 2011; Lu 1999), others have come to statistically insignificant (Ren, Folmer 2017) or opposite results (Musterd, van Kempen 2005).

For older households, Temelová et al. (2010) emphasise that, due to restricted mobility, their residential satisfaction is more connected to services and the quality of community ties within a walking distance from their place of residence. The quality of apartments and the perception of safety are also of importance (Phillips et al. 2004). According to Phillips et al. (2004), fundamental civic amenities for seniors comprise grocery stores, social services or meeting spaces. Temelová et al. (2010) add also the accessibility of healthcare facilities.

Presence of the above-mentioned elements might function as a trigger for tight ties between older inhabitants, their place of residence and the time which they spend there (Golant 1984, in Temelová et al. 2010). In comparison to younger households, older households account for higher satisfaction values (Newman, Duncan 1974; Lu 1999). Parkes et al. (2002) find the reason in tighter embedding to a locality if an older household has been living there for a long time. Lovejoy et al. (2010) explain that by milder expectations and needs which may further decrease with the growing age.

The level of income may also be reflected in different expectations and demands in regard to civic amenities (Swindell, Kelly 2005). Sharp (1986, in De Hoog et al. 1990) mentions that the inhabitants of low-income localities more likely emphasises social services whereas those residing in high-income localities rather demand educational and recreational services (see also Gans 1967). Nevertheless, neither Lovrich and Taylor (1976) nor Stipak (1979) show the statistically significant relationship between the evaluation of civic amenities and socioeconomic characteristics.

The connexion between satisfaction with civic amenities and residential stability is also often solved. While Swindell and Kelly (2005) exhibit a positive relationship between these components, Špačková et al. (2016) find that relationship only for educational facilities, moreover, according to their own capacity (similarly Karsten 2007). Varady (1983) does not confirm for any of the civic amenities the statistically significant relationship regarding residential stability of households. Both Newman and Duncan (1979) and Špačková et al. (2016) notice the higher meaning of the position of a household in a life cycle or housing characteristics in comparison to the residential quality of the environment in which civic amenities undoubtedly belong to (Lee, Guest 1983; Temelová et al. 2010).

## 7. Research postulates and hypotheses

Based on the theoretical embedding can be assumed that better accessibility and quality of civic amenities will lead to higher satisfaction of inhabitants with

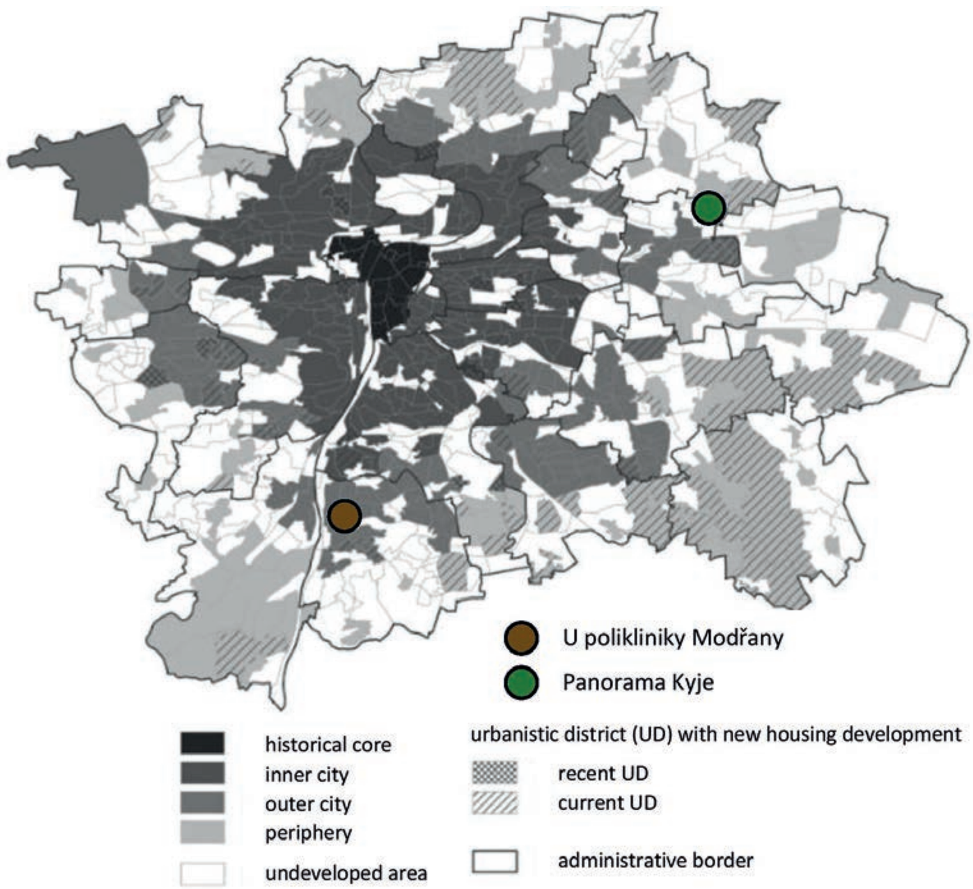


Fig. 3 Research localities and their position within Prague.
Source: Ouředníček et al. (2012); own elaboration

this component of residential satisfaction. Moreover, authors often assert that higher satisfaction with civic amenities is positively reflected in overall residential satisfaction. On the other hand, it is probable that the inhabitants of better-served localities will, due to increased concentrations of population and transport, suffer from the less favourable living environment. Lower satisfaction of residents with civic amenities might be thus compensated, for instance, by more tranquil and safe surroundings.

The relationships between households and their satisfaction with civic amenities in the neighbourhood are strongly influenced by the composition of households. Families with children will ordinarily demand the basic civic amenities such as educational and leisure facilities and grocery stores within the proximity of their home while for singles or young childless couples those will not be that important. According to presumptions, less mobile older households will also emphasise the accessibility or quality of civic amenities inside their neighbourhood, especially concerning grocery stores, healthcare facilities, leisure services or public transport.

## 8. Research localities

The usual methodical problem, when comes to research of relationships between residential satisfaction and civic amenities, is an excessively wide research area. The results are thus often distorted by the allocation of households within a larger area

**Fig. 4** U polikliniky Modřany (left).
Source: own photo (July 2018)

**Fig. 5** Panorama Kyje.
Source: own photo (May 2018)

where some spatial variability is obvious (Lovrich, Taylor 1976; Basolo, Strong 2002; Špačková et al. 2016). Therefore, the research localities containing apartment houses of high-density have been selected – (1) U polikliniky Modřany (further Modřany) and (2) Panorama Kyje (further Kyje). Figure 3 shows the position of both localities within Prague. They were built during the 2010s. Modřany, was developed on a remaining plot between a socialist housing estate and single-housing development in the outer city of Prague (Fig. 4). On contrary, Kyje was built in a tranquil and prevailingly single-housing setting farther from the city centre inthe peripheral (further suburban) zone of Prague. Kyje forms the coherent but spatially separated set of blocks (Fig. 5).

As for the types of apartments and the development density both localities are comparable. However, whereas in Modřany the spaces between buildings are filled with relaxation areas with maintained greenery and playgrounds, in Kyje those are parking lots, grasses or unused private gardens. On the other hand, the close surroundings of Kyje comprise ploughlands, meadows and unmaintained greenery whereas the proximity of Modřany is very busy due to the adjoining housing estate, its shopping mall, a health centre and ground-floor businesses (compare Figs. 4 and 5).

The physical accessibility of civic amenities is in both localities very unequal. The inhabitants of Modřany may, owing to the central placement of their apartment houses, profit from the walkable proximity of various services including a tram line to the city centre whereas the residents of Kyje have only a bus stop leading to a metro station. Therefore, the households of Kyje are much more dependent on motorised types of transport in commuting to services which, on the contrary, decrease the time distances.

Both housing developments are popular amongst young families with planned or born children who search for tranquil localities in the hinterland of Prague with better living environment (Ouředníček 2003; Čermák 2005; Špačková, Ouředníček 2012) as well as unary or unmarried households demanding the affordable housing in Prague (Ouředníček, Temelová 2009; Ouředníček, Novák 2012). Modřany has become slightly more favourite between families with children whereas Kyje is preferred by younger childless cohorts (Fig. 6). The shares of older residents are low in both localities, but the percentage raises a little at the end of the productive age. Interestingly, both localities are in their demographic structure very different in comparison to their own city districts.

## 9. Research methods

Regarding a qualitative approach to this research of residential satisfaction with aim of representative outputs, a questionnaire comprising mainly enclosed

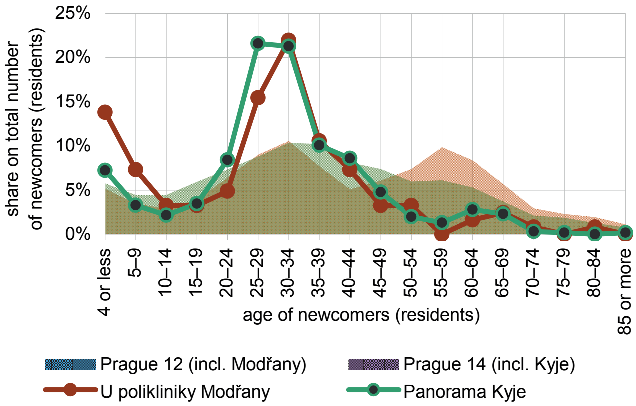


**Fig. 6** The age structure of residents of both localities
Source: Czech Statistical Office (2011; 2018)

questions had been composed. Respondents had been asked for the evaluation of their satisfaction with various household and neighbourhood aspects on a 5-point scale (1 – very unsatisfied to 5 – very satisfied) with particular emphasis on services where both satisfaction and importance (1 – very unimportant to 5 – very important) were considered. In the questionnaire, the term neighbourhood was defined as "close surroundings of residents' home". The total number of inquired households (i.e. 80 in Modřany and 114 in Kyje) had come from the total number of flats (i.e. 298 in Modřany and 704 in Kyje), chosen statistical methods and time plus financial feasibility of the research. The questionnaire survey was realised between June 2017 and March 2018 using the stratified random choice of questioned households.

The questionnaires were distributed into respondents' mailboxes with a cover letter, a stamped returning envelope and a pencil. Households may have sent the filled questionnaire by Czech Post or email. During the second week, the respondents were reminded in person which has been positively reflected in the overall return rate (i.e. 56.2%; 46 gathered questionnaires from Modřany and 63 from Kyje). The research sample appropriately corresponds to the overall demographical structure in both localities mentioned in the previous chapter. On its basis three categories of households have been defined – (1) singles and young childless households (further young adults) up to 39 years of age (26% in Modřany; 33% in Kyje), (2) families with children (39% in Modřany; 25% in Kyje) and (3) older childless households (further empty nesters) of 54 or more years of age (17% in Modřany; 18% in Kyje).

For the comparative purposes of statistical analysis between both research localities, nonparametric Mann-Whitney test, which compares ranks instead of means amongst two groups, has been chosen (Mareš et al. 2015). This is *the ordinal method* that assigns to numeric data the ranks after their sorting based on their size (Hendl 2004). Secondly, nonparametric Kruskal-Wallis test, which tests the differences

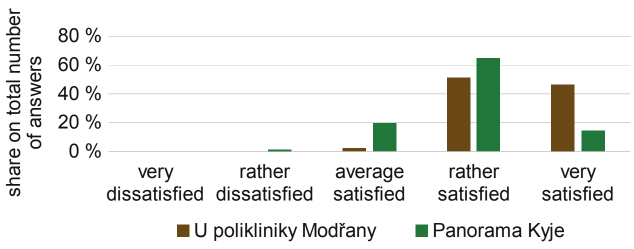


Fig. 7 Overall residential satisfaction in both localities.
Source: own questionnaire survey

amongst three or more groups, has been mainly used for the comparison of households in the different position of a life cycle. The third utilised method is Kendall's correlation coefficient in the tau b modification. This nonparametric coefficient is appropriate for ordinal data with a low number of categories (Hendl 2004). This method differs from other nonparametric coefficients by its elaboration with values in so-called *rank sequences* – values of one or two variables that are identical for two observations (Mareš et al. 2015).

For the evaluation of residential satisfaction with civic amenities, variables entering the correlation analysis have been further weighted by the ascribed scale of importance because residents may have different demands for civic amenities and, thus, dissimilarly evaluate their quality (Stipak 1979). During the weighting process, ascribed values of importance were kept and multiplied by values of satisfaction that had been modified to −2 – very unsatisfied to +2 – very satisfied. This approach maximizes the difference between the situation when a certain service is demanded but not available and when it is demanded and available.

| Tested variable | Used method | Average rank | | Sig. |
|---|---|---|---|---|
| | | Modřany | Kyje | |
| overall residential satisfaction (RS) | Mann-Whitney | **66.86** | 44.67 | **<.001** |

| Tested variable | Locality | Used method | Avg. rank | | | Sig. |
|---|---|---|---|---|---|---|
| | | | | | (54+) | |
| overall RS | Modřany | Kruskal-Wallis | 19.50 | 19.47 | 17.25 | .346 |
| | Kyje | | 26.21 | 22.22 | 24.55 | .608 |

Fig. 8 Statistical analysis: overall residential satisfaction.
Source: own questionnaire survey

| Tested variable | Used method | Average rank | | Sig. |
|---|---|---|---|---|
| | | Modřany | Kyje | |
| **satisfaction** with flat size | Mann-Whitney | 55.04 | 54.97 | .990 |
| with housing quality | | 58.97 | 51.19 | .174 |
| with parking lots | | **59.88** | 48.80 | **.059** |

| Tested variable | Locality | Used method | Average rank | | | Sig. |
|---|---|---|---|---|---|---|
| | | | | | (54+) | |
| actual flat size | Modřany | Kruskal-Wallis | 16.58 | 23.00 | 16.00 | .120 |
| | Kyje | | 16.69 | **37.19** | 20.95 | **<.001** |
| **satisfaction with** flat size | Modřany | | **23.67** | 15.44 | **22.38** | **.073** |
| | Kyje | | 21.67 | 24.13 | 30.45 | .210 |
| w. housing quality | Modřany | | **25.17** | 17.69 | 15.06 | **.046** |
| | Kyje | | 23.48 | 24.25 | 24.70 | .966 |

| Tested variables | Used method | Modřany | | Kyje | |
|---|---|---|---|---|---|
| | | $R^2$ | Sig. | $R^2$ | Sig. |
| **satisfact.** with flat size × overall RS | Kendall's tau b | .202 | .143 | **.311** | **.006** |
| with housing quality × overall RS | | **.391** | **.006** | **.429** | **<.001** |
| with parking lots × overall RS | | −.104 | .452 | **.429** | **<.001** |

Fig. 9 Statistical analysis: housing characteristics.
Source: own questionnaire survey

## 10. Satisfaction of households in case localities

The difference between the overall satisfaction of households in both localities is statistically significant at 0.01 level (Figs. 7 and 8). Moreover, in this case, the dissimilarities are *not* significant amongst identified types of households. It suggests that surveyed households would generally prefer to live in the housing estate environment of Modřany than in suburban Kyje.

Neither the satisfaction with flat sizes nor with housing quality differs amongst both localities (Fig. 9). Nevertheless, the detailed analysis of Kyje shows that families with children inhabit larger flats therein while young adults or empty nesters live in smaller units. This might explain the lower satisfaction with size and quality of housing in case of families with children in Modřany where the differences between the actual size of flats are not statistically significant (similarly Dekker et al. 2011).

The satisfaction with housing quality exceeds the satisfaction with flat sizes in their contribution to overall residential satisfaction. As for Kyje, there are more dependencies in the housing domain including the satisfaction with parking lots. It may generally derive an important meaning of housing characteristics for the composition of overall residential satisfaction in suburban localities (likewise Phillips et al. 2004; Ren and Folmer 2017).

In comparison to housing characteristics, the satisfaction with many neighbourhood characteristics

| Tested variable | Used method | Average rank | | Sig. |
|---|---|---|---|---|
| | | Modřany | Kyje | |
| **sat.** w. natural environment | Mann-Whitney | **60.46** | 50.08 | **.068** |
| with public spaces | | **61.58** | 48.29 | **.022** |
| with playgrounds | | **73.77** | 34.60 | **<.001** |
| with quietness | | 46.27 | **61.37** | **.009** |
| with safety | | 52.51 | 56.82 | .443 |
| with access. of Prague | | **60.26** | 49.28 | **.056** |

| Tested variable | Locality | Used method | Average rank | | | Sig. |
|---|---|---|---|---|---|---|
| | | |  |  |  (54+) | |
| **sat.** w. natural environment | Modřany | Kruskal-Wallis | 23.00 | 15.83 | 22.50 | .109 |
| | Kyje | | 26.86 | 18.88 | 26.20 | .147 |
| with public spaces | Modřany | | 19.04 | 17.86 | 23.88 | .385 |
| | Kyje | | **27.33** | 16.69 | **28.70** | **.024** |
| with playgrounds | Modřany | | 17.75 | 17.42 | 23.25 | .425 |
| | Kyje | | 26.38 | 18.09 | 24.22 | .138 |
| with quietness | Modřany | | 24.50 | 16.06 | 19.75 | .104 |
| | Kyje | | **28.71** | 18.91 | 24.59 | **.073** |
| with safety | Modřany | | 17.54 | 19.78 | 21.81 | .654 |
| | Kyje | | 28.83 | 20.22 | 22.45 | .106 |
| with accessibility of Prague | Modřany | | **25.50** | 15.92 | 18.56 | **.047** |
| | Kyje | | 20.24 | 29.19 | 23.60 | .121 |

| Tested variables | Used method | Modřany | | Kyje | |
|---|---|---|---|---|---|
| | | $R^2$ | Sig. | $R^2$ | Sig. |
| **satisfaction** with natural environment × overall RS | Kendall's tau b | **.435** | **.002** | **.301** | **.009** |
| with public spaces × overall RS | | **.293** | **.036** | **.272** | **.017** |
| with playgrounds × overall RS | | **.518** | **<.001** | **.240** | **.041** |
| with quietness × overall RS | | **.284** | **.037** | **.399** | **.001** |
| with safety × overall RS | | **.336** | **.016** | .185 | .110 |
| with accessibility of Prague × overall RS | | .027 | .848 | **.219** | **.054** |

**Fig. 10** Statistical analysis: neighbourhood characteristics.
Source: own questionnaire survey

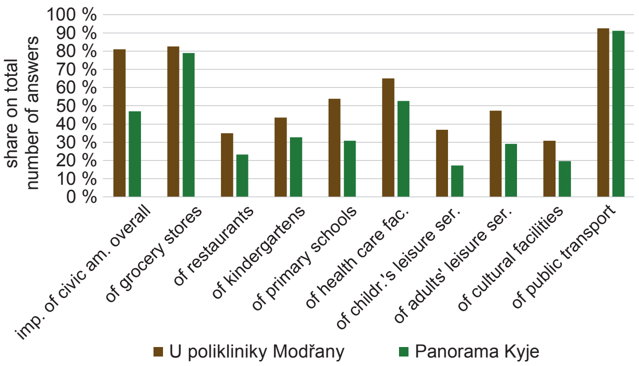


**Fig. 11** The importance of proximity of civic amenities (rather or very important).
Source: own questionnaire survey

varies across both localities and significantly correlates with overall residential satisfaction in both localities (Fig. 10, see also Fried 1982; Hourihan 1984; Gruber, Shelton 1987). Modřany residents feel besides the higher quality of the natural environment also better satisfaction with public spaces and playgrounds as they at least exist. The worse condition or non-existence of these spaces in Kyje belongs among common problems of suburban localities (Havlíčková 2012; Kährik et al. 2012; Špačková et al. 2012).

Conversely, the inhabitants of Kyje are very satisfied with a tranquil suburban environment of their locality (see also Musterd, van Kempen 2005; Karsten 2007). Nevertheless, noisier surroundings of Modřany is lesser reflected in overall residential satisfaction. The perception of safety is similar in both areas (compare with Temelová et al. 2010). Finally, the satisfaction with the accessibility of Prague is expectedly higher for Modřany residents, probably owing to wider public transport options.

Families with children in Kyje are more vulnerable to deficiencies regarding public spaces and tranquillity (similarly Newman, Duncan 1979; Dekker et al. 2011). As for Modřany, less mobile households such as families with children and empty nesters are less satisfied with the accessibility of Prague than young adults. The explanation for that is offered by Karsten (2007), who considers hectic environment as the possible cause of restricted movements, for instance, in case of the journeys to public transport stops.

The inhabitants of Modřany put generally more weight on the adequate accessibility of civic amenities (Fig. 11). On the contrary, the importance of proximity to civic amenities might has been a minor factor when households make their choice for a suburban Kyje (similarly Kährik et al. 2012). However, the higher values of importance for daily-used services such as grocery stores or public transport are comparable for all residents in both localities (Fig. 12). Educational and leisure facilities are mainly emphasised amongst

| Tested variable | Locality | Used method | Average rank | | | Sig. |
|---|---|---|---|---|---|---|
| | | | | | (54+) | |
| **importance** of civic amenities overall | Modřany | Kruskal-Wallis | 14.41 | 15.87 | 17.13 | .812 |
| | Kyje | | 20.83 | 26.12 | 16.33 | .141 |
| of grocery stores | Modřany | | 15.95 | 16.44 | 18.25 | .876 |
| | Kyje | | 22.43 | 23.93 | 22.78 | .927 |
| of restaurants | Modřany | | 20.00 | 14.38 | 15.88 | .267 |
| | Kyje | | **26.48** | 22.83 | 15.17 | **.083** |
| of kindergartens | Modřany | | 13.55 | 18.65 | 15.50 | .339 |
| | Kyje | | 18.86 | **28.80** | 17.56 | **.025** |
| of primary schools | Modřany | | 12.68 | 19.62 | 13.75 | .110 |
| | Kyje | | 18.78 | **28.57** | 17.75 | **.031** |
| of health care facilities | Modřany | | 15.95 | 15.76 | 21.13 | .528 |
| | Kyje | | 19.62 | 24.93 | 27.67 | .214 |
| of children's leisure services | Modřany | | 12.27 | 19.13 | 13.75 | .120 |
| | Kyje | | 17.30 | **30.60** | 17.63 | **.002** |
| of adults' leisure services | Modřany | | 17.95 | 13.77 | 15.25 | .456 |
| | Kyje | | 21.93 | 26.80 | 15.94 | .128 |
| of cultural facilities | Modřany | | 17.32 | 15.00 | 16.38 | .791 |
| | Kyje | | 19.43 | 27.07 | 24.56 | .187 |
| of public transport | Modřany | | 19.59 | 14.35 | 17.13 | .180 |
| | Kyje | | 23.21 | 24.43 | 20.11 | .529 |

**Fig. 12** Statistical analysis: neighbourhood characteristics – the importance of proximity of civic amenities.
Source: own questionnaire survey

| Tested variable | Used method | Average rank | | Sig. |
|---|---|---|---|---|
| | | Modřany | Kyje | |
| **satisfaction** with civic am. overall | Mann-Whitney | **57.65** | 28.46 | **<.001** |
| with grocery stores | | **70.95** | 29.70 | **<.001** |
| with restaurants | | **54.02** | 44.20 | **.073** |
| with kindergartens | | **53.22** | 28.93 | **<.001** |
| with primary schools | | **54.07** | 28.22 | **<.001** |
| with health care | | **61.28** | 34.02 | **<.001** |
| with children's leisure services | | **52.16** | 28.59 | **<.001** |
| with adults' leisure services | | **55.14** | 39.86 | **.005** |
| with cultural facilities | | 48.13 | 44.33 | .461 |
| with public transport | | **62.20** | 36.61 | **<.001** |

| Tested variable | Locality | Used method | Average rank | | | Sig. |
|---|---|---|---|---|---|---|
| | | |  |  |  (54+) | |
| **satisfaction** with civic amenities overall | Modřany | Kruskal-Wallis | 13.30 | 14.85 | 8.33 | .389 |
| | Kyje | | 21.15 | 20.96 | 18.56 | .831 |
| with grocery stores | Modřany | | 16.50 | 15.13 | 18.13 | .805 |
| | Kyje | | **25.79** | 15.89 | 18.56 | **.044** |
| with restaurants | Modřany | | 20.09 | 15.78 | 18.00 | .513 |
| | Kyje | | 23.82 | 18.90 | 20.88 | .479 |
| with kinder-gartens | Modřany | | 12.35 | 17.47 | 14.83 | .320 |
| | Kyje | | 20.88 | 15.21 | 15.42 | .219 |
| with primary schools | Modřany | | 12.45 | 17.62 | 13.67 | .296 |
| | Kyje | | 20.74 | 15.42 | 15.42 | .271 |
| with health care facilities | Modřany | | 17.09 | 15.71 | 18.25 | .853 |
| | Kyje | | 20.50 | 23.08 | 19.06 | .692 |
| with children's leisure services | Modřany | | 11.05 | **17.72** | 6.00 | **.033** |
| | Kyje | | 20.32 | 15.46 | 16.50 | .329 |
| with adults' leisure services | Modřany | | 16.18 | 17.88 | 12.80 | .541 |
| | Kyje | | **27.79** | 15.53 | 18.07 | **.008** |
| with cultural facilities | Modřany | | 15.88 | 16.47 | 18.50 | 856 |
| | Kyje | | **23.63** | 15.30 | **23.58** | **.082** |
| with public transport | Modřany | | 19.36 | 13.62 | 20.88 | .150 |
| | Kyje | | 18.42 | 26.37 | 22.28 | .159 |

| Tested variables | Used method | Modřany | | Kyje | |
|---|---|---|---|---|---|
| | | $R^2$ | Sig. | $R^2$ | Sig. |
| **sat.** w. civic am. overall × overall RS | Kendall's tau b | **.357** | **.022** | **.270** | **.033** |
| with grocery stores × overall RS | | **.409** | **.006** | **.348** | **.003** |
| with restaurants × overall RS | | **.365** | **.008** | .144 | .224 |
| with kindergartens × overall RS | | .135 | .374 | .094 | .483 |
| with primary schools × overall RS | | .132 | .380 | .159 | .233 |
| with health care × overall RS | | **.394** | **.005** | .124 | .311 |
| with children's leisure services × overall RS | | .139 | .368 | .114 | .408 |
| with adults' leisure services × overall RS | | .129 | .377 | −.009 | .938 |
| with cultural facilities × overall RS | | −.086 | .566 | .121 | .319 |
| with public transport × overall RS | | .217 | .136 | .106 | .383 |

Fig. 13 Statistical analysis: neighbourhood characteristics – weighted satisfaction with the quality of civic amenities in the proximity of the neighbourhoods.
Source: own questionnaire survey

| Tested variables | Used method | Modřany | | Kyje | |
|---|---|---|---|---|---|
| | | $R^2$ | Sig. | $R^2$ | Sig. |
| satisfact. w. community ties × overall RS | Kendall's tau b | .213 | .127 | **.373** | **.001** |
| **length of stay** × overall RS | | – | | −.161 | .209 |
| × satisfaction with civic amenities overall | | – | | .092 | .507 |
| **income level** × overall RS | | −.106 | .473 | .143 | .230 |
| × importance of civic amenities overall | | −.123 | .441 | −.034 | .790 |
| **education level** × overall RS | | .076 | .589 | −.004 | .970 |
| × importance of civic amenities overall | | −.007 | .963 | .096 | .432 |
| × importance of adults' leisure services | | **−.305** | **.031** | **.200** | **.080** |
| × importance of cultural institutions | | **−.294** | **.034** | .069 | .541 |
| **residential stability** × overall RS | | .188 | .200 | **.406** | **.001** |
| × satisfaction with civic amenities overall | | .006 | .968 | .137 | .297 |

**Fig. 14** Statistical analysis: household characteristics.
Source: own questionnaire survey

families with children in Kyje (similarly Karsten 2007; Kostelecký 2016) while young adults demand restaurants where they might have spent their leisure (Špačková, Ouředníček 2012). Finally, empty nesters surprisingly do not have any special requirements regarding the proximity of civic amenities (compare with Phillips et al. 2004; Temelová et al. 2010).

Even though the satisfaction with civic amenities is weighted by the degree of the ascribed importance to them, Modřany residents are generally more satisfied with their quality (Fig. 13). This method shows that the inhabitants of Kyje mostly lack daily-used services such as grocery stores and public transport, or health care facilities (see also Kährik et al. 2012; Špačková et al. 2016). While the ascribed importance of these services by households does not vary significantly between both localities (see again Figs. 11 and 12), the evaluation of satisfaction is very dissimilar. In this way, satisfaction corresponds to different accessibility of services in both localities.

In contrast to Modřany respondents, the different life-cycle position of Kyje households plays a considerable role in the evaluation of satisfaction with civic amenities. Young adults in Kyje are more satisfied with grocery stores and leisure services than families with children or empty nesters who especially put emphasis on these services and, therefore, miss these services hereabouts (see Temelová et al. 2010). This might be explained by bounds of childless households to everyday commuting for activities – they might perceive the local civic amenities more benevolently than others (Morrow-Jones et al. 2004; Phillips et al. 2004).

The degree of satisfaction with civic amenities as a neighbourhood characteristic is positively reflected in overall residential satisfaction (likewise Lovejoy, Taylor 1976; Ahlbrandt 1984, in Basolo, Strong 2002; Lu 1999; Dekker et al. 2011). While the satisfaction with grocery stores is reflected the most in overall residential satisfaction (see also Wilson et al. 1995, in Dekker et al. 2011; Temelová et al. 2010), the satisfaction with educational facilities, which are utilised only by certain households, is not as much related. As for Modřany, the nonnegligible role in composing overall residential satisfaction might be also ascribed to the physical proximity of restaurants and health care facilities reflected in significantly higher satisfaction with these services.

Generally, characteristics of households play only a minor role in composing overall residential satisfaction (Fig. 14, similarly Hourihan 1984; Lu 1999; Parkes et al. 2002; Hur, Morrow-Jones 2008; Lovejoy et al. 2010). The importance must be, however, ascribed to the quality of social relationships and residential stability of residents in suburban Kyje despite the lack of public spaces therein (also Speare 1974; Amérigo, Aragones 1997; Parkes et al. 2002; Špačková et al. 2016).

Surprisingly, the less educated households of Modřany consider as more important the presence of leisure and cultural facilities than those of higher education. The inversed and oftener relationship is partly valid for Kyje inhabitants (as in Gans 1967; Sharp 1986, in De Hoog et al. 1990, compare with Lovrich, Taylor 1976; Stipak 1979). Finally, the level of residential stability is not influenced at all by the satisfaction with civic amenities (Varady 1983, compare with Swindell, Kelly 2005; Špačková et al. 2016) except the quality of health care facilities in case of Kyje (Karsten 2007).

## 11. Discussion

The demographic structure of new apartment-house localities in Prague significantly differs from the city districts they belong to. High shares of young adults and families with children are the typical feature of that residential areas with adequate accessibility of the city centre and with a good-quality environment (e.g. Čermák 2005; Ouředníček, Temelová 2009; Špačková, Ouředníček 2012). A slightly increased attractiveness is noticed also for empty nesters at the frontier between productive and post-productive age.

Modřany residents are generally more satisfied than inhabitants of suburban Kyje. The housing estate environment dominates especially in spheres of the residential quality of the neighbourhood which, with the contribution of civic amenities, is very significantly reflected in overall residential satisfaction (likewise Hourihan 1984; Gruber, Shelton 1987). However, increased movements of population and transport around Modřany bring one considerable drawback – an increased noise (see also Musterd, van Kempen 2005; Karsten 2007) which is, on the other hand, sufficiently compensated through the higher quality of other neighbourhood characteristics. The civilly well-facilitated locality of Modřany is apparently mostly appreciated by families with children and empty nesters who give higher weight to the residential quality of the neighbourhood (e.g. Temelová et al. 2010; Dekker et al. 2011).

Quite the reverse, the suburban environment of Kyje remains attractive only for young adults which do not put much emphasis to ambient features of the neighbourhood (Morrow-Jones et al. 2004; Kährik et al. 2012) which for children or other residents with restricted mobility is not much friendly (also Špačková et al. 2016). Generally, households demand fair accessibility of daily-used services such as grocery stores or public transport (Vackářová 2014). While educational facilities are rather important for families with children only, childless individuals or couples have not missed them much so far. These smaller households thus probably mostly aim to the decent quality of flats which is comparable within both localities and, at the same time, creates a nonnegligible contribution to overall residential satisfaction (Fried 1982; Lovejoy et al. 2010).

Compared to the above-mentioned position of the household in a life cycle, which is one of the key factors influencing the constitution of residential satisfaction (e.g. Lu 1999; Phillips et al. 2004; Grinstein-Weiss et al. 2011), other scrutinised individual features of households such as socioeconomic characteristics or the length of stay in a locality are less significant. However, firmer social embedding of a household, especially in the suburban locality of Kyje, contributes to the overall satisfaction (also Parkes et al. 2002) even though this connexion is typical for localities with the high scale of residential satisfaction (Amérigo, Aragones 1997; Hur, Morrow-Jones 2008).

## 12. Conclusion

This paper aimed to discover and explore potential distinctions in the evaluation of the various components of residential satisfaction, mainly of civic amenities, within the different types of households in the dissimilarly situated localities of new apartment houses in post-socialist Prague. It also pursued to answer the question, how is satisfaction with civic amenities reflected in overall residential satisfaction in comparison with its other components. For these purposes, two new apartment-house localities with an entirely different environment (housing estate and suburban), the unequal position towards the compact city and with the different accessibility of civic amenities have been chosen. Residential satisfaction, as well as other characteristics of households, have been found out by the questionnaire survey and its subsequent statistical analysis.

Dwelling in newly built apartment houses is migratory attractive especially for young adults, families with children and, at the lower scale, for empty nesters. Although for that demographic structure, in almost all indicators of residential satisfaction, suits better an environment of a housing estate, young adults also fairly adapt the life in flats of comparable quality inside a suburb, which envisages commuting for various activities to other parts of a city. Besides the higher level of residential satisfaction with civic amenities inside a housing estate, the difference is also significantly manifested in the majority of neighbourhood features such as public spaces or accessibility of Prague. The only and genuinely appreciated benefit of the observed suburb remains in the tranquil living environment, which busy surroundings of the housing estate lack.

The constitution of overall residential satisfaction is either conditioned by the quality of housing itself or by the quality residential environment in neighbourhood surroundings and its attractiveness for the various groups of inhabitants. The similar weightis given to the quality of civic amenities, especially of such that are used the most frequently such as grocery stores or public transport. However, the scale of importance of other services varies according to the position of households in a life cycle. For instance, educational facilities are thus mostly demanded by families with children. Individual factors of households such as socioeconomic background or the length of stay are of less importance for overall satisfaction of all household types. Surprisingly, relations with neighbours still play a nonnegligible role.

The paper enriches the ordinarily scrutinised concept of residential satisfaction for more detailed research of the importance of civic amenities for the inhabitants of the new apartment-house localities in post-socialist Prague. Nevertheless, the main outcomes could be generalised to other post-socialist cities since they provided comparable results in this environment. For further research, it would be prospective to aim in more detail for distinguishing preferences of households in different positions within a life cycle regarding civic amenities as well as other neighbourhood features or to seek for other compensations of missing civic amenities in suburbs besides the noiseless environment.

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# The evaluation of local governance effectiveness in the selected cities of Czechia

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**ABSTRACT**
The aim of this article is to measure the effectiveness of public administration by comparing long-term budget expenditures with goals specified in strategic documents of four cities from less developed regions in Czechia. The content analysis of strategic documents of these cities was carried out over the past 10 years. Next, the budget expenditure during the 2002–2017 period was analyzed and compared with goals specified in strategic plans of these cities. The results show the under-funding of the majority of the planned development goals.

**KEYWORDS**
local governance; effectiveness; self-government; local development; budget expenditure

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## 1. Introduction

Over the course of the 1990s, the municipal level was strengthened while continuing territorial fragmentation resulted in the existence of over 6,250 municipalities, i.e. a relatively high number of elected local governments. This fact poses a number of problems especially in the financial area (i.e. an insufficiency of funds for larger investment projects in small municipalities). There are also problems associated with the exercise of public administration within the scope of delegated competencies at municipal level. The problem is that there are no precise boundaries between activities carried out by municipalities within self-government and the activities within state administration provided by municipalities, which also applies to the public funding of these activities. However, the role of local government for the development of the territory of the municipality or even the entire micro-region remains crucial. In this case, the role of larger cities (i.e. municipalities with extended powers) is important, although their potential as an initiator of local development has currently been utilized to a limited extent only.

With regard to their topicality, the matters of governance as an indispensable part of the exercise of public administration are at the heart of the interest of a number of scientific disciplines. Each such scientific discipline, either from the field of political science, sociology or economy, contributes to the research with its own theories and approaches (see Bovaird 2002). In Czechia, the matters of governance are addressed especially within the scope of political-science research (e.g. Jüptner et al. 2014), within the scope of public policy research (e.g. Potůček et al. 2005; Nekola 2004) and within the scope of sociology combined with political geography (e.g. Kostelecký, Patočková, Vobecká 2007). However, the geographic approach to governance studies is still very rare, although the interconnection of effectiveness with local development has political-geographical potential. An example of such geographical studies is the work of Rumpel, Slach, and Koutný (2013) focused on the process of urban shrinkage in Ostrava in the period 1990–2010. It is a shift from earlier studies of regionalization and administrative division of the state (e.g. Hampl, Ježek, Kühnl 1978; Hampl 1996).

In relation to governance, the growing demand for increasing the effectiveness and inspecting the activities of governments results from the ongoing changes in public administration (e.g. the introduction of the New Public Management methods), and it is also supported by the overall efforts of all public administration levels to reduce operating costs. Increasing the effectiveness and the quality of local governments was also the objective of various reforms of public administration (Silva and Buček 2017: 49). The problem is the fact that effectiveness may be perceived in various ways and its measurement is difficult in practice also with regard to the common unavailability of relevant data. Moreover, a number of activities of local governments are "non-profit" by their nature (e.g. provision of public services), so it is better to evaluate rather the fulfilment of long-term objectives than the economic performance.

The presented article aims to analyse the management of selected cities in terms of funding the development areas (policies) reflected in strategic documents. The assumption is that all the cities being analysed make active efforts to direct budgetary expenditures to the fields of local development. The comparative analysis of budgetary expenditures is to confirm or disprove this assumption. The result of the analysis will also provide information about the effectiveness of governance which, in geographical terms, will mean the existence or absence of support directed to the fields of local development. The subjects of comparison are the selected cities with the same input conditions, which are supposed to determine the real utilization of budgets.

## 2. Governance and local democracy

The basic preconditions of the existence of governance at a local or regional level is the decentralization and the creation of local self-government units. So governance may be regarded as one of the concepts of local democracy (Sisk 2001: 13). However, the problem is the non-existence of a uniform definition of the term "governance". The relatively frequently used concept of governance is the result of the functional shift in the perception of governance that is no longer connected only with the local government but also involves other actors (e.g. Bovaird and Löfflered 2003, Jüptner et al. 2014). According to Fukuyama (2013: 350), governance may be expressed as the ability of the government (either a democratic or non-democratic one) to create and subsequently enforce compliance with rules and the provision of services. Lynn, Heinrich, and Hill (2000) say governance is a legal framework and various aspects of governing associated, in particular, with the creation and provision of public goods and services. Human geography sees governance as the coordination within an organization (Gregory et al. ed. 2009: 213–313). Despite various concepts of governance, its basic characteristic is the involvement of multiple actors (and thus a larger complexity) but also greater opacity.

Potentially, due to territorial fragmentation, the exercise of local governance is in Czechia closer to citizens. However, given that the tools of direct democracy (local referendums, participatory budgeting) are used in Czechia only to a limited extent, the political power of citizens in relation to local governance is limited to the right to vote, in particular. However, it does not mean that the citizens do not have any influence on the political decisions of the local government.

The development of interactions and communication within the scope of public administration is seen in practice e.g. in the form of meetings of political representatives with citizens or the engagement of citizens in the process of the planning of development and the provision of public services (see community forms of governance). What is also important is the inspectional role of citizens in relation to the local government and public authorities (e.g. Blakely and Leigh 2013). On the other hand, some experts (e.g. Swianiewicz ed. 2010) point out that territorial fragmentation on such a scale may hinder the enhancement of the effectiveness of the local governance.

Political geographers tend to study rather global governance and power disputes at the national level, but the local level of governance deserve their attention as well. It is possible to examine the effect of the environment on political decisions as well as the spatial changes and transformations of cities in the consequence of political decisions (e.g. analysis of shrinkage of the city of Ostrava in Rumpel and Slach 2012). Although the local level is influenced by globalization and by processes and decisions taken at higher hierarchy levels, the space where we live is still determined by the local government decisions. This assumption, namely that governance is regarded as an expression of executive power influencing the development of both the community and the territory, triggers the need to study local governance.

## 2.1 Effectiveness and efficiency of governance and public administration

The growing effort to measure the effectiveness and efficiency of governance results from the demand by the public as well as the public authorities themselves. The definition of efficiency and effectiveness is not so clear. In the case of efficiency, the emphasis is on reducing local spending. From the private sector perspective, efficiency is measured as the input to output ratio (e.g. Afonso, Schuknecht, Tanzi 2010; Kalb, Geys, Heinemann 2011). On the other hand, effectiveness means how the government achieves the policy goals (e.g. Worthington, Dollery 2000). This includes the evaluation the fulfillment of objectives with the lowest possible costs (e.g. Jüptner et al. 2014).

Most studies in the sphere of governance and public administration focus on measuring efficiency. Different approaches apply here, e.g. the cost-effectiveness method (e.g. Balaguer-Colla et al. 2019; Šťastná and Gregor 2011) or analyses efficiency in the provision of selected services and examine the effect of various factors. Geographic factors are of minor importance in the examination of the efficiency of governance – e.g. the study of Ermini and Santolini (2010) who used Italian examples to prove the effect of the deciding in neighbouring municipalities on the decisions of local politicians in the field of expenditures. As outputs, various analyses use indicators such as the number of lamps (for public lighting), total area (for infrastructure, parks, etc.) or, according to Kuhlmann (2010), the number and quality of administrative decisions as well. A disadvantage of this economic view of efficiency (measurement of inputs against outputs) is that it does not say anything about the quality of the service itself. The thing is that the perception of a service by the citizens is also very important. According to Potůček et al. (2005), political representatives find the results of interviewing respondents more helpful; in practice, such subjective measurements have the form of various satisfaction surveys carried out e.g. at municipal authorities. Although efficiency defined in this way allows the benchmarking of individual municipalities on the one hand, it often does not make it possible to explain the causes of the differences in efficiency on the other hand. An example of quite an extensive benchmarking at the level of municipalities with extended powers in Czechia is the study carried out by Šťastná and Gregor (2011).

Measuring the effectiveness of governance is not common due to the difficulty implementation in practice. The implementation of specific local policies is also influenced by factors that local governments can not change, but this should not be a reason to resign from measuring effectiveness. An example of this different approach is the work of Lankina, Hudalla, and Wollmann (2008), who evaluated local governance by analyzing the budgetary expenditures for the support of economic growth. Taking selected cities in Czechia as an example, the authors showed (p. 78–79) differences in both the budgetary expenditures and the implementation of long-term strategies. The cities also differed from one another in the ability to obtain grants or direct investments. Instead of effectiveness, many researchers focus rather on the quality of governance. But the quality (e.g. represented by transparency, openness) can be perceived as a part of the effectiveness measuring.

## 2.2 Municipal budgeting as a tool of local development

At all levels of public administration, budgeting is a political process (see Potůček et al. 2005) in which the interests of all the political actors are naturally reflected. Budgets should respect predefined objectives and priorities. In terms of local development, such objectives should be based on the adopted strategic documents so as to contribute to the solving of long-term problems and the local development. In this case, we consider specific local development policies in selected cities (LAU in NUTS classification) with potential extension to the regions of municipalities with extended power. For the Ministry of the Interior, these regions are considered as a cornerstone of the current territorial division of the state.

The budget breakdown (classification of revenues and expenditures) is set out in Regulation of the

Ministry of Finance No. 323/2002 Coll. As a preliminary point it should be noted that there are two types of budgets: (1) a current budget to fund public services and goods; (2) a capital budget to fund investments. The structure of a capital budget is influenced to a certain extent by the municipality's ability to draw grants from various sources (EU, ministries, regions, etc.) and there may be large differences in the amount of total investments from year to year. The existence of a uniform budget breakdown is a necessary precondition for analysing the management of municipalities and for their benchmarking.

What is of key importance for studying the effectiveness of governance is the expenditures within the scope of self-government competencies (see Act No. 128/2000 Coll.), because the local government must find a compromise between its interests, the interests of the other actors and the funds available in the budget. Moreover, the competencies of municipalities and the requirements for their activities change over the course of time, e.g. after districts were cancelled, the vast majority of their competencies was not transferred to the newly established regions but to the municipalities (Hemmings 2006: 6–7). The fields funded within the scope of self-government competencies include: (1) education; (2) housing; (3) transport; (4) culture and recreation; (5) security; (6) social care; (7) health care; (8) other public services; (9) land use planning. Although the provision of basic public services is perceived very sensitively by the inhabitants of the given municipality and is often used as one of the governance evaluation criteria (e.g. Bovaird and Löffler 2003), the non-existence of any standards of public service availability does not place any greater demands on the local government for securing the necessary services. Despite that, as pointed out by Plaček et al. (2016: 5–6), capital expenditures, in particular, are one of the tools for municipal politicians to gain the favour of their electors.

## 3. Methodology

The methodological procedures and data sources used in this research reflect the set objective, i.e. evaluation of the effectiveness of governance in 4 selected cities in Czechia. Although data on the management of municipalities are relatively well accessible in the databases of the Ministry of Finance, they have their limitations, so data obtained directly from municipal authorities under Act No. 106/1999 Coll., on free access to information, were also used.

### 3.1 Effectiveness

To evaluate effectiveness, this analysis compared the current and capital expenditures directed in the period 2002–2017 to the predefined development policies with the representation of such policies in the strategic documents of cities.

If confronting the fields of funding within the scope of self-government activities with the basic fields of support of local development (according to Blakely and Leigh 2013), we can set out the development fields to which "spare" funds within the scope of the budget, in particular, should be directed as a matter of priority: (1) support of entrepreneurship; (2) human resources (education, research and development, employment); and (3) strategic planning. These development areas should also be naturally reflected in the strategic documents of the cities concerned. Definition of the development policies pursued at the local level was based on the national strategies and reflected the obligations of municipalities within the scope of self-government under Act No. 128/2000 Coll., on municipalities. Contrary to the definition of such policies at the national level, their definition at the level of municipalities has a much narrower focus. In total, expenditures in 6 development policies (Table 1) were studied. When analysing the expenditures in the field of social prevention services, subdivision 437 covering a total of 9 sections (according to Regulation of the Ministry of Finance No. 323/2002) was studied in the budgets.

With regard to the nature of development fields, varied amounts of expenditures (capital ones, in particular) may be expected. Large infrastructure projects in the environmental field constitute higher budgetary items than e.g. educational projects in the social field. The total budgetary expenditures are, however, only one of the indicators; it is important whether funds are directed to development policies at all and whether it is a long-term trend. Although the proportion of capital expenditures to the total expenditures was growing in general until the economic crisis in 2009, this was followed by a trend of reducing investments (Zdražil 2019: 381).

### 3.2 Data sources and data processing

In the first phase of the research, the contents of strategic documents of all the examined cities were analysed. These strategic documents are generally drawn up for a multiannual period and their updating is not exceptional, so the analysis of the contents also included their updated versions. All the documents were obtained from the websites of the examined cities. As part of the content analysis, the presence of keywords and key phrases for the given development policy in strategic documents was examined. The result was either YES if the keywords appeared in the document, or NO if they were not present in the document. Methodologically, a quantitative content analysis was used (Hendl 2008: 388). In terms of topics or the nature of the development documents, the analysed cases included both quite general strategic documents and thematically narrower strategies

**Tab. 1** Local development policies in relation to municipal budgets.

| Development policy | | Budget item analyzed |
|---|---|---|
| Environmental policy | | 37xx, 23xx |
| Research, development and innovation policy | | 2125, xxx8 |
| Employment policy | | 422x |
| Economic policy | | 2123, 2124, 2131, 2139 |
| Social policy | Education policy | 31xx, 32xx (under current expenditure only items 3212, 3292, 3293) |
| | Policy of combating poverty and social exclusion | 3421, 437x (under current expenditure in addition item 4342) |

Source: Author

focused e.g. on the field of social inclusion (see Appendix 1). There were also community plans of social services, which constitute an illustrative example of the application of new forms of political decision-making at the local level. In order to compare the examined cities, the analysis used the overall percentage of the representation of the development policies (i.e. in how many documents the given development policy was represented) in all types of strategic documents.

In the field of budgeting the examined cities, the main data source was the web application "Monitor" administered by the Ministry of Finance (from 2013) or its preceding version "ÚFIS" (from 2010 to 2012) and "ARISweb" (until 2009). As another source, the analysis used the economic results for individual years published on the websites of the concerned cities. The reason for the use of multiple sources concerning the management of examined cities is a certain error rate of the data obtained from the Ministry of Finance. A problem is that in practice it happens sometimes that municipalities assign expenditures to incorrect budget items, so it is necessary to compare the data from the Ministry of Finance with the data from the municipalities regarding certain items. The incorrectly assigned items were mechanically added to the correct ones afterwards. The analysis always used the economic results for the given year. The assignment of individual budget items to the given type of development policies (Table 1) is based on the description of the budget items (see Regulation of the Ministry of Finance No. 323/2002 Coll.) as well as on the findings derived from formerly conducted analyses.

### 3.3 Selection of cases

In practice, the support of local development is more often discussed with respect to problematic regions, which this analysis is focused on. To comply with the condition of identical entry socioeconomic conditions, the examined cities were selected from the regions that have ranked among the problematic ones over a long period, especially for the following reasons: they are mostly (1) economically weak and structurally affected regions (e.g. with a higher unemployment rate and a specific economic structure); (2) regions with a low level of social capital (Kostelecký, Patočková, Vobecká 2007: 926) and a larger number of inhabitants at the risk of social exclusion (Ministry of Labour and Social Affairs 2006); (3) regions with problematic drawing of EU funds, which resulted in a number of local political conflicts.

A total of four cities, of which three (Chomutov, Most and Děčín) are located in the Ústí Region and one (Sokolov) in the Karlovy Vary Region, were selected for the analysis. The cities Chomutov, Most and Děčín have comparable populations and are in the same category in terms of the budgetary allocation of taxes (RUD). Sokolov is one category lower. Classification in RUD categories defines the amount of the tax revenues (which form the largest part of the overall revenues) and thus the amount of the budget. All the analysed cities showed a high unemployment rate over a long period and their territories included at least two socially excluded locations according to the results of a mapping in 2006 (Ministry of Labour and Social Affairs 2006). All the cities are also municipalities with extended powers, so they have a better institutional background (represented by a municipal authority), so also a greater capacity to systematically solve long-term problems. The inclusion of Sokolov, which has a lower budget (its total revenues are approximately CZK 600 million as compared to CZK 1 billion in Chomutov), and the comparison of its approach to local development with the approach of other cities is expected to shed light on the extent to which the amount of the budget is a limiting factor for the development of cities.

## 4. Management of cities and financing of development policies

As part of the analysis, both the management within the current expenditures and the management of capital expenditures were examined. Long-term trends in the management of municipalities are naturally subject to external economic and political influences. An example is the economic crisis in 2009, which resulted in an increase in the unemployment rate and a subsequent increase of expenditures for the active employment policy, or changes in the investment behaviour due to the changes of local governments after municipal elections. We also must not disregard the role of the European funds, as the period under analysis largely overlaps with two programme periods (2007–2013 and 2014–2020).

So what has the greatest influence on the structure of expenditures? Where current expenditures are concerned, these are the expenditures for the salaries of the employees of authorities and organizations established by the city, and the expenditures for the

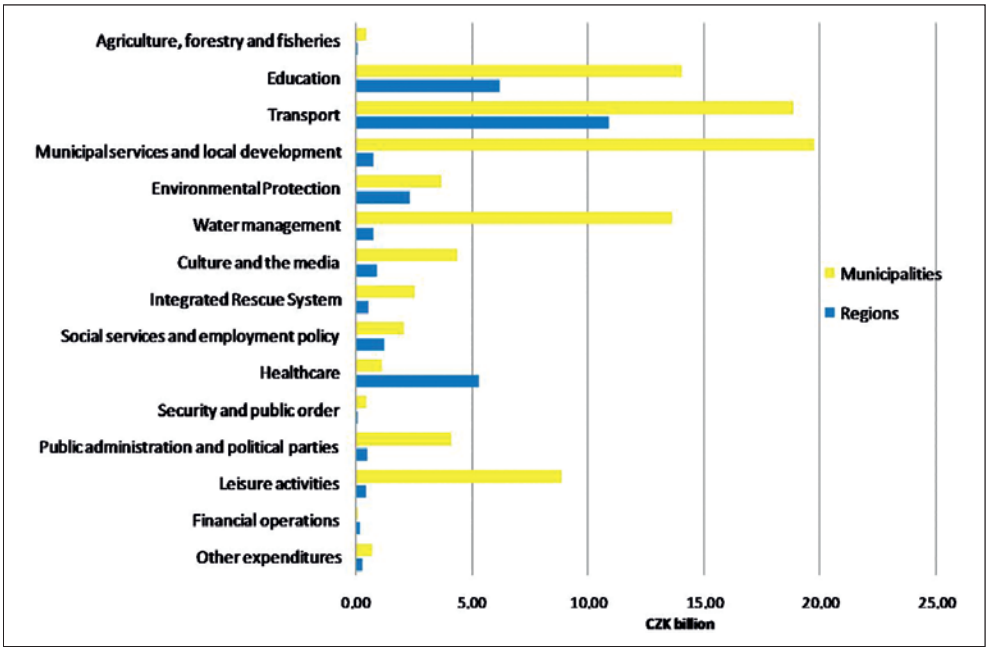


**Fig. 1** Structure of capital expenditure by municipalities and regions in Czechia in 2018.
Source: Author

operation and maintenance of buildings and other facilities. It is important to note that the amount of expenditures for the salaries of public service employees is largely covered by transfers from the state budget. In terms of capital expenditures, the most significant investments usually go to the field of housing and municipal services (Figure 1), transport and education. The significance of these investments is reflected in the fact that all these fields fall within the scope of self-government competences (Ministry of the Interior 2019: 77).

The main characteristic of capital expenditures is their limited amount. In practice, the tendency is to utilize available grants, including possible funding of investment projects from EU funds (see an example of Ostrava city in Rumpel and Slach 2012). However, the availability of grants should not be the main factor influencing investment behaviour, because the published calls for applications for grants do not always correspond to the particular needs of municipalities. From the perspective of the national level (Ministry for Regional Development 2017: 20) it is crucial that the public administration supports the involvement of all stakeholders in the process of strategic planning.

For each of the development policies, the expenditures (current and capital ones) for the entire examined period (2002–2017) are added up and their percentage in the total expenditures is calculated. In the table below (Table 2), the expenditures are confronted with the significance (expressed as a percentage) of development policies in the strategic documents. In this research, we consider the local governance effective if meets the requirements for securing local development.

As discussed above, a relatively high amount of funds towards the field of environmental and education policy was co-financed from EU funds. An overview of the most expensive investment projects (Table 3) illustrates well the level of use and purpose of EU funds. Very high investments were directed in sports facilities, not all of which serve the general public (e.g. differences between ice hockey stadium and swimming pool). From the local government perspective, the budgetary priority was given to big infrastructure projects like the revitalization of the city centers or traffic construction. On the one hand, many of these projects would not be implemented without EU co-financing, on the other hand, they are not priorities from strategic documents.

The content analysis of strategic documents showed small differences in local government priorities. All analyzed cities put great emphasis on the field of combating poverty and social exclusion, education, and employment (Figure 2). The result of the Analysis of Socially Excluded Locations (Ministry of Labour and Social Affairs 2006: 74) identified high unemployment as a big problem in these localities. The policy of combating poverty and social exclusion is more discussed in the partial chapter. On the contrary, only Chomutov and Most focused their strategic documents on the field of research, development, and innovations. It must be emphasized that all the cities are located in structurally affected regions where the efforts to develop a high-tech industry and innovation environment have not been very successful so far, even with the use of money from EU funds (Hána and Hellebrandová 2018). The support for this field should be one of the priorities of local governments.

**Tab. 2** Comparison of expenditure on local development policies, 2002–2017.

| Development policy | City | Representation of development policies in strategic documents (%) | The share of current expenditure 2002–2017 (%) | The share of capital expenditure, 2002–2017 (%) |
|---|---|---|---|---|
| Environmental policy | Děčín | 8.00 | – | 8.52 |
| | Chomutov | 14.00 | – | 3.44 |
| | Most | 17.00 | – | 6.62 |
| | Sokolov | 8.00 | – | 7.38 |
| Research, development and innovation policy | Děčín | 0.00 | 0.00 | 0.00 |
| | Chomutov | 7.00 | 0.00 | 0.00 |
| | Most | 5.00 | 0.00 | 0.00 |
| | Sokolov | 0.00 | 0.00 | 0.00 |
| Employment policy | Děčín | 23.00 | 0.00 | 0.00 |
| | Chomutov | 22.00 | 1.22 | 0.01 |
| | Most | 17.00 | 0.09 | 0.00 |
| | Sokolov | 23.00 | 0.00 | 0.00 |
| Economic policy | Děčín | 15.00 | 0.00 | 0.00 |
| | Chomutov | 7.00 | 0.00 | 0.00 |
| | Most | 11.00 | <0.01 | 0.00 |
| | Sokolov | 8.00 | 0.00 | 0.00 |
| Education policy | Děčín | 23.00. | 0.00 | 7.34 |
| | Chomutov | 22.00 | 0.03 | 4.23 |
| | Most | 22.00 | 0.10 | 7.03 |
| | Sokolov | 15.00 | 0.00 | 10.71 |
| Policy of combating poverty and social exclusion | Děčín | 23.00 | 0.62 | 0.23 |
| | Chomutov | 21.00 | 0.11 | <0.01 |
| | Most | 22.00 | 0.90 | 5.15 |
| | Sokolov | 38.00 | 0.97 | 1.30 |

Source: Author

At the same time, this field requires a certain degree of cooperation between stakeholders at various territorial levels – from the state agencies (e.g. CzechInvest) through the regional level to the local level represented by the examined cities. However, neither current nor capital expenditures were directed to this field in any of the analyzed cities.

In terms of strategic plans, environmental policy was given greater attention in Most and Chomutov. Problems associated with a lower quality of the environment and with environmental burdens have been one of the main limitations of development of the Ústí Region (and partially the Karlovy Vary Region) over a long period. In particular, this policy was long funded with support from EU funds. When considering absolute amounts, the highest amount was invested in this field by Most (over CZK 273 million), but when considering their proportion to the total

**Tab. 3** The most significant investments from EU funds, 2005–2017.

| Děčín | Chomutov |
|---|---|
| ▪ revitalization of a brownfield in the city center into a library and multimedia center over CZK 119 million<br>▪ reconstruction of schools and their sports grounds over CZK 60 million<br>▪ reconstruction of the retirement home over CZK 40 million<br>▪ extension of the swimming area over CZK 39 million | ▪ sports fields projects (athletic stadium, winter stadium) over CZK 800 million<br>▪ landfill reclamation over CZK 40 million<br>▪ complex revitalization of housing estates over CZK 40 million |
| **Most** | **Sokolov** |
| ▪ reconstruction of schools over CZK 50 million<br>▪ transport infrastructure projects (stations etc.) over CZK 40 million<br>▪ projects aimed at the integration of socially excluded people over CZK 20 million | ▪ reconstruction of the winter stadium over CZK 110 million<br>▪ wastewater treatment maters over CZK 51 million<br>▪ revitalization of the city swimming pool over CZK 42 million<br>▪ another sports fields projects over CZK 40 million |

Source: Ministry for Regional Development 2020

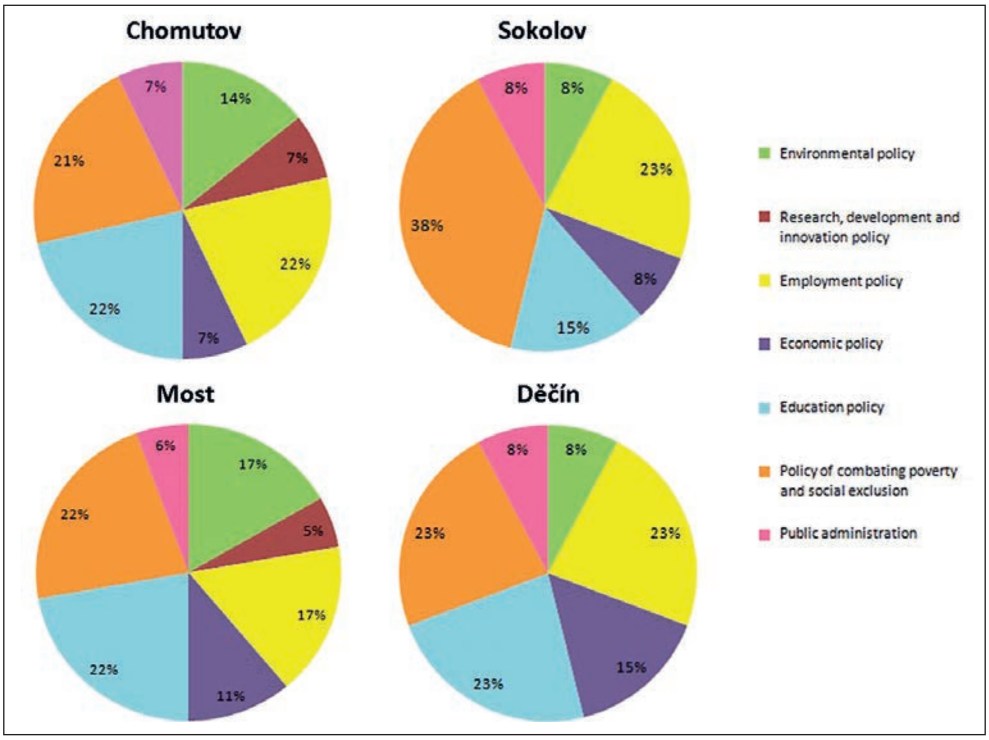


**Fig. 2 a–d** Representation of development policies in strategic documents of the cities of Chomutov, Sokolov, Most and Děčín.
Source: Author

investments, such investments were more significant in Děčín (approximately 8.5%) and Sokolov (approximately 7.4%). In Chomutov, the proportion of such expenditures is only 3.4%, but in absolute terms it is more than CZK 150 million. The environmental field includes investments e.g. in the revitalization of urban vegetation, landfilling, wastewater treatment matters and, in Děčín, safety measures to address the risk of rockslides along the Elbe river. Although the environment is an area that EU funds have also significantly helped to improve, in the future, at least Most will have to respond to the end of lignite mining.

Like environmental policy, education was a key part of strategic plans. With respect to current expenditures, the field of the education policy is defined only as the support for university activities, including research and development at university institutions, and multicultural education and education events focused on the integration of disadvantaged groups of the population. The matters of the integration of disadvantaged groups are often addressed and financially supported by non-profit organizations rather than by the cities themselves. The only cities of the analysed ones that directed expenditures to this field were Chomutov and Most. As for Chomutov, the aggregate expenditures for the entire period amounted to approximately CZK 4 million (0.03% of the total current expenditures), while the expenditures of Most amounted to CZK 16 million (0.1% of the total current expenditures). In both cities, 100% of such expenditures consisted of expenditures for the support of universities and research and development.

For Chomutov, Most and Sokolov, the education policy is a field to which these cities directed most of their capital expenditures. The total amount of investments in this field ranges from CZK 167 million (Děčín) to CZK 290 million (Most). The proportion of such expenditures to the total investments was highest in Sokolov (10.7%), slightly lower in Děčín and Most (7%) and lowest in Chomutov (4%). With the use of such expenditures, many investment projects (co-financed from EU funds) were completed, such as the renovation of school buildings and the purchase of classroom equipment in order to enhance the quality of education. Unlike the current expenditures, which also partially include educational projects, the investments serve to improve the “infrastructure”. Both these groups of expenditures supplement each other and must be mutually interconnected in order to enhance the quality of education. The field of education policy illustrates well the difficulties in measuring its efficiency (from an economic point of view). We can relate the invested funds to the number of pupils, but it is not possible to say simply that more funding per pupil is (in)efficient. On the other hand, the reconstruction of the school playground and making it available to the general public (e.g. the long-term policy applied in Most) can be considered as effective.

Employment policy was the second or third most important topic in the content of strategic documents. Despite this, only two cities – Chomutov and

Most directed current expenditures to this field. Both the cities differ considerably in both the absolute amounts and their relative proportions. The expenditures of Chomutov amounted to more than CZK 150 million while the expenditures of Most amounted to CZK 15 million for the entire examined period. The funding of this field was stable in both the cities throughout the period, except that in certain sub-periods different forms of employment support were preferred (socially purposeful jobs, etc.). Although the cities are located in a structurally affected region, the current unemployment rate is low, in January 2019 it was 5.8% (Chomutov) and 6.1% (Most). The fact that not all the cities funded this field demonstrates a certain inconsistency with the analysed strategic documents, as the field of employment ranked among the most frequently represented ones, even in Sokolov and Děčín.

The economic policy is a specific development field that is relatively harder to examine and that includes the support of industrial zone development, the enhancement of industry competitiveness and the support of entrepreneurship. Industrial zones, their construction and development, in particular, are supported quite considerably by some of the cities (similar to Ostrava, see Rumpel and Slach 2012: 122). This mostly concerns the industrial zones in the territory of the cities, but many large and development industrial zones are also located along the main traffic routes and are co-funded by the state and regions as well. Regrettably, the expenditures of the cities directed to the construction of industrial zones (e.g. construction of the infrastructure) are often included and distributed in other budget items (e.g. under transport expenditures), so they cannot be precisely quantified. Current expenditures in the economic policy were only seen in the budgetary items of Most, namely in the amount of less than CZK 0.5 million. It is a negligible percentage of the total expenditures. These expenditures are disproportionate to the importance of this policy in the strategic documents.

### 4.1 Policy of combating poverty and social exclusion

Currently, the principles of community planning are applied in solving the problems of social exclusion at the same time they contribute to the development of representative democracy in a broader context. As stated by Bovaird (2007: 846), politicians should try to find ways to connect service providers and users. Community planning may also help prevent social exclusion if implemented in the field of social services (Ministry of Labour and Social Affairs 2006). The analysis of the strategic documents confirmed that in all the community plans of development of social services, the topic of social exclusion and combating it was in the spotlight (Figure 1). Other policies mentioned and associated with community planning were the fields of employment and education. For comparison, it is possible to state the results of a formerly conducted research among mayors and city representatives in European countries, where Czechia, just like e.g. France, did not place any emphasis on combating social exclusion (see Getimis and Magnier 2013: 240).

The policy of combating poverty and social exclusion is the most significant development policy in terms of current expenditures. All the examined cities directed less than 1% of the total current

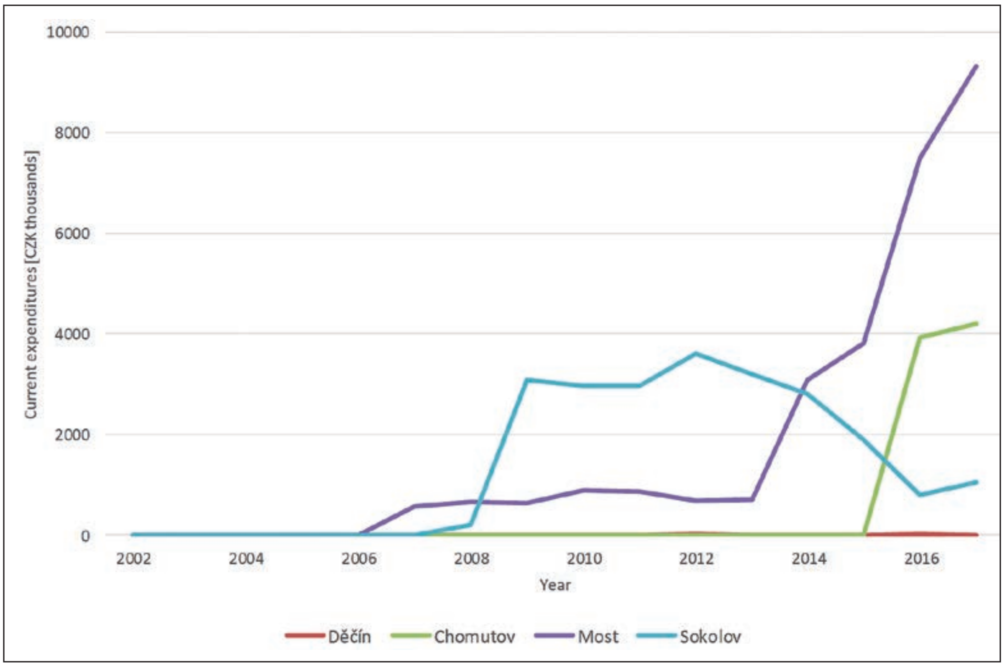


Fig. 3 Current expenditure on social prevention.
Source: Author

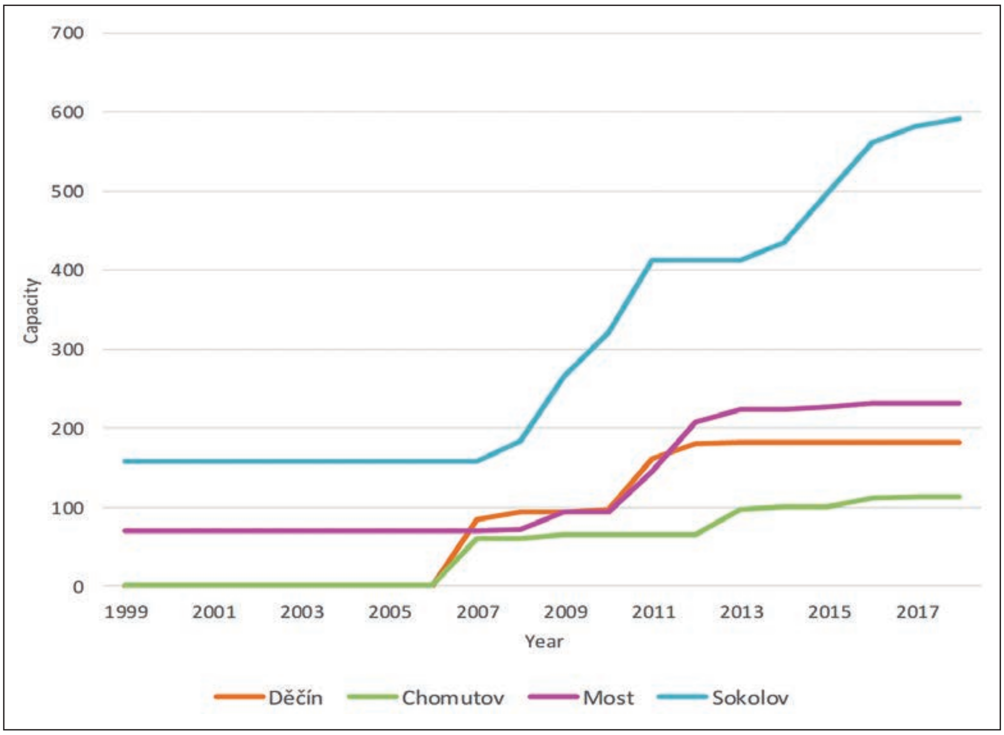


**Fig. 4** Capacity of places in social prevention facilities.
Source: Author

expenditures to this field. In absolute terms, the highest amount (approximately CZK 148 million) for the analysed period was directed to this field by Most. The expenditures of the other cities are one order of magnitude lower. The capital expenditures were invested in leisure time activities of children and youth and in strengthening the capacity of social prevention services, e.g. in the purchase of equipment of low-threshold facilities for children and youth. The support for leisure time activities, no matter whether provided under the umbrella of institutions or whether provided through the extension of opportunities in the form of building sports ground, is supposed to serve to prevent social pathologies.

Social prevention as a part of this policy was summarized in two analyses (dated 2006 and 2015) from the Ministry of Labour and Social Affairs. The analysis carried out in 2015 (Ministry of Labour and Social Affairs 2015: 84) points out that social prevention services are distributed unevenly at the level of municipalities with extended powers, so they do not fully reflect the needs of inhabitants of socially excluded locations. In this context, their current distribution is partially a result of a response to the socioeconomic development and partially a result of an active approach of local authorities. It should be noted that in practice there are also situations where the most deprived areas are not targeted by programmes, because priority is given to those areas where results may be achieved faster and cheaper (Atkinson 2000).

As for the expenditures in the field of social prevention, the measurement of effectiveness in terms of long-term impacts is very difficult. It can be expected that any greater effects brought about by these expenditures will only appear in the longer term. On the other hand, it is possible to analyse e.g. the degree of the provision of social prevention services. Such facilities include low-threshold facilities for children and youth, field services, expert social consultancy, shelters and halfway houses and other special social services (social rehabilitation, etc.). In absolute terms, the highest growth of (weekly) capacities for the entire examined period was seen in Sokolov (Figure 4) where the capacities of facilities increased four times over 10 years. In Děčín and Most, the greatest extension of the capacities of social prevention facilities took place in the period from 2007 to 2012. Chomutov has the lowest capacities (114 clients).

The first budgetary expenditures in social prevention in Most appeared in 2007, in Sokolov in 2008, in Děčín in 2012, and in Chomutov in 2016 (Figure 3). In contrast to the increasing offer and capacity of services in this field, the current expenditures have gradually grown only in Most and Chomutov in recent years. Děčín funded this field only in 2012 and 2016 in amounts not exceeding tens of thousands of CZK per year.

## 5. Summary

As discussed in the theoretical introductory part of this article, several methods are used in practice to measure effectiveness. In this research, such governance that meets the requirements for securing local development is considered effective. In particular, this concerns addressing long-term problems emphasized in various types of strategic documents adopted in the cities in the course of several years. A basic assumption is that the local governments reflect the objectives set out in the strategic documents (despite the fact that they are not binding and legally enforceable) in their decision-making associated with the budget. In practice, expenditures should be directed more frequently and regularly to the fields most frequently mentioned in the strategic documents. So the objective was to compare the effectiveness of governance of the four examined cities and to determine which of them support local development systematically.

The analysis of the expenditure parts of budgets of the examined cities showed considerable differences in the priorities of individual local governments. While the proportion of "development" current expenditures to the total current expenditures was negligible, the situation differed for capital expenditures. The reason is a smaller overall volume of the capital budget, so any quite a large investment results in a higher proportion of the given development area to the total capital expenditures. In terms of absolute amounts, the most funds were directed to the education policy, closely followed by the environment. These total expenditures in individual development policies and their relative proportions tothe total expenditures may be compared with the representation of such development policies in the strategic documents to indicate the (non-)effectiveness of the local governments.

As the first one, we can compare the expenditures in the field of combating poverty and social exclusion, which is the policy that is most frequently represented in the strategic documents in all the examined cities. All the cities directed expenditures to this field, but only in Sokolov and Most did such expenditures amount to at least 1% of the total expenditures, and this percentage is even higher in capital expenditures. The effort to actively address the matters of social exclusionin these cities may also be proved by the growth of capacities of social prevention facilities throughout the examined period.

Another key development policy frequently mentioned in the development documents is the field of employment. However, its significance in the strategic documents does not correspond to its representation in the expenditure parts of the current and capital budgets of the examined cities. Two cities (Děčín and Sokolov) even had zero expenditures in this field. As for the capital budget, any greater expenditures may not be expected, because the employment policy is covered from current expenditures. Like many other policies, the employment policy is strongly influenced by the setting of its support at the national level, although, as a matter of course, the municipalities are free to use their own initiative.

The field of education is considered in the budgets much more than the employment policy. As for the current expenditures, the amounts are minimal, but as for the capital expenditures, their proportion is relatively high in all the cities, ranging from 4 to 10%. The support for the education policy largely consists of investments in the buildings and the purchase of equipment. However, improving the quality of infrastructure is only one of the conditions for improving the quality of education. To achieve improvement, this form of investments must be supplemented by investments in "soft" (i.e. education) projects. In this development policy, governments are effective, i.e. show the efforts to fund this field systematically and on a long-term basis.

These three development policies make it possible to compare the cities and their use of current and capital budgets in the best manner. In general, the degree of representation of various development policies in the strategic documents does not correspond much to their percentage in the budgetary expenditures. The fields of the environment and education can be identified as the development policies most supported by capital expenditures. In both these fields, investments co-funded from EU funds have a role that cannot be ignored. So it is unclear whether the local governments really want to solve long-term problems or whether they primarily use the available financial sources regardless of the necessity of the given investment.

## 6. Conclusion

The objective of this article is to show one of the possible approaches to measuring effectiveness, namely the comparison of the long-term trends in budgetary expenditures with the "trends" in the strategic documents. It was assumed that all the examined cities represented by their local governments would show efforts to address problematic fields and fund selected development fields on a long-term basis.

The presented analysis of the budget expenditure of four selected cities revealed an insufficient degree of funding of a majority of the defined development policies. Although a number of strategic documents emphasizing various types of policies were drawn up, in fact only the fields of the environment and education and, to a considerably lower extent, the field of combating poverty and social exclusion experienced a certain development. By contrast, e.g. support for innovations, research and development was not reflected in the expenditures at all. So the effectiveness of governance within the meaning of the fulfilment of long-term objectives in the field of local development cannot be evaluated positively in the analysed cities.

In addition to the priorities of various governments and the necessity to respond to current problems and challenges, some other influences are also reflected in the budgetary behaviour. The higher percentage of certain types of expenditures (investments, in particular) that were co-funded from other sources (predominantly grants from EU funds) may reflect the efforts of local governments to utilize available grants with a lower emphasis on their development potential. Moreover, the implementation of large investment projects requires more time for the preparation of all the necessary documents, so priority is naturally given to formerly prepared projects as long as funds are available for the implementation. In the future, the analysed cities should focus more on the fulfilment of strategic documents and on the addressing of long-term problems and should try to lower its dependence on various grants from external sources.

The reason to keep paying attention to this category of cities is their role in the local development that cannot be ignored. Given the size of their budgets that make it possible to implement multiple costly projects, their activities have an effect on the other municipalities in the entire micro-region. The transfer of competencies to the local level on the principle of subsidiarity was associated with the expectations that this category of cities would be an initiator of development activities. However, this article shows certain pitfalls in the form of problems with the fulfilment of own strategic and development objectives. It remains unclear whether cities will manage to meet expectations and will become not only the key actors of local development but also partners for other municipalities in the micro-region. For political geographers, this topic constitutes potential for further research of public administration and governance in the Czech context.

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**Appendix 1** Overview of strategic and development documents of analyzed cities.

| City | Strategic document | City | Strategic document |
|---|---|---|---|
| Děčín | Strategic development plan of the city Děčín (2001) | Sokolov | Strategic plan for sustainable development of the city |
| | Strategic development plan of the city Děčín (2004) | | Development plan of social services of Sokolov city for the period 2009–2013 |
| | II. Strategic plan of the city Děčín (2013) | | Development plan of social services of Sokolov city for the period 2014–2018 |
| | Strategic development plan of the city Děčín 2014–2020 | | Strategic plan of social inclusion of Sokolov for the period 2017–2019 |
| | I. community plan of social services of the city Děčín 2006–2008 | | Strategic plan of local partnership in Sokolov for the period 2014–2016 |
| | II. community plan of social services of the city Děčín 2010–2013 | | |
| Chomutov | The city development framework strategy 2014–2024 | Most | Strategic development plan of the city Most by 2020 (2016–2020) |
| | Community plan of social services | | Integrated plan of city development: "Deprived city area and civic coexistence" |
| | Social policy of the city Chomutov with a focus on social Inclusion 2013–2015 | | Integrated plan of city development Most: Housing estate Liščí Vrch and Výsluní |
| | A long-term plan for the development of education and promoting employment in the Chomutov city by 2020 | | III. community plan of social services of the city Most 2015–2018 |
| | Integrated plan of city development: "Area of the former barracks and the surrounding area" | | Strategic plan of local partnership in Most for the period 2013–2014 |

Source: Strategic documents provided upon request under Act No. 106/1999 Coll., on free access to information, websites of the town of Děčín, Chomutov, Most, and Sokolov.

# Analytical maps as a basis for understanding the development of rural architecture

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**ABSTRACT**
This article deals with the creation of maps that depict the development of selected villages in Czechia in the 19th and 20th centuries. These maps are used for the artistic and historical research of rural architecture, which focuses on the type and detail of the surveyed buildings in the selected time period. Its results can be interpreted in a wider cultural context of the respective rural region. The maps of the development of rural architecture were created on the basis of a detailed analysis of available archival maps. The article describes the practical experience with the creation of these maps, contains an overview and description of available archive maps and the procedure of their processing using geographic information system (GIS) tools. The interactive presentation of the created maps on the Internet is also discussed.

**KEYWORDS**
development of rural architecture; archival maps; georeferencing of maps; vectorization of maps; web-map-presentation

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## 1. Introduction

The beginning of the 21st century is associated with a rapid development of Information and Communication Technologies (ICT), which have gradually affected most areas of human activity, including cultural heritage. In the field of monitoring the development of rural architecture, it is primarily the use of Geographic Information Systems (GIS).

In Bohemia and Moravia, the rural architecture has been influenced by intense political, economic and social changes taking place since the second half of the 19th century. In particular, they involved the abolition of drudgery (1848), the establishment of the cadastre unit institute and building legislation, i.e. specification of construction management, fire regulations, and the arrival of qualified architects, etc. The gradual emergence of industry (19th century) and large migration after World War I and World War II (20th century) had major influence on the development of villages. In addition, the appearance of rural architecture has been changing rapidly since the end of the 20th century.

During the research into rural architecture, the main focus often aims at the Building Archaeology Survey and metric survey documentation of the oldest preserved medieval buildings and their fragments. The study of rural Baroque and Classicism architecture (Mencl 1980) also attracts a great deal of attention. Rural architecture of the second half of the 19th century and its development during the 20th century have been highlighted since the 1990s (Dittrich 1990; Kuča, Kučová 1995; Škabrada 1999).

Generally, the approach to research into rural architecture is divided into two types:
1. individual,
2. areal.

In the first case, it is usually an Operative Survey (Bláha et al. 2005) or a Building Archaeology Survey (Beránek, Macek 2015; Pešta 2014) or a metric survey documentation (Veselý 2014; Pavelka 2017; Poloprutský 2018) of a specific building or a block of buildings. An interesting source of information about rural architecture can be the projects of village buildings, which capture objects in their original form, i.e. not obscured by later modifications, rather than on real buildings (Ebel, Škabrada 2016).

In the second case, it is usually an area survey in which attention is focused on a particular region. With this approach, archival maps of various types and ages can be used to describe, monitor and analyse anthropogenic and environmental phenomena that have been involved in and contribute to the development of the region of interest of this article. Recent research studies in Czechia which deal with thematic changes of the landscape over time are often focused differently in their specific objectives, e.g. on the development and reconstruction of extinct villages in the Ústí Region (Brůna et al. 2015a, 2015b) or the development and reconstruction of the historical Vltava River valley (Cajthaml, Kratochvílová, Janata 2019).

Valuable data sources for landscape and urban development analyses are large-scale maps created in various historical periods as well as digital orthophotos – historical (Adami 2015; Cogliati et al. 2017) and contemporary. In these approaches, advanced GIS tools can be successfully applied (Liu, Wang, Long 2010; Čurovič, Popovič 2014; Adami 2015).

The article provides an overview of old and current large-scale map datasets available in Czechia. The basic properties of maps with regard to the solved problems are stated (Chapter 2). The main goal of the article is to apply the basic methods of processing old maps (georeferencing, vectorization, topology control and online presentation – Chapter 3) for the creation and presentation of maps of the built-up area development (Chapter 4). The described workflow identifies problems that occurred during processing and lists their solutions that can be inspiring when processing similar tasks.

Created maps of the built-up area development are used for Artistic and Historical Research of processed localities (Hůrková, Mezihoráková 2018, 2019).

### 1.1 Artistic and historical research

Artistic and Historical Research focuses on a specific part, an element or a type of building under investigation in the chosen time period. Its results can further be developed and interpreted in a wider cultural context of the respective rural region. In this way, it is possible to describe the cultural and social environment of the given rural region and external influences which have guided its future development in the given time period (Hůrková, Mezihoráková 2016). Artistic and Historical Research is the domain of the ÚDU staff.

In the future, the results of Artistic and Historical Research can be used as a supplement to the Building Archaeology Survey (Pešta 2014; Beránek, Macek 2015). Artistic and Historical Research consists of four basic parts:
1. background research of available historical sources and literature,
2. analysis of urban development based on the analysis of large scale maps from the 2nd half of the 19th century to the present,
3. survey of rural buildings in the region and selection of the building which formally and by style best characterizes rural architecture in the region (Poloprutský 2018),
4. interpretation, presentation and archiving of the results.

### 1.2 Maps of built-up area development

The maps of the built-up area development are made on the basis of a detailed analysis of available archive maps and subsequently serve for the analysis of building development. In the light of these facts, these maps are referred to as *analytical maps* in the text below. In the early stages of research, it has proven useful to produce analytical maps of two types:

1. *Summary maps* of the development of a built-up area which show the buildings (their outline) in all used underlying maps.
2. *Detailed maps* of the development of a built-up area which show the buildings in terms of building construction in the two oldest time periods. These maps benefit from the fact that in the maps of a Stable Cadastre, it is possible to tell from the colour of the filling of the building whether it is a brick or wooden one.

Analytical maps capture the transformation of the ground plans of buildings. However, caution must be paid – there is a number of buildings that were completely rebuilt although their ground plan has been preserved. By comparing the time layers, it is possible to deduce interesting facts from analytical maps that can be approximately dated (Poloprutský 2018):

- Ground plan of the building has not changed – it is likely that the original core is preserved in the building, although the facades of the building can be completely changed;
- Ground plan of the building has changed – building modifications have been made;
- Ground plan of the building has shifted on the plot – the original building has been replaced by a new building;
- Change in colour of the building filling – the building was rebuilt using another building material (wood – brick).

An essential prerequisite for the creation of analytical maps of surveyed sites is the existence and availability of a sufficient number of base-maps, which may be supplemented by other data sources such as Aerial Survey Photographs or Orthophotos.

## 2. Base datasets

First, it was necessary to search for archival datasets that show the main subject of research – buildings with sufficient detail and accuracy. Detailed maps charting the whole territory of today's Czechia cover the time period of almost 200 years. The quality of individual map-sets is influenced by the purpose for which they were made, the available and used technical means, the financial possibilities, as well as other factors, and does not apply proportionally: the older the map the lower the quality. For a correct interpretation of the content of underlying maps (Hauserová, Poláková 2015), it is favourable to know these technicalities, and therefore we give an overview of the basic characteristics of the used data sources (Bumba 2009; Geoportal ČÚZK 2020). Generally, data sources can be divided into archival and current datasets by the date of creation.

### 2.1 Archival base datasets

Archival maps made for cadastral purposes are kept and made accessible to the public mainly by the Central Archive of Surveying and Cadastre (ÚAZK). The most frequently used maps are scanned and continuously published on its website (ÚAZK 2020). Scanned maps can be ordered through the E-shop of the *ČÚZK Geoportal* (Geoportal ČÚZK 2020). Maps that have not been scanned can be requested and examined in the ÚAZK study room where they can also be scanned. The issue of archive documents is charged according to the current price list.

The following map titles are taken from official sources (Geoportal ČÚZK 2020; Terminological Dictionary 2020). The overview of the maps is presented in chronological order (from the oldest).

*Imperial Obligatory Imprints of the Stable Cadastre* (CO, Figure 1) were made on the basis of the Imperial Patent of 1817, which established the Stable Cadastre. Cassini-Soldner's projection was used as the map projection; for Bohemia the Gusterberg datum of cadastre coordinates was used, and for Moravia and Silesia the St. Stephen datum of cadastre coordinates was used. Maps were created by using a method of the plane table in the fathom scale of 1 : 2,880 directly in the field. Imperial Obligatory Imprints were not used for plotting additional changes in the field, and thus depict the landscape in its original state from the mapping period (Bohemia 1826–1843, Moravia and Silesia 1824–1836). Maps were manually coloured. It was a unique map series, which has still been used in a large part of Czechia in digital form until today. Imperial Obligatory Imprints generally belong to the most demanded archival maps.

*Original maps of the Stable Cadastre* (OM, Figure 2) are original maps created during the mapping of the *Stable Cadastre* (one of the copies served as an Imperial Obligatory Imprint). The changes that occurred in the field were not continuously drawn into the maps and therefore the maps gradually became obsolete.

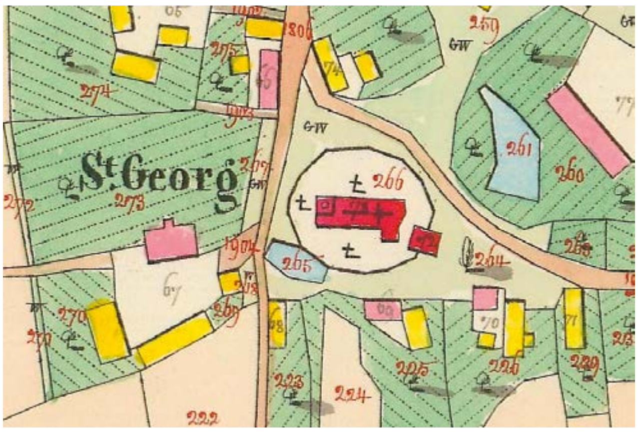


**Fig. 1** Imperial Obligatory Imprint (1840), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

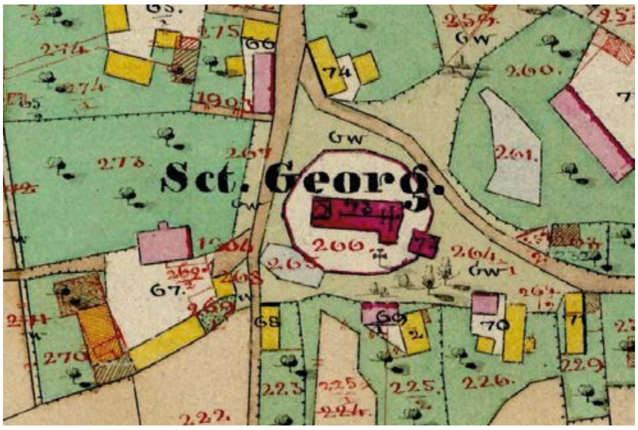


Fig. 2 Original map (1877), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

In 1867, it was decided to perform a one-time update (reambulation) of maps. Unfortunately, due to the lack of time, changes were often mapped and plotted less accurately than the original mapping. The changes were drawn into the original maps by red colour for highlighting. When the drawing became confusing due to a large number of changes, the map was redrawn in its current valid state.

*Correction sheets of the Stable Cadastre* (EM, Figure 3) were depicted based on the legislation of 1883, which introduced the obligation to keep maps in accordance with reality (obligation to report changes of owners). The coordinate system and the content of these maps remained the same, only from 1887, new maps were formed in a decimal scale, usually 1 : 2,500. On the basis of numerically measured geometric plans, the changes in maps were sketched in red colour. If the drawing became confusing due to a large number of changes, the map was redrawn in its current valid state.

All the above-mentioned types of maps of the Stable Cadastre are maps of a selected area, i.e. the drawing does not cover the entire map sheet, but ends at the border of a cadastral unit. In terms of built-up area development studies, it is important that the maps distinguish wooden buildings from brick ones.

All types of maps of the Stable Cadastre, i.e. CO, OM and EM, are available in the raster scanned JPG format with a resolution of 300 DPI. With the exception of CO, where the mapping year is clearly stated, it may not be easy to reliably determine the date to which the map refers, i.e. when the map was completed. Sometimes, the date can be read from a handwritten note on the edge of the map; sometimes, it is necessary to consult the problem with the ÚAZK staff; and sometimes, the exact date of the map remains uncertain.

*Land Cadastre maps* (PK, Figure 4) were made in *Křovák's projection* in the *Datum of the Uniform Trigonometric Cadastral Network* (S-JTSK) according to a law from 1927 and related instructions. The new mapping was carried out only in a smaller part of the territory, preferably in locations with major changes (usually in a reference scale of 1 : 2,000 for rural and 1 : 1,000 for built-up areas). In other localities, the maps of the Stable Cadastre remained valid.

Land Cadastre maps are provided by ÚAZK in a binary (black and white) CIT format with a resolution of 400 DPI without georeferencing (individual map sheets) or as one file (complete cadastral unit) georeferenced to the coordinate S-JTSK system. The relatively low scanning resolution and especially the used data-format made the drawing of the scanned map often difficult to read. The date of completion of the drawing into the map must be discussed with the locally relevant cadastral office, where the map is stored. There, it is also possible to request a new, i.e. higher quality, scan of the map.

*State Maps 1 : 5,000 – derived* (SMO5, Figure 5) were made for the needs of state administration in the years of 1950–2000. The topography was derived from current cadastral maps. The maps also contain hypsography, which was taken from the most suitable existing data (usually a smaller scale). The maps can be used in a situation when the original cadastral

Fig. 3 Correction sheet (1939), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

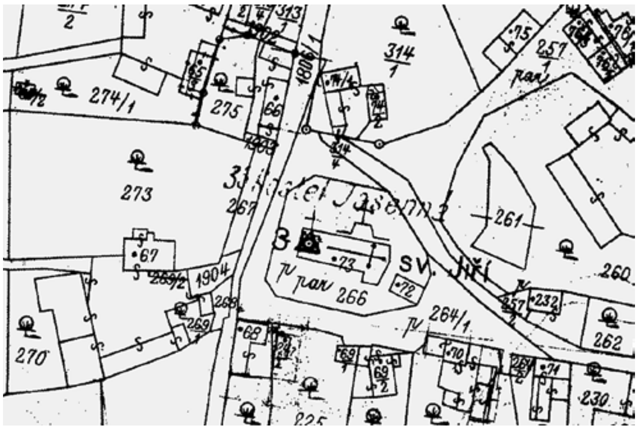

Fig. 4 Land Cadastre map (1955), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

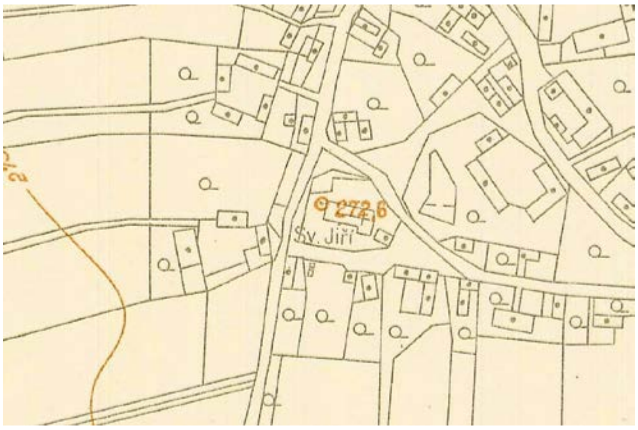


**Fig. 5** State Map 1 : 5,000 – derived (1953), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

**Fig. 7** Aerial survey photograph (1975), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

maps have not been preserved for the given period. A smaller map scale provides less detail, even with regard to the shape of buildings. The maps are scanned at a resolution of 300 DPI and provided in the JPG format.

*Maps of the Unified Land Registry* (JEP) were made in the years of 1956–1964 recording only actual land use relations (not ownership relations). For the measurement and plotting changes in the map, simplified procedures and looser tolerances were allowed, which resulted in less geometrically accurate maps.

*Maps of the Registry of Real Estate* (MEN, Figure 6) were introduced by legislation in 1964. The projection and the coordinate system remained unchanged. The drawing continuously covers the whole map sheet – individual maps of selected areas were connected; irregularities at the interface drawing are partially aligned with the consequence of a local loss of geometric precision.

The maps of JEP and MEN are scanned and provided in the JPG format with a resolution of 300 DPI. These maps may be available in several editions of different dates.

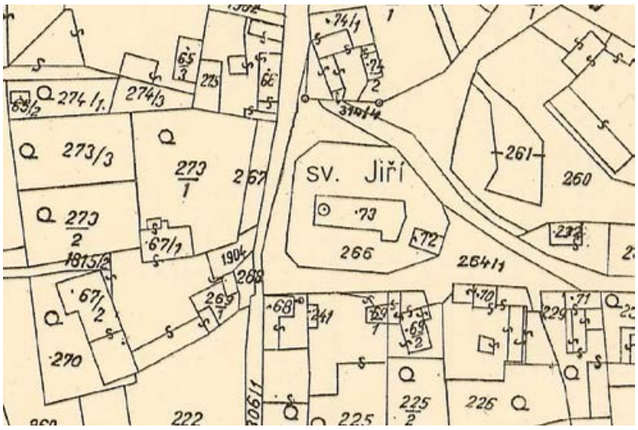


**Fig. 6** Maps of the Registry of Real Estate (1964), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

*Aerial survey photographs* (LMS, Figure 7) have been taken since 1936. The photograph scale is smaller than in the previously mentioned base maps, and their content is affected by the weather at the time of photography, but they capture non-generalised situations and represent a usable data source. If a relief elevation model is known, the photographs can be converted to an orthophoto (Hodač, Zemánková 2018).

*The National Archive of Aerial Survey Photographs* is administered by the *Military Geographic and Hydrometeorological Office* in Dobruška. Original aerial photographs are gradually digitized in cooperation with the *Czech Office for Surveying, Mapping and Cadastre* (ČÚZK). Some photographs are available on the website of the archive (LMS 2020).

Other usable historical maps of a local scope (various thematic maps, manor maps, homestead plans, etc.) may be a part of the funds of local regional archives.

## 2.2 Current base datasets

From the current base datasets *Cadastral maps of the Real Estate Cadastre* and the *Orthophoto of the Czech Republic* can be used to monitor the development of built-up areas.

*Maps of the Real Estate Cadastre* (KN, Figure 8), i.e. current cadastral maps, are made according to legislation from 2013 (Cadastral Decree 2013). Today, cadastral maps exist in digital vector form in the S-JTSK system (EPSG: 5514) for almost the whole territory of Czechia. The maps, created by new mapping or by reworking of numerical surveys, are called *Digital Cadastral Maps* (DKM); the maps created by the digitization (vectorization) and transformation (georeferencing) of analogue maps are called *Digitalized Cadastral Maps* (KMD). On a very small part of Czechia, there are still maps in the Stable Cadastre system (KM-D) or even in analogue form.

Cadastral maps in digital vector form can be freely downloaded from the website for individual cadastral

**Fig. 8** Map of the Real Estate Cadastre (2018), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

**Fig. 9** Orthophoto of the Czech Republic (2018), the centre of the village of Jasenná (Náchod District), data: ÚAZK.

units (Geoportal ČÚZK 2020) in several types of vector formats (DGN, DXF, SHP, VFK). Analogue cadastral maps in the CIT raster format can be downloaded from the website (for a fee).

*The Orthophoto of the Czech Republic* (Figure 9) depicts the current non-generalised earth surface at the time of photography. Currently, it is produced in a two-year period with a pixel size of 0.20 meters. The orthophoto is available as a data file in the JPG format in a range of 2.5 × 2 km, i.e. map layout of the State map at a scale of 1 : 5,000 (for a fee) or as a Web Map Service (free). The orthophoto may contain buildings that are not drawn into the cadastral map – they are not subject to the cadastre or have not yet been measured and displayed.

## 3. Methods for processing datasets

During the processing of analytical maps, a number of methods which are briefly presented in the following text was used.

### 3.1 Georeferencing

In this article, georeferencing is understood as the placement of raster maps in a known coordinate reference system. The georeferencing operation is performed by a geometric transformation determined on the basis of identical points, i.e. points that are simultaneously drawn on both maps – a georeferenced map and a reference map (Cajthaml 2012).

Identical points determine the accuracy of the transformation. It is necessary to choose these points in areas that did not change during the gap between the creations of both maps. The most common identical points are corners of important buildings, distinct breakpoints on the cadastral boundary, common points of two or more parcels, etc. Identical points should be distributed throughout the area of interest as evenly as possible. Sometimes, it is difficult to find a sufficient number of appropriately spaced identical points. In that case, it is necessary to take into account the possible impacts on the accuracy of the resulting transformation.

For the georeferencing of scanned map sheets, affine transformation is often chosen (Luhmann et al. 2014), which reflects the various shrinkage of a map sheet in longitudinal and transverse directions. With an excessive number of identical points, i.e. with more than three, the transformation accuracy can be estimated and offsets at identical points can be calculated by the least squares adjustment. The use of a higher degree of transformations leads to smaller deviations at identical points, but to greater local deformations.

### 3.2 Vectorization

The vectorization of the map means “reworking a map in analogue form, or a digital map in raster form, into vector form” (Terminological Dictionary 2020). During vectorization, a digital vector presentation of spatial elements is created. Vectorization can be performed manually one by one point, or by the use of various forms of automation. The manual vectorization method is very time-consuming, but it is often the only way to get a well-usable vector map. With manual vectorization, individual map elements can be divided into thematic layers and additional properties (attributes) may be added to them.

### 3.3 Topology control

Vector map elements form a topology that is understood as “defining the structure elements of geosystems based on their relationships connectivity (interconnection) and continuity (relative positions); map elements create topological structures consisting of nodes, edges, and walls” (Terminological Dictionary

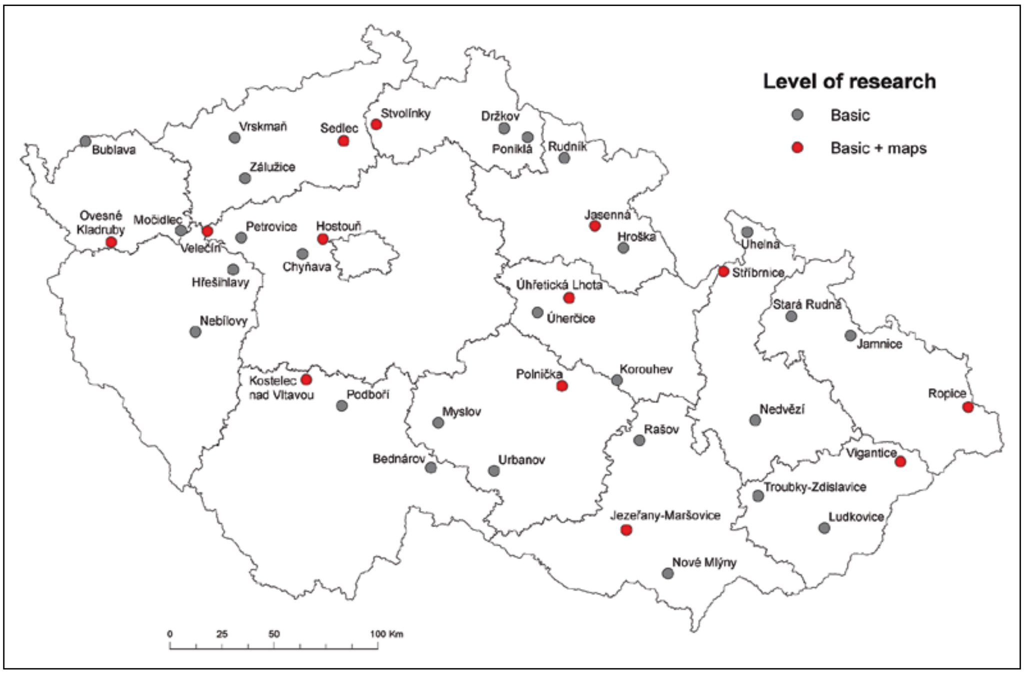


**Fig. 10** Location of examined villages in Czechia.

2020). From a practical viewpoint of the vectorization of a map, it is the verification that the drawing does not contain free line ends, intersections of lines without intersection points, isolated points etc. It would not be possible to perform subsequent spatial analyses correctly without removing these imperfections. Their general theoretical overview is beyond the scope of this article, therefore only the specific process that was used is described in subsection 4.4.

### 3.4 Online presentation of maps

Digital maps can be made available to a wide range of users on the Internet websites nowadays. An attractive online presentation of maps requires the use of tools that offer interactivity, i.e. at least the possibility of changing the scale of the map display, shifting the viewport, eventually the possibility of working with layers or the availability of additional information about each map element. For complex solutions, it is possible to talk about a certain information system based on a concrete map.

Generally, presented digital maps can be divided according to format into raster and vector maps. For displaying larger raster maps, it is favourable to use a solution that allows selectively downloading and displaying only the necessary data based on the current viewport and the display scale. For this purpose, the so-called *pyramid of raster tiles* is usually used. Presenting maps in the vector format allows zooming in and out of the drawing at any time without a loss of display quality. Complex map contents can be divided into separately viewable thematic layers.

Generally, individual maps, thematic layers or additional external data sources may be in different coordinate systems. For a positionally correct common view of all parts of the map, it is necessary to ensure the appropriate transformation of their display into a uniform coordinate system.

Today, many applications allow advanced ways of online presentations of raster and vector data (e.g. Tile Map Service, Zoomify, OpenStreetMaps, OpenLayers, GeoServer, MapServer, ArcGIS Server, etc.). For digital maps with a richer or significantly overlapping content, it is preferable to allow users to turn on and off the display of individual thematic map layers. In this case, it is more relevant to use maps in the vector format, which allows sufficient map zooming without a loss of display accuracy in addition. Choosing the right application is an important moment in the solution of every project.

## 4. Workflow for processing datasets

For clarity, the creation of maps of the built-up area development can be divided into several steps which are described below.

### 4.1 Selection of examined villages

First, it was necessary to choose suitable villages. The focus was on villages that have not been subjects of intensive research so far, but which contain significant values of rural architecture. The village selection was made by the ÚDU working group (ÚDU 2020). In each administrative region of Czechia (with the exception of the Prague region, i.e. a total 13), three villages were selected and included in the basic Artistic and Historical Research. One village out of three was then selected for the processing of built-up area development maps.

The existence and availability of suitable base datasets is an essential prerequisite for the creation of analytical maps. For some villages originally considered for processing, a sufficient number of archival maps was unfortunately not found and therefore they had to be replaced by other villages. The locations of selected villages are shown in Figure 10.

## 4.2 Collection of base datasets

The availability and quality of datasets differed for individual villages. The basic sets of archival maps were searched and ordered from the ČÚZK Geoportal E-shop (ČÚZK Geoportal 2020). Based on a concluded contract specifying the scope and terms of use of the data, it was possible to download the datasets from the website after paying the fee. Some archival maps have not been scanned yet and are therefore not available in this way. Such documents had to be searched directly in the archives (Národní archiv, ÚAZK 2020). Searched maps can either be photographed or scanned by the archive staff. When some of the maps could not be found, it was necessary to look for alternative data sources, such as archival *Aerial Survey Photographs*, or the *State Maps 1 : 5,000 – derived* (SMO5).

Based on the processed time period and available base datasets, it was determined that four archival base datasets would always be used to create analytical maps, displayed as evenly as possible over time. These maps were supplemented by the current cadastral map. The base datasets used for each site are listed in Table 1. For archival base datasets, the type of map and the year to which it relates are shown. The current cadastral map is differentiated according to the type of DKM and KMD with the percentage of the cadastral unit coverage. The last column of the table shows the number of created map sheets of analytical maps.

## 4.3 Pre-processing of base datasets

Before the processing of analytical maps, it was necessary to modify the used datasets. The whole process consisted of several follow-up steps and was implemented using ESRI software – ArcGIS.

### 4.3.1 Georeferencing

The S-JTSK national coordinate system (EPSG variant: 5514 i.e. S-JTSK East North – the X axis points to the East, the Y axis to the North) was chosen as the reference coordinate system. The current cadastral map was chosen as the reference map, i.e. DKM or KMD, which can be considered as the most accurate base map. Affine transformation was used for the georeferencing of all archival base maps.

An extensive number of identical points was used to transform each map sheet. In ArcMap software, the total georeferencing accuracy is determined by the *Total Root Mean Square (RMS) Error* value. Its value ranged from 1.0 to 6.8 m, which is an accuracy that corresponds to the level of accuracy of the used base maps. The results of the georeferencing stage are sets of raster maps transformed into a common coordinate system.

### 4.3.2 Vectorization

The built-up area was the primary subject of vectorization, i.e. the drawing of buildings in all archival base maps. For easier orientation in maps, the following items were also vectorized from the oldest maps (Imperial Obligatory Imprints of the Stable Cadastre):

**Tab. 1** Summary of used base datasets.

| ID | Village | 1st set | 2nd set | 3rd set | 4th set | DKM | KMD | MS |
|---|---|---|---|---|---|---|---|---|
| 1 | Hostouň | CO 1840 | OM 1876 | PK 1938 | JEP 1961 | 65 | 35 | 1 |
| 2 | Jasenná | CO 1840 | OM 1877 | EM 1939 | LMS 1975 | 100 | 0 | 2 |
| 3 | Jezeřany-Maršovice | CO 1825 | OM 1873 | PK 1940 | MEN 1963 | 0 | 100 | 2 |
| 4 | Kostelec nad Vltavou | CO 1830 | OM 1873 | EM 1914 | MEN 1967 | 0 | 100 | 1 |
| 5 | Ovesné Kladruby | CO 1839 | EM 1887 | LMS 1956 | MEN 1982 | 48 | 52 | 1 |
| 6 | Polnička | CO 1838 | OM 1872 | PK 1953 | MEN 1967 | 100 | 0 | 2 |
| 7 | Ropice | CO 1836 | OM 1880 | PK 1930 | MEN 1980 | 60 | 40 | 3 |
| 8 | Sedlec | CO 1843 | OM 1872 | PK 1939 | MEN 1978 | 0 | 100 | 1 |
| 9 | Stříbrnice | CO 1835 | OM 1871 | PK 1955 | MEN 1982 | 0 | 100 | 2 |
| 10 | Stvolínky | CO 1843 | EM 1897 | PK 1931 | LMS 1954 | 100 | 0 | 2 |
| 11 | Úhřetická Lhota | CO 1839 | OM 1876 | PK 1949 | MEN 1964 | 100 | 0 | 1 |
| 12 | Velečín | CO 1841 | OM 1875 | EM 1908 | PK 1964 | 48 | 52 | 1 |
| 13 | Vigantice | CO 1833 | EM 1905 | PK 1950 | MEN 1982 | 6 | 94 | 2 |

– basic road network – roads, paths, or railways,
– waters – watercourses and surface water (ponds and lakes),
– boundaries of cadastral units,
– small sacral objects (chapels, crosses and wayside shrines).

The descriptive or registration numbers of buildings, parcels of the Real Estate Cadastre and the boundaries of cadastral units were taken from the current cadastral map. Vectorized elements were stored in the file geodatabase in the form of feature classes. In the attribute table of a feature class that contains buildings, additional columns have been added to the columns automatically generated by ArcMap:

– Type – a wooden or a brick building,
– Category – buildings,
– Year – dating of the map,
– Note – an optional item.

The routine vectorization process contains an element of "sophisticated assessment" in this case, because the accurate georeferencing of maps does not lead to an identical representation of the same building on individual maps. Each map of the cadastral unit for a given year can be viewed as a layer of the map composition in the used software. Due to many factors, e.g. inaccuracies of mapping, drawing, scanning, georeferencing, vectorization, etc., an identical building is displayed in a slightly different position in each map layer. Our effort was to eliminate these graphical errors in maps and to capture only real changes in the position and shape of individual buildings (extensions, reconstructions). Thus, the identical building had to be vectorized in the same position in all maps. The assessment of the identity, or, on the contrary, the dissimilarity of buildings was an essential vectorization skill, with some degree of subjectivity.

As already mentioned, the current cadastral map was chosen as the reference map. The building which was detected on the archival map as identical to the building on the reference map has been vectorized to the position of the building on the reference map (in mode snapping to existing points). This eliminated the inaccuracies of map drawing, which would otherwise complicate any subsequent analyses.

The vectorization proceeded from the oldest map to more recent maps. First, the map of the Imperial Obligatory Imprint was vectorized. In order to speed up the process, another map (time stage) was vectorized above the copy of this map. Only subsequent changes were manually incorporated: new buildings, extinct buildings, reconstructions, extensions.

The described vectorization method had to be performed manually. This was the most time-consuming stage of the process. The sets of vector maps with attributes are the result of the vectorization stage.

### 4.3.3 Topology control

Two simple basic topological rules were checked in drawing each vectorized map:


**Fig. 11** Example of the summary map legend.

1. whether there is no overlap of two or more polygons,
2. whether the continuity of individual edges of polygons is not interrupted.

Any found errors had to be removed by the editing functions of the software. This processing step resulted in topologically pure data, prepared for subsequent analyses.

## 4.4 Creation of analytical maps

As mentioned in the Introduction to the article, the analytical maps of the built-up area development were divided into two variants: summary and detailed.

*A summary map* shows the built-up area from all selected data sources (4 archive and 1 current) organized into individual thematic layers. Since individual buildings usually appear in multiple base maps at the same time, it was necessary to choose the appropriate way to display them. The archival thematic layers of buildings are displayed (from the oldest) by the perimeter, the symbol on the perimeter, the hatching and the area fill. The current state of buildings is shown by a transparent filling of the area (Figure 11). In this way, it is possible to clearly distinguish all time layers of individual buildings on the map.

*A detailed map* shows the built-up area of the two oldest base maps, showing the development of the building construction of buildings. On the maps of the Stable Cadastre, it is possible to distinguish from the colour of the building filling whether it is a brick or a wooden building.

In terms of the occurrence of buildings on both of the used base maps, two situations could have been detected. A building occurred on both base maps or on one base map only. If a building (or a part of a building) was on both base maps, four options were distinguished (*Intersect* function):

1. Wooden building remained wooden (wooden-wooden)

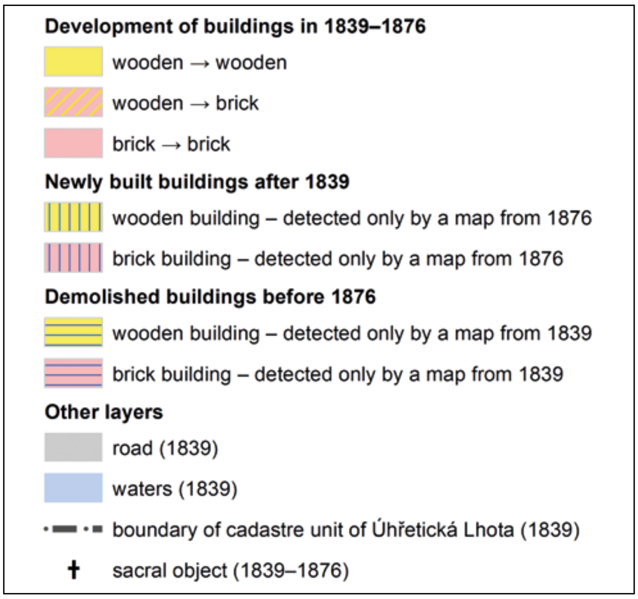


Fig. 12 Example of the detailed map legend.

2. Brick building remained brick walled (brick-brick)
3. Wooden building was transformed into a brick building (wooden-brick)
4. Brick building was transformed into a wooden building (only exceptionally)

If a building (or a part of a building) was on one base map only, four options were distinguished (*Erase* function):

1. Newly built wooden building
2. Newly built brick building
3. Demolished wooden building
4. Demolished brick building

A graphical representation of each option is shown in the used map legend (Figure 12). The chosen colours evoke the used building material; the hatching direction indicates the construction or destruction of a building.

## 4.5 Online presentation of analytical maps

The created analytical maps of the built-up area development are presented on the website in the vector data format (summary maps) and raster data format (detailed maps). Responsive webpages (ČVUT, FSv 2020) are created for the presentation of all maps and other project results continuously.

For our purposes of the presentation of summary maps, a comprehensive and freely available JavaScript library *OpenLayers* (OpenLayers 2020) has proven to be a suitable tool that can display both data types – vector and raster. This solution allows the users to define map properties such as layer and legend display settings, centre and zoom coordinate settings for the initial map display, spatial limits on map movement, define layer symbology and much more. The vector map layers are presented in the KML format, which was created by exporting from ArcMap software.

In the online presentation, the set of standard layers (Figure 11) is extended by a layer of geographical names, a layer of the current Orthophoto of the Czech Republic and a layer of the digital elevation model (Figure 13). These additional layers are loaded online from the ČÚZK source servers in the form of a Web Map Service. Thus, historical data about built-up areas can easily be projected to the current state of the landscape and terrain.

For our purposes of the presentation of detailed maps, a simple and freely available JavaScript library *OpenSeadragon* (OpenSeadragon 2020) has proven to be a suitable tool which works with pyramid raster tiles. The authors chose the Deep Zoom Image (DZI) format for the layout of tiles which is very similar to the solution used by Google Maps. Individual layers of the pyramid are stored separately in numbered folders. The tile file names consist of the column and layer numbers of the grid. For creating pyramid patterns in this layout, there are many applications from

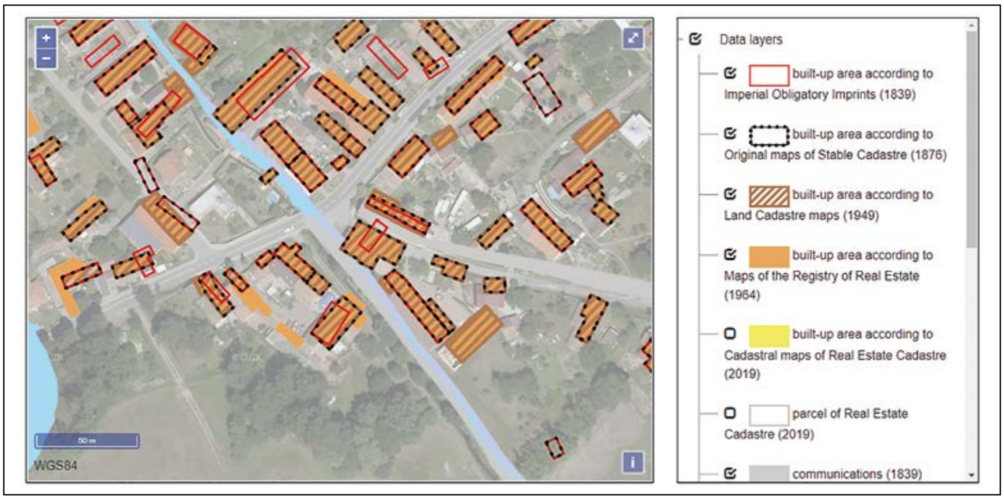


Fig. 13 Web-presentation of the summary map of the built-up area development of the village of Úhřetická Lhota (Pardubice District), detail, data: ÚAZK, ČÚZK.
Online: http://venkov.fsv.cvut.cz/projekt/mapy_vektor/uhreticka_lhota/uhreticka_lhota_en.html.

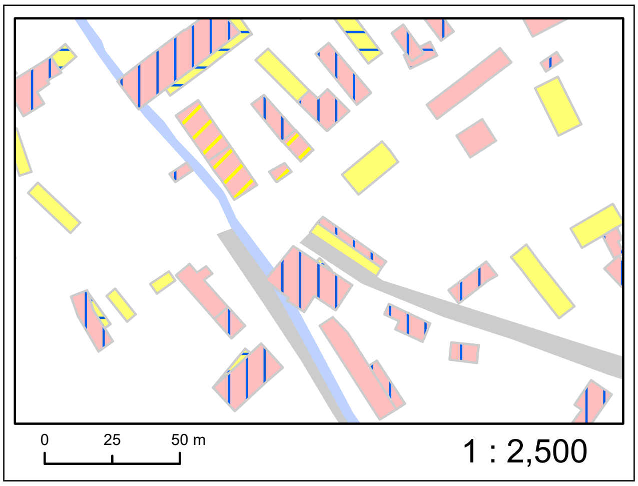


Fig. 14 Web-presentation of the detailed map of the built-up area development of the village of Úhřetická Lhota (Pardubice District), detail, data: ÚAZK, ČÚZK.
Online: http://venkov.fsv.cvut.cz/projekt/mapy_rastr/uhreticka_lhota/uhreticka_lhota_en.html.

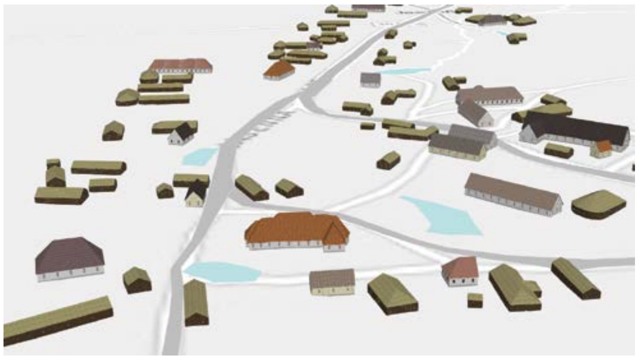

Fig. 15 Web-presentation of 3D models of buildings in Úhřetická Lhota (Pardubice District), detail, data: ÚAZK, ČÚZK.

various development environments. In this case, the authors used freely available desktop software *Deep Zoom Composer* from Microsoft (DEEP ZOOM 2020), which allows generating the resulting tiles in JPG and PNG formats. For our purposes, we used the lossless PNG format.

In this way, the whole map sheet is presented online including the map frame with the S-JTSK coordinate grid, legend, map imprint, graphical and numerical scale (Figure 14).

ArcGIS Online (ESRI ArcGIS Online 2020) offers interesting web presentation options as well. Within the student work (Münzberger 2019), outputs using a template that allows effectively comparing different pairs of maps of the same area were presented (Swipe and Spyglass tools).

Web AppBuilder (ESRI Web AppBuilder 2020) offers more advanced options to create a 3D scene for presenting maps of built-up areas on a digital elevation model covered with a current orthophoto (Frommeltová 2019). The application also includes control elements (widgets) allowing working with layers and navigation view (tilt and rotation). As an example of advanced methods of the online presentation of created analytical maps, we can mention a 3D map of a built-up area (Figure 15). The map contains parametrically generated schematized building models. However, this type of output is not used for our needs because it contains a fictional appearance of buildings that could be misleading for subsequent interpretations.

## 5. Conclusion

The article describes practical experience in the creation of analytical maps and possibilities of their online presentation. Considerable attention is also paid to available archival datasets. Created maps show the gradual development of built-up areas of selected villages over the last two centuries. They serve as an important basis for the Artistic and Historical Research of rural architecture.

The technological process of creating analytical maps proposed, implemented and described in the article has proved its worth. Careful execution of all phases of the process provides valuable final maps that contain new information on the development of built-up areas in selected localities.

The described procedure could serve as inspiration for research teams resolving similar problems aiming to obtain information from archival data. In this context, the advantage of this article is that it also contains an overview of the main large-scale base datasets, their characteristics and availability.

Analytical maps were created as part of a joint project of the Institute of Art History of the Czech Academy of Sciences and the Department of Geomatics of the Faculty of Civil Engineering of CTU in Prague. Individual stages of the presented workflow were continuously consulted by interested experts from both workplaces.

Analytical maps of the built-up area development have been prepared for 13 carefully chosen villages altogether, equally spread throughout Czechia. The created maps are published on the website and are also available in PDF files.

The outcomes of our research activities are continuously presented to professionals and the general public – through thematic exhibitions (Hůrková, Mezihoráková 2018; 2019), book publications (Hůrková, Mezihoráková 2016; Vlček 2017), academic articles (Hodač, Zemánková 2018; Poloprutský, Soukup, Gruber 2017; Poloprutský 2018; 2019) and workshops for students (Hůrková, Mezihoráková 2017).

The final output of the project will be a publicly accessible database containing complete textual and pictorial documentation drawing on the Artistic and Historical Research of selected villages. Analytical maps will be an integral part of the final database.

## Acknowledgements

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# Reflection of mining in mining and post-mining landscapes using cartographic sources

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## ABSTRACT

This article compares mining and post-mining landscapes on old maps and in modern aviation photography of three regions around the towns of Jáchymov, Most and Kladno in Czechia. The three regions differ not only in the type of mining, but also in their historical development and current management. The goal of the article is to compare these regions and evaluate the changes and consequences of mining on the landscape in different time periods using cartographic sources. Another aim is to identify specific landscape elements related to mining by drawing on old maps and state map series of the three regions.

## KEYWORDS

mining; cartographic sources; old map; historical cartography; historical geography

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## 1. Introduction

Human socio-economic activities have shaped different types of cultural landscapes for centuries. Agricultural, industrial, transportation and other activities change the landscape and leave their imprints even years or centuries after they are over (Taylor 2003). Different types of cultural landscapes reflect specific human activities (or their combination) and they can also remind us of the past that is imprinted in them. Documentation and identification of different types of landscapes help to maintain cultural memory of the landscape heritage (Ashworth, Graham 1997; Harvey 2008; Hewison 1989).

Apart from food production, mining is considered one of the oldest human activities and it can be documented already in the Stone Age (Mrázek 1996; Přichystal 2002). Since the ancient times, people have been acquiring different raw materials in order to hunt, build shelters or craft tools. The three prehistoric periods are even named after important materials (Stone Age, Bronze Age, Iron Age). During the development of society, mining has gained importance, together with discoveries of chemical elements or resources. The presence of raw materials in a territory determines its economic development; it has an impact on the inhabitants and the landscape (Kopačka 1996). Mining is important mainly because it makes the industrial production possible and therefore it is a sort of a starter of any production or even industrialization itself.

Mining raw materials usually means substantial changes in the environment and it creates a new type of landscapes – mining landscapes. The end of mining is then usually related to massive investments in restoration, increase in unemployment or social and environmental problems (Bridge 2004). The end of mining can also be perceived as a new opportunity to create a post-mining landscape with particular characteristics. Such landscape can be, when properly managed, converted and used as a fully-fledged cultural landscape. This process always depends on specific conditions, for instance the raw material mined or the technique of mining (underground or surface mining, chemical or mechanical mining, etc.). Time and extent also play a role. Mining and post-mining landscapes need to be perceived as complexes of tangible and intangible landscape elements that reflect their past and represent certain values and meanings (Daugstad, Grytli 1999; Conesa, Schulin, Nowack 2008).

One way of observing changes in (not only) mining landscapes is to use modern technologies to compare old maps or to compare maps with aerial photographs (Niederöst 2004). The scope of this article is to use different cartographic sources to identify landscape elements related to mining in the selected areas and to discuss the use of cartographic sources for research on mining landscapes. Another aim is to use selected old maps and state map series of the three regions to present specific landscape elements in the territories and to discuss the possibilities of these products for the study of mining landscapes. The article compares three selected regions around the towns of Jáchymov, Most and Kladno, comparing mining and post-mining landscapes on old maps and in modern aviation photography. The three regions differ above all in the type of mining, but also in their historical development as in their current management. The scope of the article is to compare the regions and evaluate the changes and consequences of mining for the landscape in different time periods using cartographic sources. Selected regions represent territories that are studied within the project of the Ministry of Culture of the Czech Republic "NAKI II" called: Heritage of Lost Landscapes: Identification, Reconstruction and Presentation.

## 2. Theoretical-methodological framework

Currently, mining landscapes are studied within different disciplines and from different points of view. Cultural geography, for example, has moved from the perception of mining activities and their relicts as only industrial activities to the perception of these as parts of culture as well. Definitions of specific cultural and social values related to mining are made. Mining has brought specific types of miners' settlement and communities. If the relicts of mining activities are maintained, interpreted or reused, it is possible to speak about mining heritage (Conesa, Schulin, Nowack 2008; Coupland, Coupland 2014; Turnpenny 2004; Jelen 2018).

When managing mining landscapes, it is possible to use the relicts as part of culture and society, e.g. for tourism (Cole 2004; Coupland, Coupland 2014; Conlin, Jolliffe 2014). One of the clearest examples is the conversion of the German mines Zollverein in Essen. After the mining finished, the mines were converted into one of the most attractive places of industrial history. Cultural and social events are held there, there are a museum of design and many other places of interest: restaurants, concert halls, theatres, conference venues, etc. Zollverein was inscribed into the UNESCO list of World Heritage Sites in 2001.

When researching mining landscapes, it is important to analyze values and meaning of areas as well as its development and changes. Historical geography and historical cartography provide tools for such research that enable us to understand the processes in the past and use them to explain and understand the current state of these landscapes.

Thanks to historical geographical analysis, it is possible to compare and research development of areas. Such knowledge is important for realizing values and meanings of an area, maintaining landscape heritage and responsible management. It also allows a combination of time and space organisation of processes, one of the main tasks of historical geography and cartography (Schenk 2011; Jelen 2018).

## 3. Cartographic sources as a source of information about mining landscapes

Historical geography uses a diverse range of historical geographical sources that include not only historical sources, but also sources from related technical disciplines and natural sciences (Semotanová 2006). The sources of information about the past can be categorized in multiple ways. Most commonly, the categories are the following: tangible sources, written sources, and images/iconographic sources that include a distinct group of cartographic sources. These are old maps that provide valuable information about the shape of landscapes in the past and that help us to trace anthropogenic landscape changes. They can provide visual information about landscapes and specific buildings as well as processes in the past and about the ways they were captured in maps (Tůmová 2018; Win 2014). The most useful and the most used categories of cartographic sources are so called comparative sources (e.g. Müller's survey, military surveys, Stable Cadastre or old aerial photographs and orthophotography) and individual sources (e.g. Klaudyán's map of Bohemia, Aretin's map of Bohemia, Vogt's map of Bohemia). This division is related to the evolution of map production as individuals were the first ones to initiate creating maps, followed only later by state institutions (Tůmová 2018).

### 3.1 The oldest maps of Bohemia – individual maps

The first maps with simple thematic map elements, mostly related to economic activities, but also to cultural ones, appeared in the Czech lands already at the beginning of map production in the 16th and 17th century. These old maps, together with written and iconographic materials, allow a complex study of scarcely studied pre-industrial landscapes. They can also contribute to improve the knowledge and reconstruction of the past landscapes and also to evaluate long-term changes of landscapes. They also provide material for discussion on relationships, approaches and landscape protection and protection of landscape heritage in the present and the future (Marcucci 2000; Antrop 2005).

In the early modern period (from the 16th to the 18th century), there were mostly individual maps made. Cartographic research on semiotic and cartometric analyses of selected old maps uses mostly individual maps of early modern period (Bayer 2009; Potůčková 2012; Semotanová 2001). The oldest maps of Bohemia, e.g. Klaudyán's map, Aretin's map, Vogt's map, do not, however, provide much detailed and accurate information about landscape (Mucha 1992; Kuchař 1959). But many of them already include cartographic symbols to provide information about locations of raw materials and about mining activities.

The first testimony of mining activities and sources of raw material in Bohemia is found in the third oldest individual map of Bohemia that was published in 1619. Its original title was *Regni Bohemiae Nova et Exacta Descriptio,* i.e. New and Accurate Description of the Bohemian Kingdom. Its author was Pavel Aretin from Ehrenfeld and the scale was set by Karel Kuchař to be 1 : 504,000.

The Pavel Aretin included names of 1,200 settlements, mostly in Czech, but also in German. The elevation is depicted by hill profiles. The map legend (figure 1) contains 16 symbols for free royal towns, royal towns, serfdom town (2 symbols), villages, castles, forts, monasteries, towns with castles, villages with castles, deposits of gold, silver, tin and iron ore, spa and glass production (Kuchař 1936).

In the 18th century, the cartographers started to use new symbols also for important economic, natural and cultural processes. The example is the map by Johann Gregor Vogt published in 1712. The map's

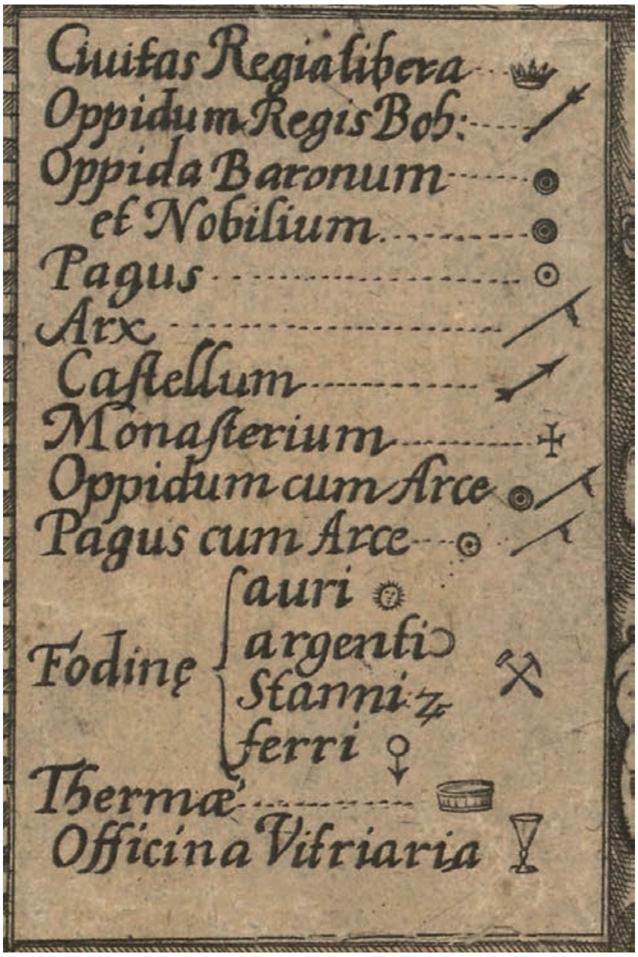


Fig. 1 The legend of Aretin's map of Bohemia (1632) with symbols for deposits of raw materials.
Source: The Map Collection of the Faculty of Science, Charles University


Fig. 2 The legend of Vogt's map of Bohemia (1712) with symbols for deposits of raw materials.
Source: The map collection of the Faculty of Science, Charles University

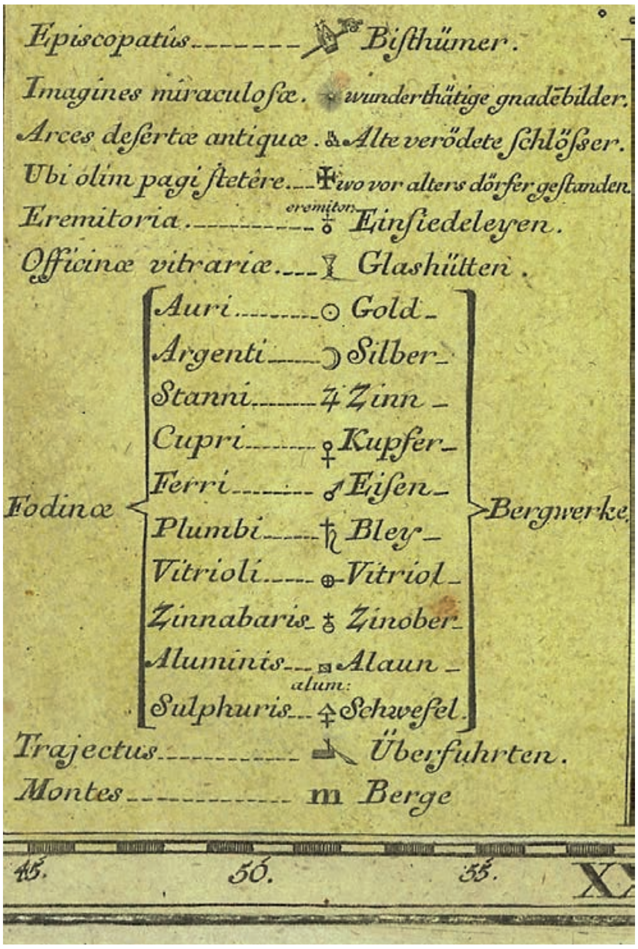


Fig. 3 A part of the map legend of Müller's map of Bohemia (1720) with symbols for deposits of raw materials.
Source: The map collection of the Faculty of Science, Charles University

dimension are 853 × 656 cm, the scale at the central meridian is 1 : 396,800 (Bayer 2009). It is a thematic map of Bohemia with elevation depicted by hill profiles. In the map legend, Vogt included 24 map symbols (figure 2): towns with fortification, towns without fortification, castles, monasteries, villages, chapels, ruins of castles, castles and monasteries, mills, post offices, dioceses and archdioceses, Latin schools, deposits of gold, silver, tin, copper, locations of pearl mussels, hot springs, glass production, vineyards, iron smelters and customs (Kuchař 1959; Novotná 2020).

The map of the Bohemian Kingdom *(Mappa Geographica Regni Bohemiae)* published in 1720 by Jan Kryštof Müller is considered one of the most important cartographic works of Czech history. The map is divided into 25 sheets and its dimensions are 282.2 × 240.3 cm. The scale is around 1 : 132,000 (Kuchař 1959). The map was ordered by the state (the Austrian Empire) to map military, administrative and economic features. That is why there is not only detailed topographic information (settlements, water, elevation, vegetation, roads), but also farms, abandoned settlements, mills, vineyards, mines of gold, silver, tin, copper and iron, brass casting, hammer mills, iron smelters, glass production, post offices and others. As the approved symbols were not enough for Müller, he added written information in the maps or used different symbols than those in the map legend. According to Kuchař (1959), the map includes the total of 12,495 places with names and the map legend describes (in Latin and in German) 48 well selected symbols (figure 3).

The explanations in the map prove the importance of raw materials for the economy at the time. The most important were the deposits of gold, silver, iron ore, copper, alum, sulphates and related places of metalworking (Semotanová 2011). Müller's map is more detailed compared to the ones by Aretin and Vogt, also thanks to its scale. The map legend maintains the symbol of two crossed hammers as the symbol of mining.

## 3.2 State map series from the second half of the 18th century

State map series cover larger areas, usually whole countries, using the same map projection, scale and usually also the same legend. Among these series, we can already find the first maps by Jan Kryštof Müller, then military surveys, Stable Cadastre, sets of aerial photography, newer maps of larger areas (for instance regions) and of course the newest state map series. Such series, called comparative cartographic sources, allow wider comparative research (Tůmová 2018). Important comparative sources on the territory of Bohemia are the map series created and used between the mid-18th century and the beginning of the 20th century. These sources are so called military surveys whose scale is suitable for landscape studies. Combined with Stable Cadastre sources, they are a wonderful starting point for the study of landscape changes in the modern period. On these maps, we can observe buildings and building complexes that have undergone many changes or have disappeared, partially or completely (Hauserová 2015).

### 3.2.1 Military surveys

The three military surveys were the first attempt to capture the whole area of the Habsburg Monarchy. They were done because of an urgent need to have a unified map system for military purposes. The first military survey was done between the 1760s and 1780s with the scale 1 : 28,800. It captures the baroque landscape at the end of the early modern period still with some remainders of the feudal relations.

The second military survey was done between 1806 and 1869 in the territory of Austria-Hungary. The scale was the same, i.e. 1 : 28,800. The mapping was based on an accurate trigonometric net and it was based also on the map documentation of the Stable Cadastre (see below). Due to the time period that elapsed from the first survey, the object of the mapping was the landscape of the Czech lands in the time of the Industrial Revolution. The content of the survey is basically the same as of the first one. It contains roads, brick buildings, and stone bridges. The natural elements included are fields, meadows, woods, ponds and watercourses. The elevation is indicated by Lehmann's slope hachures.

The third military survey of Austria-Hungary was done between 1869 and 1885 when the number of new railways, roads, ore and coal mines, industrial projects and plans to make some of the rivers navigable required precise topographic information (Hauserová 2015). The new survey had the scale of 1 : 25,000. Compared to the second survey, the elevation is recorded in a better way – not only by hachures, but also by contour lines and spot heights. The result of the survey are coloured so called topographic sections that were reprinted in special maps (1 : 75,000) and general maps (1 : 200,000). The survey was once again based on the Stable Cadastre.

The third survey managed to capture the period of intensive industrialization of the Czech lands – this is visible mainly at the edges of cities and town. The landscape on the map is full of different types of roads. Mining and processing of raw materials is increasingly intensive. The map legend is very detailed and as such it provides deep insight into types of soils, vegetation, structure of settlements and sometimes even into functions of different buildings. The agricultural land, on the other hand, did not change significantly compared to the second survey (Hauserová 2015; Semotanová 2006).

### 3.2.2 Stable Cadastre

Information about all the land in the Austrian Empire was included in the Stable Cadastre whose scope was to provide exact documentation for land taxation. The mapping of Bohemia took place from 1826 to 1830 and again from 1837 to 1843. The scale was 1 : 2,880.

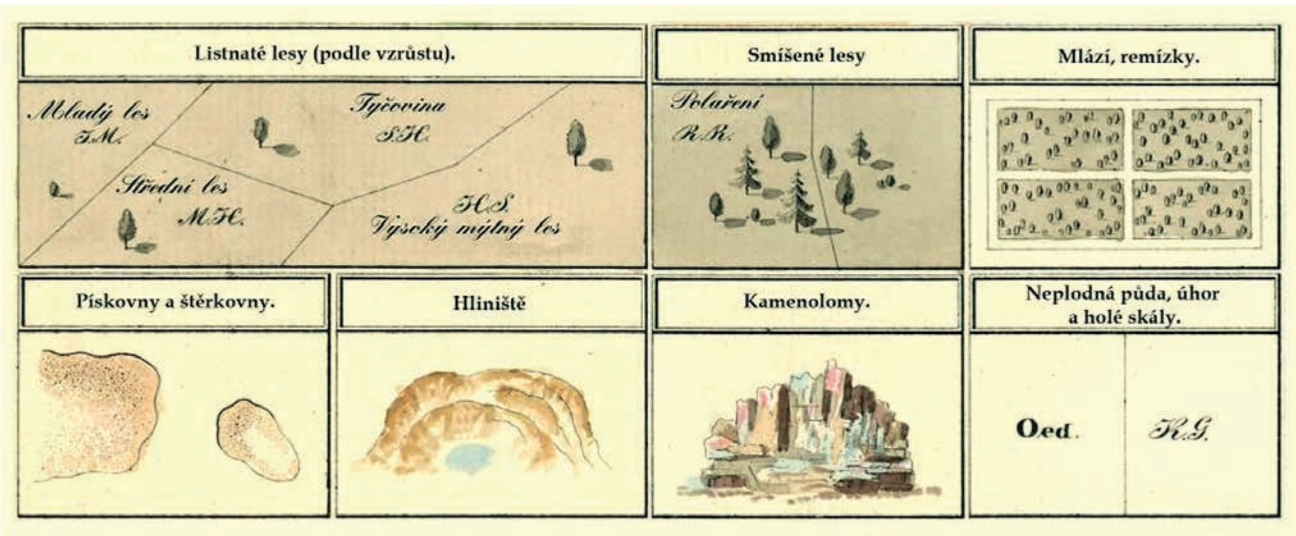


**Fig. 4** Part of the map legend of the Stable Cadastre with symbols for surface mines. First row: deciduous forests (by growth), mixed forests, thickets, draws; second row: sand pits and gravel pits, clay pits, quarries, barren soil, fallow land.
Source: The Map Collection of the Faculty of Science, Charles University

One cadastral map was made for each municipality and its land lots, including all the borderlines. Due to the need to express the value of each lot, the land cover and land use were documented very precisely and in much detail. The cadastral maps capture the Czech lands in the time of intensification of agriculture and beginning of the Industrial Revolution. Due to the scope of the cadastre (taxation), there is no information about elevation. The maps were made with a single map legend and the same colours (figure 4). For example brownish grey is used for woods, bright green for parks, gardens and meadows, ochre for fields, light green for pastures (with letters G or GW which signal municipal pastures). Carmine is used for brick buildings, stone bridges, weirs and roads, dark carmine for public buildings, yellow for wooden buildings and bridges. White is used courtyards and squares and brown is used for roads, blue for water (Plánka 2014). As for the surface mines, the maps include clay pits, stone, sand and gravel quarries that are indicated by symbols (figure 4).

### 3.2.3 Aerial photographs

It is possible to compare the information from old maps with newer or modern maps. From the documentation that is easily, it is necessary to point out the importance of orthophotographs of the surface of Czechia that have been taken from 1936 onwards (with only a break during the Second World War) for military purposes. The photographs are archived in the Military Geographical and Hydrometeorological Institute in Dobruška (VGHMÚř in Dobruška 2020).

The next military survey was done in the 1950s. The result was the first Czechoslovak map series of the whole country done by aerial photogrammetry. It is a unique representation of the country before the post-1948 societal changes could be reflected in the landscape. The collectivization of agriculture was still not much visible in the photographs and the towns were captured before the construction of flat complexes. The photographs capture in detail mountain landscapes and it is possible to identify mines, mining operations and other elements.

### 3.2.4 Contemporary orthophotography of Czechia

Orthophotography of the Czech Republic is a periodically updated set of coloured orthophotographs in the same format of the state map, i.e. 1 : 5,000 (2 × 2.5 km). The photographs are coloured and georeferenced representation of the Earth's surface. Each zone reflects the territory in the same year. Since 2016, the orthophotographs have been made in pixel 0.2 m. Moreover, the photographs have been taken with a digital camera since 2010 and as a result, the quality of photographs has been much higher (Geoportál ČUZK 2020). Since 2003, the orthophotographs have been provided by the State Administration of Land Surveying and Cadastre and the Military Geographical and Hydrometeorological Institute. As of 2012, the photographs of Czechia and the preparation of the orthophotographs are done every two years. Each year, half of the territory is photographed.

## 4. Analysis of the sample territories

Three locations in Czechia were chosen for the comparative study. They have all been changed by intensive mining. Each of them represents a different raw material, historical period and method of mining. Thanks to that, it is possible to compare the way mining was reflected in different map series and what landscapes changes have occurred in relation to mining. For the comparison, the Stable Cadastre, the third military survey, aerial photographs from the 1950s and current orthophotography were used.

### 4.1 The region of Jáchymov

The first region is the region of Jáchymov in the Ore Mountains. It is an area with the oldest mining history in Czechia. The first evidence of mining dates back to 1300 (Hloušek 2017). At the beginning of the 16th century, the mining of silver ores expanded and Jáchymov became the second biggest town in the Bohemian Kingdom after Prague as it had almost 25,000 inhabitants. During the same century, many new mines were founded and the centre of the miners' town was built. There was also a new royal mint built to produce silver coins – thalers. The mining is documented already in the oldest maps. In the Aretin map we can see two simple symbols: crossed hammers for a mine and a moon for the material, i.e. silver (see figure 5). Müller's survey uses only the symbol for silver (moon), but it is used five times in the region (see figure 7) to emphasize the extent of mining in the area. Also in Vogt's map of Bohemia, the


**Fig. 5** Silver mining in the Jáchymov region in Aretin map of Bohemia (1632).
Source: The Map Collection of the Faculty of Science, Charles University


Fig. 6 Silver mining in the Jáchymov region in Vogt's map of Bohemia (1712).
Source: The Map Collection of the Faculty of Science, Charles University


Fig. 7 Silver mining in the Jáchymov region in the Müller's survey of Bohemia (1720).
Source: The Map Collection of the Faculty of Science, Charles University

mining in Jáchymov is documented by two symbols: crossed hammers for a mine and a moon for silver (see figure 6).

When the deposits of silver were used, the mining in the region continued from the 17th to the 19th century with cobalt, bismuth, nickel, tin, and later also uranium. Since the mid-19th century, radioactive materials were mined. Firstly, to be used in uranium colours, later for extraction of radium and in the mid-20th century the uranium was extracted for military purposes. The last period of mining between 1945 and 1964 changed the landscape the most as it was very intensive mining of uranium ores to be used in the former USSR. After 1945, more than 25 mines were opened in the region, more than 1,000 kilometres of shafts and 8,000 tons of uranium were excavated (Jelen, Kučera 2017). The landscape was changed the most by huge soil tips, but also by new buildings intended for separation and elaboration of ores. In relation to the uranium extraction, there were large numbers of miners working in the Jáchymov region. Some of them were prisoners convicted for both political and non-political crimes. The prisoners lived in labour camps – there were dozens of them around Jáchymov (Hloušek 2017).

After the uranium deposits were gone, the communist government wanted to delete all the traces of mining that remained in the landscape. The mines were destroyed; labour camps were razed to the ground. The uranium mines were supposed to be forgotten. This is documented also by construction of new cottages and recreation areas in the place where the mines and labour camps had been (Hloušek 2017). The situation changed in 1989 and the remaining traces of the mining started to be used to remember the local heritage. The idea is to protect the landscape that witnessed more than 800 years of mining and keep it as a complex. The highlight of these attempts was the inscription of the landscape of Krušnohoří/Erzgebirge in the UNESCO World Heritage List in 2019 (Karel, Kratochvílová 2013; Jelen, Chromý 2018, UNESCO 2020).

When comparing the cartographic sources, it is possible to see that the landscape right around the historical centre of Jáchymov is labelled as a place of silver mining in the Stable Cadastre (figure 8). The soil tips on the hillside of Kailberg, to the west from the church, are partly covered with grass. There are pastures (*W – Weiden*) and rubble (*E – Egärten*). However, some hillsides are still bare and rocky – and not fertile (Ö – Öde). The large soil tip with the soil from the closest mine Svornost is also marked as not fertile (1). In contrast to the current situation, there are no woods on the hills above the town because wood was commonly used in the mine constructions. On the platform above the square, a horse mill was still maintained in the time of mapping (2). The horse mill provided vertical communication in the silver mine of the Emperor Joseph II. The map of the third military survey documents the mining with the symbol of crossed hammers (figure 9). The soil tips are indicated by contour lines and hachures, but they are not labelled, therefore it is almost impossible to identify them without previous knowledge of the area. The uranium extraction is then visible in the orthophotograph from 1953 (figure 10). In the photograph, there is also visible the labour camp Svornost (next to the mine Svornost). The current state of the landscape is documented by the orthophotograph from 2019 (figure 11). The soil tip of Svornost is covered with wood and the grasslands are used as pastures. There are almost no remainders of the labour camp. After careful examination, it would be possible to recognize parts of fences, which, however, are not original, but they are from 2016 when some parts of the labour camp were renewed to serve as a memorial to the suffering of the political prisoners from the 1950s and 1960s (Jelen, Chromý 2018).

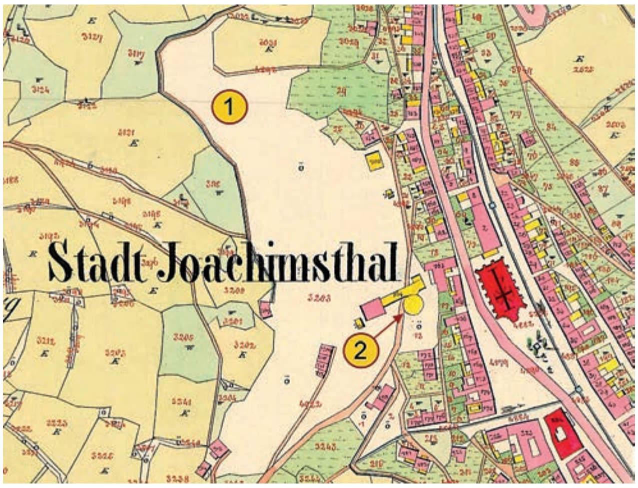


**Fig. 8** The centre of Jáchymov in the Stable Cadastre.
Source: State Administration of Land Surveying and Cadastre

**Fig. 10** The centre of Jáchymov in an orthophotograph from 1953.
Source: Cenia

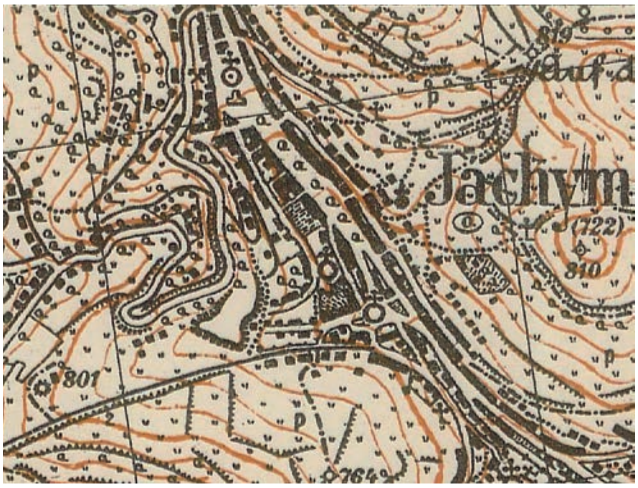


**Fig. 9** The centre of Jáchymov on a revised map of the third military survey (1938).
Source: State Administration of Land Surveying and Cadastre

**Fig. 11** The centre of Jáchymov in an orthophotograph from 2019.
Source: State Administration of Land Surveying and Cadastre

## 4.2 The region of Most

The region around Most has experienced mining for a shorter period than Jáchymov, but to a larger extent and with much more visible changes of landscape due to the type of mining. Starting in the mid-19th century, the mining of lignite (brown coal) was done underground. As the volume grew, it switched to surface mining. The expansion of mining brought rapid population growth. Between 1869 and 1910, the number of inhabitants grew more than six times in some municipalities. As a result, many new buildings appeared around the mines (Kafka 2003; Růžková, Škrabal 2006). For the comparison, the municipality of Souš (the region of Most) was chosen. The map of the Stable Cadastre (figure 12) documents the prevalence of fields (light brown), orchards and meadows (green). In relation to the underground mining, there are non-brick buildings (yellow) *Sta. Maria Opferung Zech*, *Sta. Maria Himmelfahrt Zech* and *St. Antonius Zech*. There is no symbol for the underground mines on the map, unlike on the map of the third military survey from 1938. The map in scale 1 : 25,000 already captures the current surface mines (Kafka 2003). Pingen are visible were the ground collapsed because of the mining activities underground (figure 13). The surface mining is indicated by the mine's borders and hachures. The expanding extraction in open mines and growing soil tips in the area are even more visible in the orthophotograph from 1953 (see the Vrbenský mine and its soil tip in figure 14).

The current landscape in the region of Most is almost completely newly created – as visible in the orthophotograph from 2019 (figure 15). The memory structure of the landscape is kept only in the intangible landscape structure (e.g. the name of the extinct village Třebušice is kept in the name of a railway stop on the way from Ústí nad Labem to Chomutov, a Jewish cemetery in Most-Souš that survived because it was, according to the convention, kept away from buildings). Alongside the surface mining of lignite, there has been restoration in progress in the areas where the mining process has finished and on soil tips. The forest and hydric restorations are used – the example is Lake Matylda in the location of the former mine Vrbenský. As the town Most is very close to the area, the restoration of soil tips is specific in regards to the social functions of the new landscape. Lakes are supposed to serve as recreation spots and there is now a racetrack on the restored soil tip of the mine Vrbenský. There are also many roads and railways that make the landscape very fragmented, gigantic industrial projects such are the power plant in Komořany and the petrochemical plant Chemopetrol in Záluží, bucket-wheel excavators, conveyor belts, abandoned mining and industrial operations and buildings. There is a net of surface energy and product conductive pipes (figure 15).

The switch in the public perception of the mining landscape in the region of Most and its history is shown in the common project of two mining companies (Vršanská uhelná and Severní energetická). The project is called Coal Safari (Uhelné safari) and the scope is to provide excursions in the functional mines and the restored areas. The participants can visit the coal mines (mines ČSA and Vršany) and to learn about technical equipment and large machinery. At the same time, the restoration is stressed as well and the landscape changes related to mining are presented (Severní energetická 2020).


**Fig. 12** Underground mining around the village Souš in the Stable Cadastre.
Source: State Administration of Land Surveying and Cadastre

**Fig. 14** Surface mining around the former village Souš in an orthophotograph from 1953.
Source: Cenia

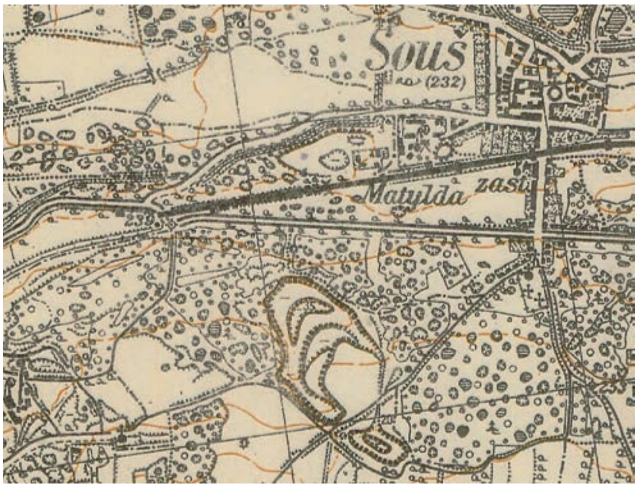


**Fig. 13** Surface mining around the village Souš on a map of the third military survey (1938).
Source: State Administration of Land Surveying and Cadastre

**Fig. 15** Restored post-mining landscape around the former village Souš in an orthophotograph from 2019.
Source: State Administration of Land Surveying and Cadastre

## 4.3 The region of Kladno

Until the end of the 18th century, the landscape around Kladno had been agricultural. The maps of the Stable Cadastre show mostly fields, meadows and needleleaf forests around the village Dubí u Kladna (see figure 16). At the end of the 18th century, the first mineral deposits were discovered and the mining started to expand quickly after the beginning of the 19th century. In 1846, the main coal deposit in the region was discovered and more followed after 1850. An ironworks was founded in 1854 and it was the most important industrial project in the 19th century in the whole Bohemia (Kafka 2003). All these anthropogenic changes in the landscape are visible on the maps of the third military survey. The example in figure 17 shows the creation of the industrial zone and new mines between Kladno, Dubí and Hnidousy (the scale is 1 : 25,000). The map includes for instance smelters, ironworks and mines Praga I and Praga II. Surface mining is indicated by the mines' borders, hachures and information about the height of the material extracted or brought.

At the end of the 19th century, some of the important deposits had been exhausted and the mining activities started to decrease. Ironworks started to be the main economic strength of Kladno. The system of mines was reduced and the industrial areas grew. In Kladno and its parts (Dubí and Hnidousy – nowadays Švermov) experienced rapid population growth. The industrial zone in Kladno is clearly visible in the orthophotograph from 1953 (figure 18). The growth and expansion of Kladno continued to the 20th century, with some slowdowns in times of crises. Reforested soil tips and the current state of the industrial zone (e.g. heating plant, railway station, former company Kablo Kladno) is easily identifiable in the orthophotograph from 2019 (figure 19).


Fig. 16 The surroundings of Dubí in the region of Kladno, a map of the Stable Cadastre.
Source: State Administration of Land Surveying and Cadastre

Fig. 18 The surroundings of Dubí in the region of Kladno in an orthophotograph from 1953.
Source: Cenia

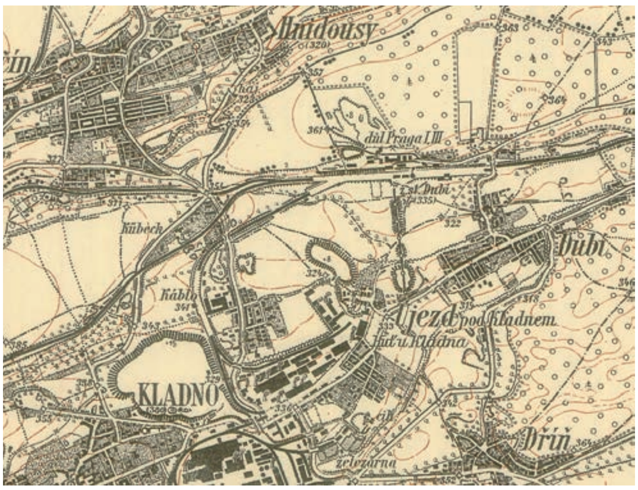


Fig. 17 The surroundings of Dubí in the region of Kladno on a map of the third military survey (1933).
Source: State Administration of Land Surveying and Cadastre

Fig. 19 The surroundings of Dubí in the region of Kladno in an orthophotograph from 2019.
Source: State Administration of Land Surveying and Cadastre

## 5. Conclusion

The imprints of mining can be found in many places in Czechia. Often, there are landscape elements that are related to mining even though it is not clear at the first sight. Mining causes profound landscape changes that are identifiable dozens of years after it is over. To study the changes, it is important to provide a historical geographical approach where the study of old maps, state map series and their comparison with current sources plays a crucial role.

Each of the sample territories locations has a different history, but all of them have undergone major changes and the original landscape has been turned into a new type of landscape – post-mining landscape. Each area contains different elements and is managed in a different way. In the region of Jáchymov, the mining ended more than 50 years ago and the landscape is perceived as part of cultural heritage (which has been confirmed by the inscription in the UNESCO World Heritage List). The mining in the region was not followed by any significant restoration; the landscape around towns and villages has been basically left without interventions. Today, it is used mainly as a memorial to the mining history and its importance. The extraction of silver in the region of Jáchymov is documented already on the oldest maps (Aretin's map, Vogt's map, Müller's survey of Bohemia – the symbol of crossed hammers, sometimes accompanied by the symbol of the moon). Using the cartographic symbols, the maps provide information about the location of mines and materials extracted. However, none of them provides any detail information on mining landscape elements or the extent of the mining activities. To get such information, it is better to use state map series (military surveys, Stable Cadastre) and orthophotographs from the 1950s onwards. These maps allow us to identify the whole mining area and other mining elements. It is however necessary to take into account that for example the Stable Cadastre labels the remains of mining (e.g. soil tips) as infertile soil. Therefore it is necessary to analyze these areas further and to compare them to other cartographic sources. Naturally, the same is true also for the other two locations examined. These locations have a shorter mining history compared to the region of Jáchymov and therefore it is not possible to identify mining in the oldest maps of these areas.

In contrast, the map series from the second half of the 18th century and newer provide valuable information about type, localisation and extent of mining. Each map series then has its specific characteristics. The Stable Cadastre is in a large scale and it captures the Bohemian lands in the times of agriculture intensification and at the beginning of the Industrial Revolution. Thanks to the scale, it is possible to identify the mines and mining operations. An example can be the symbol for a horse mill on the map of Jáchymov. The maps of the third military survey provide information about the period of intensive industrialization in Bohemia. This is documented for example by co-existence of the finished underground mining and the new surface mining in the region of Most. The military surveys also included both contour lines and spot heights to show the elevation and therefore it is easier to identify the changes in the terrain, such are new soil tips and surface mines.

A unique representation of the landscape is then the map series done in the 1950s by aerial photogrammetry. Thanks to these pictures it is possible to identify very accurately mining operations and other elements that do not exist anymore. Typical examples are the expansion of mining in the Most region and the labour camps in the region of Jáchymov. The reminder of the existence of the labour camps is an important aspect in the creation of cultural heritage, because it is part of history and it should not be forgotten. Thanks to the comparison of aerial photographs, it is possible to reconstruct the landscape and to remember the events that have taken place there (Hloušek 2017).

Mining is one of the most important landscape forming processes. The identification of processes and remains helps us to understand the current state of the landscape and it can also help in decision-making and in the creation of cultural heritage.

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Czech Office for Surveying, Mapping and Cadastre, http://www.cuzk.cz (Orthophoto of the Czech Republic from the present time)

# Indirect economic costs of avoidable mortality in Moldova

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**ABSTRACT**
In this article, we carry out the cost-analysis of the total premature mortality and avoidable causes of death for Moldova by applying the human capital approach. The results show that the indirect costs of avoidable mortality represent slightly over 85% of total economic losses due to premature mortality in Moldova. The highest economic losses are due to injuries, cardiovascular diseases, and alcohol and drug-related deaths. For males, the leading cause is represented by injuries, whereas for females the two leading causes include cardiovascular diseases and alcohol and drug-related deaths. The results of this study can be used for a cost-benefit analysis to design economic mitigation strategies aimed at lowering the avoidable mortality in Moldova.

**KEYWORDS**
premature mortality; avoidable mortality; causes of death; human capital approach

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## 1. Introduction

The premature mortality is defined by Australian Institute of Health and Welfare as “deaths that occur at an age earlier than a selected cut-off” (Australian Institute of Health and Welfare 2016), in work of Canadian researchers is made an important remark and is stated that “premature mortality refers to people who die of a health condition earlier than expected” (Pham, Shack, Cheung 2019). In this state of ideas *premature deaths* represent deaths that occur from birth to a set age threshold (Joel 2017). In fact, premature death represents important multi-aspectual losses, not just in term of irrecuperable human life losses, but from the potential economic, creative and social resource point of view.

The more important segment of premature mortality is represented by avoidable mortality. The concept of avoidable mortality refers to deaths that given current medical knowledge and technology, could be prevented, treated or both. So, *avoidable deaths* are represented by preventable, amenable, or both. The preventable causes of death are causes of death that can be mainly avoided through effective public health and primary prevention interventions. The amenable causes of death are causes of death that can be mainly avoided through timely and effective health care interventions, including secondary prevention and treatment (OECD/Eurostat 2019). The concept of avoidable mortality was used and developed by numerous authors. Because of different conceptualization of avoidable mortality, there are known several lists of preventable or amenable causes of death (Holland 1997; Nolte, McKee 2004; OECD/Eurostat 2019). The last version was presented by OECD in November 2019 (OECD/Eurostat 2019).

Moldova is characterized through a high level of mortality in the working-age population that mostly maintain low life expectancy at birth compared to West European countries (Gagauz et al. 2016). However, in the last two decades, a slow but steady growth trend in life expectancy at birth has been recorded. The substantial parts of noted gains in life expectancy in that period are determined by reductions in avoidable mortality (Stirba, Pahomii 2019). On the other hand, the level of premature and avoidable mortality remains higher comparative with other European countries and it is noted a significant gap between sexes (Pahomii 2018; Gagauz, Onofrei, Pahomii 2019).

Both nationally and internationally, there are studies aimed at estimating losses and indirect costs caused by premature mortality. The economic losses due to premature mortality are estimated at subnational-regional (Etco, Pantea, Cernelea 2011; Sukhoveyeva, Komarova 2015), national (Carter, Schofield, Shrestha 2017; Gagauz, Onofrei, Pahomii 2019) and international level – for comparison between countries (Menzin et al. 2012). It is important to state that worldwide overall premature mortality, as well as economic losses linked with them, are several times high in males than in females (Etco, Pantea, Cernelea 2011; Carter, Schofield, Shrestha 2017; Ryngach 2016; Pahomii 2018; Gagauz, Onofrei, Pahomii 2019). Also, the top causes of death that determine the highest economic losses are represented by CVD (cardiovascular diseases), neoplasm and external causes of death (Etco, Pantea, Cernelea 2011; Díaz-Jiménez et al. 2015; Gagauz, Onofrei, Pahomii 2019). There are a lot of studies that analyse these causes separately because of the great economic impact that they had, both regarding direct and indirect economic costs (Kontsevaya, Kalinina, Oganov 2013; Hanly, Sharp 2014; Hanly, Soerjomataram, Sharp 2015; Pearce et al. 2018; Carter, Schofield, Shrestha 2019). Even if different aspects of premature mortality and related economic costs are well studied, the aspect of avoidable mortality in this field is overlooked. A team of Colombian researchers presents an important work in this area. Díaz-Jiménez et al. (2015) estimated that avoidable mortality has a huge economic impact from the lost productivity perspective, equivalent to between 1.6% and 3.0% of the annual GDP. The researchers created two distinct scenarios for the estimation of economic losses due to avoidable mortality based on average wage and annual GDP (Díaz-Jiménez et al. 2015).

**The relevance of the paper.** It is important to highlight that premature, as well as avoidable mortality, constitute important social and economic losses for society (Menzin et al. 2012; Hanly, Soerjomataram, Sharp 2015; Łyszczarz 2019), analysed both as present and as potential economic losses. Considering the high level of premature mortality in Moldova (Pahomii 2018), the studying of avoidable mortality represents a subject of major interest. The estimation of the size of the economic equivalent of irremediable losses caused by premature and avoidable deaths will allow assessing the potential economic damage to national development.

**The aim of the article and innovation character.** Most of the studies, both at the national and international levels, are focused on costs and economic losses due to premature mortality. However, the economic impact, from the perspective of indirect economic costs, of avoidable mortality for Moldova was overlooked. In order to cover this gap, this study is aimed to estimate the share and structure of avoidable mortality in total indirect economic costs of premature mortality, using the human capital approach and to highlight discrepancies between sexes.

**Research questions.** This study is designed to answer the following research questions:

– What was the proportion of avoidable mortality in overall premature mortality in Moldova, in the period 2014–2016?
– What is the indirect cost of avoidable mortality concerning the annual GDP in Moldova in the analysed period?

– What causes have the highest economic impact in the structure of avoidable mortality in Moldova in the period between 2014–2016 years?

**Conceptual framework of the study.** In this study, we used the human capital approach to estimate the value of productivity lost due to total premature mortality and of avoidable causes of death. This approach is based on the hypothesis that each person contributes to the productivity of society. Accordingly, the human capital approach relates to unrealized income or the value of potential products lost due to illness or premature death (Boccuzzi 2003). Although this theory is widely used in the literature, there are some criticisms and the main one is the overestimation of economic losses due to premature or avoidable mortality (Birnbaum 2005; Perace et al. 2014), because it assumes equivalent contribution to each member of society. However, there are some important strengths – simple and transparent methodology to value lost productivity. The main argument to use that approach was the availability of data.

## 2. Data and methods

The population age and sex distribution, as well as economic indicators, were provided by the National Bureau of Statistics. As economic indicator was used GDP per capita. Data for 2014–2016 was used due to the revised number of the population. Starting with 2014 NBS (National Bureau of Statistics) presented the revised number of population – present population. The population with usual residence or present population represent the number of the population who preponderantly last 12 months lived on the territory of Moldova indifferent of temporary absence. The methodology of calculation of present population assumes excluding of long-term emigrants, this who are absent from the territory of the country more than 12 months (Statistics 2020). The starting year is determined by the Population and Housing Census of the 2014 year.

To allow comparability through time and to bring more clarity we have converted national GDP per capita to constant $US, the year 2017 value (1$ = 18.499 MDL). The use of constant values for converting national currency (MDL) to $US allow us to exclude conversion shocks throughout the analysed period (2014–2016 years). The year 2017 was chosen mainly arbitrary, however, the $US value is used as constant for some World Bank Database indicators.

For premature mortality, the set threshold was 65 years. In the literature from the field different thresholds are discussed which define death as a premature one (Lapostolle et al. 2008; The Conference Board of Canada 2015; OECD/Eurostat 2019). In this regard, OECD proposed as threshold the age of 75 (OECD/Eurostat 2019), however, earlier OECD operated with the 70-year threshold (The Conference Board of Canada 2015). The set of the specific threshold depends mainly on observed level of mortality and interest of the researcher (Wise et al. 1988; Mingot, Rue, Borrell 1991; Pham, Shack, Cheung 2019). In our case because of the lower level of life expectancy at birth compared with OECD countries the threshold of 65 years was chosen.

The mortality data were provided by the WHO Mortality Database, where data are available at a very low disaggregation level and on 5-year age-groups and sexes. To determine the avoidable causes of death we need the disaggregation of data on the 3-digit level. The data regarding causes of death presented on the NBS page are available just for broad categories of causes and do not allow to highlight avoidable causes of death. Data can be obtained just through an official request from the Ministry of Health, Labour and Social protection, but that could take a long time of waiting. At the moment of writing, the cause of death data provided by WHO Mortality Database, therefore, represent the most recent data available at the needed level of disaggregation. For the classification of avoidable mortality, the list of ICD, Tenth Revision causes defined in the report of OECD (OECD/Eurostat 2019) was used.

For total premature deaths and broad causes of avoidable death groups, the *Potential Years of Life Lost* (PYLL) were estimated. The PYLL is a very useful indicator because it considers the impact of premature deaths, by putting more importance on deaths occurring in the youngest ages (Lapostolle et al. 2008). PYLL is defined as the number of years of life lost by persons who died before the specified age limit and is measured in person-years (Šemerl, Šešok 2002). Other authors had defined the PYLL as the indicator which allows estimating the average time a person would have lived if he/she had not died prematurely (Gardner, Sanborn 1990). The PYLL is constructed by the weighting of each death by the number of years between the age at death and the set threshold. The used formula for PYLL calculation is presented below:

$$PYLL = \sum_{i=1}^{64} d_i a_i \qquad (1)$$

$$a_i = 65 - x_i$$

In the above formula, $a_i$ = remaining years of life until the upper limit of age (in this case, 65 years); $d_i$ = number of observed deaths in each class interval; $i$ = the mid-point of age interval.

In the present study, we carried out the cost-analysis of the total premature mortality and avoidable causes of death. It is important to mention that our study is based on the Human Capital Approach. The Human Capital Approach assumes that the economic impact will be equal for all lifetime outputs and also this approach equalise the economic contribution of each society member (Boccuzzi 2003). We have focused just on indirect economic losses. In his work, Boccuzzi has defined that indirect economic costs of mortality represent the present value of future earnings lost by those individuals who die prematurely (Boccuzzi 2003). In order, to assess the indirect economic losses due to premature and avoidable mortality the observed PYLL was multiplied by GDP per capita. The used formulas for calculation of indirect economic losses are presented below:

$$IEL = \sum_{i,j} PYLL_{i,j} \times GDP\ per\ capita \qquad (2)$$

$$IEL = \sum_{i,j}^{c} PYLL_{i,j}^{c} \times GDP\ per\ capita \qquad (3)$$

In the above formulas, $IEL$ =Indirect Economic Losses; $i$ = age-group; $j$ = sex; $c$ = cause of death.

The broad causes of avoidable death groups used in analysis correspond to that proposed by OECD (OECD/Eurostat 2019). In this research, were analysed the following broad causes of death: infections, neoplasms, CVD, diseases of the respiratory system, diseases of the digestive system, injuries, alcohol-related and drug-related deaths and other causes of death. Endocrine and metabolic diseases, diseases of the nervous system, diseases of the genitourinary system, pregnancy, childbirth and perinatal period, congenital malformations and adverse effects of medical and surgical care were classified in other causes of death group. The last causes classified in a broad group of other causes registered a small number of events, this became the main argument in that grouping.

## 3. Main results and findings

Premature mortality represents an important issue for Moldova. Half of all deaths registered for males in the analysed period (2014–2016) represent premature deaths (deaths before 65 years). For female at the set threshold of 65 years are observed the quarter of all deaths registered during that period (Pahomii 2018). Another alarming fact is the stagnation of the premature mortality in the analysed period. In accordance with released calculation was observed slight fluctuation upwards and downwards, which does not change essentially the situation. The estimated PYLL in the general population in 2014 was 8513.1 person-years per 100 thousand population aged 0–64, in 2015 it registered insignificant soar to 8606.8 person-years per 100 thousand population and in 2016 was noted an averting to 8284.8 person-years per 100 population. The PYLL registered for males, throughout all the analysed period, was more than two times higher than for females.

The age distribution of PYLL shows the age groups with the highest contribution (Fig. 1). PYLL puts more importance on young ages, because of that PYLL for infant mortality had a pretty high level, even in comparison with other age-groups, especially for females. For all analysed years (2014–2016) PYLL at age 0 for females exceeded the PYLL registered for other age-groups, and just 50–54 and 55–59 age-groups PYLL approached to this level. It is important to mention that in 2016 the PYLL of females was lower for most

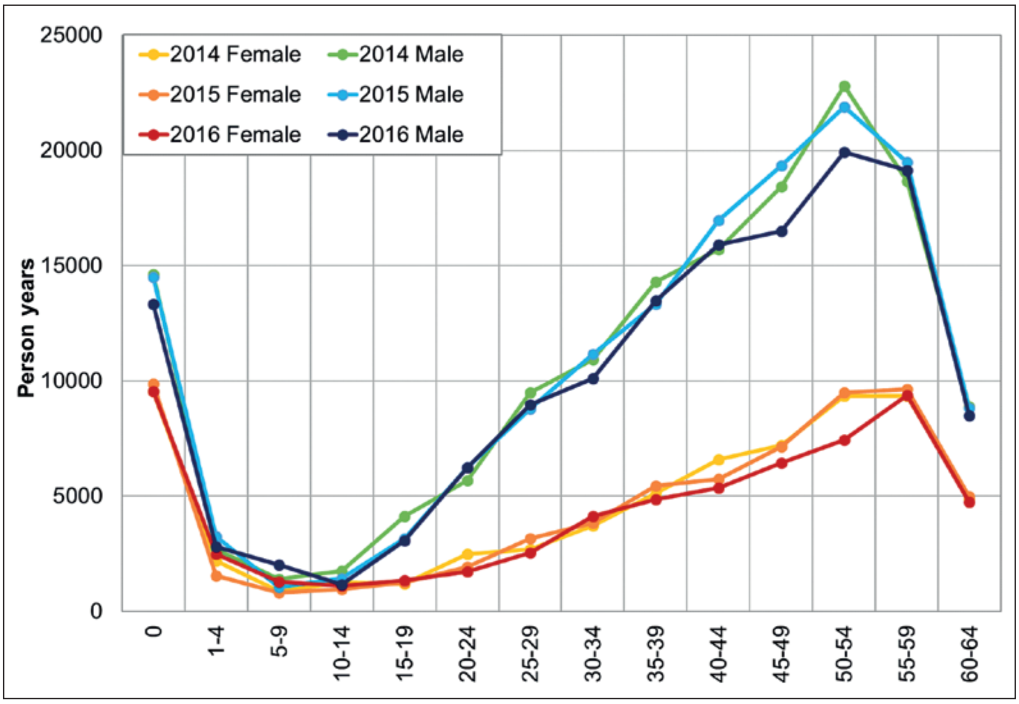


Fig. 1 PYLL by sex and age-groups, 2014–2016.
Source: Author calculation

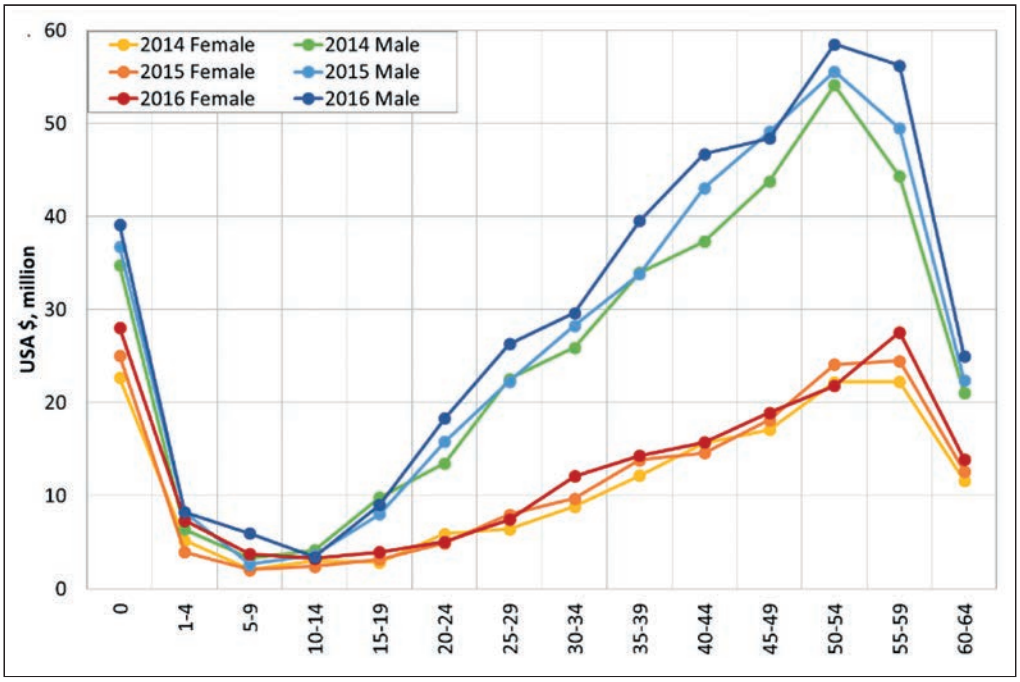


**Fig. 2** Total indirect economic costs of premature mortality by age-groups and sexes, 2014–2016.
Source: Author calculation

age-groups, as a result just 55–59 age-group come close to the level of 0 years. The highest level of PYLL for infant deaths is due to the large difference to a threshold, while the peak in 50–54 and 55–59 age-groups is determined by the greater number of deaths observed. Due to the high level of male mortality, the PYLL for 40–59 age-groups overtakes the PYLL for infant mortality. The low level of PYLL registered for last age-group (60–64 years) is determined by the small differences between the mean of age interval and settled threshold.

The age structure of male PYLL repeats the discrepancies observed at a general level between sexes. The male PYLL exceeds the female one by 1 to 3.6 times depending on age-group. In this regard is important to mention that the highest differences between male and female PYLL are observed in 2014 in 15–19, 25–29 age-groups (3.4 and 3.5 times), in 2015 in 20–24 and 40–44 age-groups (3.2 and 3.0 times) and 2016 in 20–24, 25–29 and 40–44 age-groups (3.6, 3.5, and 3.0 times). It is important to mention that the lowest differences are recorded for youngest age-groups. Up to 15 years, the highest difference between male and female PYLL is 1.6 times.

In the figure below is presented the potential economic damage determined by indirect economic costs of premature mortality. That costs were estimated through the multiplication of PYLL by GDP per capita. The absolute value of economic losses due to premature mortality as well as indirect costs of avoidable mortality grew throughout the analysed period from 512.9 million $ in 2014 to 597.7 million $ in 2016 and from 454.1 million $ in 2014 to 511.4 million $ in 2016 respectively. The growth of the absolute value of total indirect economic costs of premature mortality and avoidable causes of death is mainly caused by the growth of GDP per capita in the analysed period. Reported to the annual GDP and analysed like shares the indirect economic costs seem to be constant. The potential economic losses due to premature mortality were equivalent to 7.6% of the annual GDP in 2014 and recorded an insignificant decrease of 0.3% in 2016 to 7.3%. Thirds of the total economic losses due to premature mortality are determined by female PYLL, while 70% refer to males (Fig. 2). Economic losses due to premature mortality for infant deaths are at a relatively high level for both sexes and drop for next 4 age-groups. For females, there is another peak in the 55–59 age-group, but this does not exceed the first peak for infant mortality. Another peak in males is registered in the 50–54 age-group, but economic losses due to premature mortality of infants are exceeded starting with 35–39 age-group.

The costs of avoidable mortality in total indirect economic losses due to premature mortality represent 85% in female in 2014 and are reduced to 83.8% in 2016 (Fig. 3). In males, the share of the costs of avoidable mortality in total indirect economic losses due to premature mortality is slightly higher – represented 87.7% in 2014 and is reduced to 86.3% in 2016. An alarming fact is that the proportion of indirect economic losses due to avoidable causes of death is the same for both sexes. So even if we have significant discrepancies in absolute values by sexes, the relative structure of losses due to avoidable and non-avoidable causes of death is mainly the same for

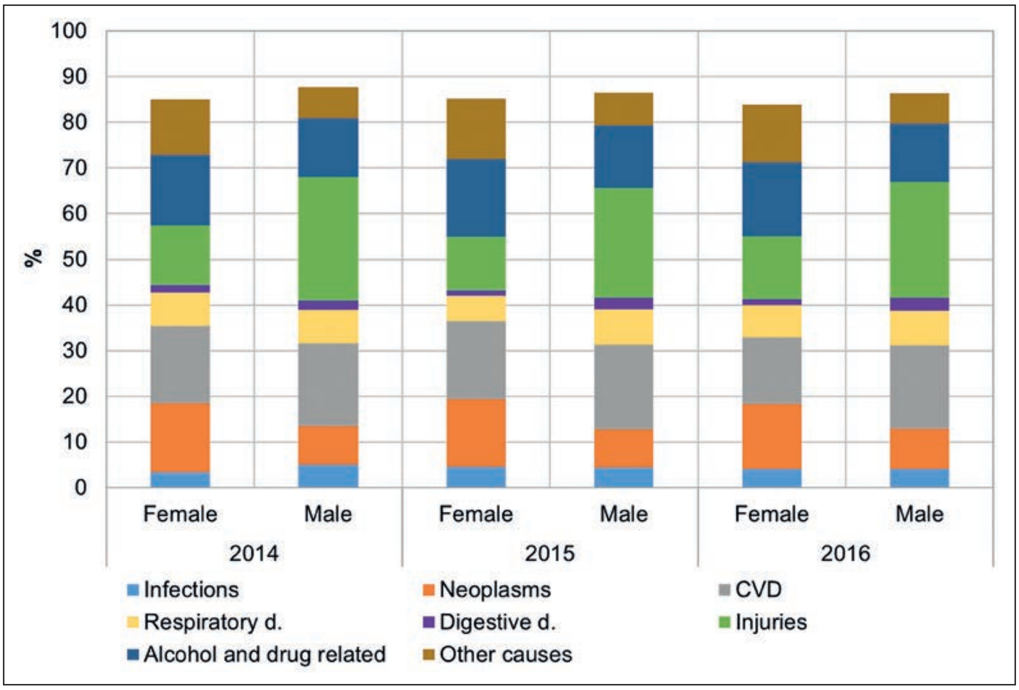


**Fig. 3** Share of economic losses due to avoidable mortality in total economic losses due to premature mortality by major causes of death and total, by sexes, 2014–2016.
Source: Author calculation

both – males and females. These significant losses represent an important potential which can be saved if needed activities will be done in the light to averted avoidable mortality. In this order of ideas is important to state that structure of avoidable mortality by causes of death become very important.

From the perspective of the structure of mortality by broad causes of death, analysed for both sexes, the highest costs corresponded to injuries (21.6% of total avoidable mortality costs), CVD (17.6%), alcohol and drug-related (14%), neoplasms (10.5%), the remaining causes of death account for 22% (infections, respiratory disease, digestive disease, other causes). The structure of avoidable mortality is different for males and females. Top five avoidable causes of death in the structure of indirect economic losses due to premature mortality in males are injuries, CVD, alcohol and drug-related deaths, neoplasms and respiratory diseases; while in females, are observed other classification: alcohol and drug-related deaths, CVD, neoplasms, injuries and other causes of death. Among both males and females, these five main causes of death account for two-thirds of all economic losses due to premature mortality.

The gender gap is not observed if data are analysed like shares from total indirect costs due to premature mortality, it became pronounced when indirect costs of avoidable mortality are analysed toward annual GDP (Tab. 1). The total indirect costs of avoidable mortality are 2.3 times higher in males compared to females throughout all analysed period. The lower gender gap is observed for avoidable mortality from other causes of death and neoplasms while the highest is observed in injuries and mortality due to the digestive system diseases. The indirect cost of avoidable mortality due to other causes of death and neoplasms are on average 1.2 and 1.3 times respectively higher in males compared with females. The avoidable mortality due to injuries and to the digestive system diseases are on average, for the analysed period, 4.5 and 4.3 times more costly for males than for females. The indirect costs of avoidable mortality due to CVD, the respiratory system diseases and infections are on average 2.6 times higher in males in comparison with females. The discrepancies in alcohol-related and drug-related mortality is a little lower – 1.8 times higher in males. The indirect costs are higher in males because of their higher level of premature avoidable mortality.

The indirect economic costs related to female avoidable mortality represented in 2014 2.11% from the annual national GDP and in 2016 reduced to 1.87%; in absolute terms, the indirect economic losses represent 143 million $ and 153.7 million $. In the males, the losses are even higher and represent 311.1 million $ in 2014 and 357.7 million $ in 2016. In the females, 4 leading avoidable causes of death – CVD, alcohol and drug-related deaths, neoplasms and injuries – in 2014 determined 66.4% (95 million $) of indirect economic costs. It is important to state that in 2016 these causes remained also actual and determined approximative 70% (107 million $) of indirect economic costs related to avoidable mortality. In the males, the same 4 leading causes are observed, but

**Tab. 1** The indirect costs of avoidable mortality, share from the annual GDP (%), by broad causes of death, year and sexes.

| Causes of death | 2014 | | 2015 | | 2016 | |
|---|---|---|---|---|---|---|
| | Females | Males | Females | Males | Females | Males |
| Infections | 0.08 | 0.26 | 0.11 | 0.23 | 0.09 | 0.21 |
| Neoplasms | 0.35 | 0.45 | 0.34 | 0.44 | 0.32 | 0.44 |
| CVD | 0.39 | 0.94 | 0.40 | 0.98 | 0.32 | 0.92 |
| Digestive system diseases | 0.17 | 0.39 | 0.13 | 0.41 | 0.16 | 0.39 |
| Respiratory system diseases | 0.04 | 0.11 | 0.03 | 0.13 | 0.03 | 0.14 |
| Injuries | 0.30 | 1.41 | 0.27 | 1.28 | 0.31 | 1.28 |
| Alcohol-rel. and drug-rel. d. | 0.36 | 0.67 | 0.40 | 0.71 | 0.36 | 0.65 |
| Other causes | 0.41 | 0.35 | 0.31 | 0.38 | 0.28 | 0.33 |
| Total | 2.11 | 4.59 | 1.98 | 4.56 | 1.87 | 4.35 |

Source: Author calculation

these are different ranged. So, the most indirect economic losses are determined by injuries, CVD, alcohol and drug-related deaths and neoplasms. These 4 causes defined, in 2014, 75% (233.3 million $) of indirect economic costs related to male avoidable mortality. The share of these 4 leading causes remained the same in the 2016, but in absolute values is higher – 270.4 million $ – because of higher absolute indirect economic losses due to male avoidable mortality. The fact that the same leading causes was observed in both, females and males, highlight that existing problems are mainly the same in both. This also shows the priority domains for interventions.

## 4. Conclusions

Economic losses due to premature mortality are twice higher for males compared to females. This is determined, mainly by a higher level of premature mortality registered for males. In this context, it is important to note that despite the high gap in the level of premature mortality between sexes the share of avoidable deaths is mainly the same in the structure of total economic losses due to premature mortality for both. The indirect costs of avoidable mortality represent slightly over 85% of total economic losses due to premature mortality.

The analysed period is too short to be able to identify stable trends in the development of the situation. It is important to note that even if indirect economic costs by broad avoidable causes of death, expressed in absolute values, rise in the 2014–2016 period, their share related to annual GDP remains the same. That fact allows us to conclude that in the 2014–2016 period indirect economic costs of avoidable mortality remained mainly constant.

The economic losses due to avoidable mortality are very significant for Moldova, especially due to injuries, CVD and alcohol and drug-related deaths. The reduction of the occurrence of these causes can diminish not only the productivity loss but also other costs related to them: reduction of costs related to treatment and other indirect costs before death.

Even if there are controversies regarding the human capital approach the obtained results are important mainly for prioritization of public health interventions. The results of the study can be used for a further cost-benefit analysis to select more economic effective potential intervention.

Different structure of avoidable mortality between males and females require targeted interventions for solving the most acute problems of both. In males, the most economic losses are determined by injuries, whereas in females are observed two causes which determined highest economic losses – CVD and alcohol and drug-related deaths.

The future work will be focused on detailed analysis of the individual avoidable causes of death and a longer period will be studied.

## Acknowledgements

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# Eutrophication of the Mastník bay of the Slapy Reservoir, Czechia

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**ABSTRACT**
This article investigates the changes in water quality in the Mastník bay, a part of the Slapy Reservoir located at the Vltava River, during the 2015–2019 period. Due to the occurrence of drought conditions smaller streams in rural areas of Czechia have suffered from a low water quality, especially in the summer. For these reasons, the Mastník stream contributes to the abnormal eutrophication of the Mastník bay. Since the exchange of water between the bay and the rest of the Slapy reservoir has been limited, a large increase in the phytoplankton biomass has been observed in the Mastník bay. Consequently, the concentrations of chlorophyll in the Mastník bay increased over the last 15 years, with the chlorophyll-α concentration exceeding 500 μg $l^{-1}$ during the summer months in several cases. Based on the concentrations of total nitrogen, total phosphorus, chlorophyll and water transparency measured by this study, the Mastník bay is evaluated as being hypertrophic. In contrast, no significant effect of the Mastník bay on the concentrations of the monitored parameters has been demonstrated in the remaining parts of the Slapy Reservoir.

**KEYWORDS**
Mastník bay; Slapy Reservoir (Vltava River); surface water quality; eutrophication; trophic state

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## 1. Introduction

Two important goals of water resources management are to restrict pollution sources and to prevent worsening of surface water quality. Eutrophication has become the primary problem facing most surface water bodies worldwide (Guo et al. 2018). Climate change also had a significant negative effect on water quality (Viney et al. 2007). According to research results, water management is an area that could be highly affected by climate change, especially in relation to water temperature and discharge (Novický et al. 2006).

Small watercourses in rural areas often show many unsecured water pollution sources. Restriction of water pollution sources is a major theme in the expert community. Surface water quality has improved over the last 25 years, primarily as a result of restriction of pollution point sources through the closing of many factories, reconstruction and modernization of technological methods in industry, and the building or modernization of sanitation and wastewater treatment plants (WWTPs) (Government of the Czech Republic 2018). Despite these efforts water quality of some small watercourses is still very poor. The problem of diffuse sources of water pollution such as rural settlements and agriculture remains unsolved (Taylor et al. 2016).

Primary production, especially that of phytoplankton, is used as a sensitive and accurate indicator for eutrophication assessment. Rosa and Michelle (2007) asserted the chlorophyll-α is the best practical measure of eutrophication problem. The chlorophyll-α level is related to a great number of hydrological, geochemical and ecological variables that impact phytoplankton growth (Park et al. 2015). In general, during the growing season eutrophication of lakes and reservoirs is strongly dependent on the release of nutrients, especially phosphorus, leading to increased phytoplankton production (Smith 2013). The consequences show that the most significant risk for river eutrophication is posed by point rather than diffuse phosphorus sources, even in rural areas with high phosphorus losses in agriculture (Jarvie et al. 2006). Classification of lakes based on various methods and indices have been made by various workers. The classical and most commonly used method, based on the productivity of the water body, is the biomass related trophic state index (TSI) developed by Carlson (1977). Based on the TSI and similar index, trophies of lakes and reservoirs around the world have been elucidated (Burns et al. 2005; El-Serehy et al. 2018; Guo et al. 2018; Hamilton and Parparov 2010; Prasad 2012; Worako 2015).

The Mastník bay at the Slapy Reservoir was selected as the object of this study. The objectives of this study were to describe the trophic state and water quality of Mastník bay and ascertain its effect on the Slapy Reservoir. Thus, nutrients and oxygen concentrations, water temperature and biomass in the Mastník bay was investigated over three growing seasons (2016–2018).

## 2. Materials and methods

### 2.1 Description of the study area

The Mastník catchment area is located in the centre of Czechia (Central Europe). The Mastník stream flows into the Slapy Reservoir at approximately river kilometre 103 of the Vltava River. Figure 1 shows the location of the catchment area, including the Slapy Reservoir. About 70% of the Mastník catchment area is part of the Agriculture Soil Fund, reflecting the predominantly agricultural character of the catchment (Mrkva 2018). Industrial production is marginal in the catchment. The Mastník bay is 4.7 km long and

**Tab 1.** Limnological variables for the Mastník bay and the Slapy Reservoir.

| | Mastník bay | Slapy Reservoir |
|---|---|---|
| Location | Central Bohemia | |
| Origin | part of the Slapy Reservoir | built in 1949–1955 |
| Geographic coordinates | 49.7334436N, 14.4132933E | 49.8238797N, 14.4341139E |
| Length [km] | 4.7 | 44 |
| Depth [m] | 0.5–40 | max. 53, avg. 20.7 |
| Width [m] | 4–230 | x |
| Volume [$m^3$] | 6 000 000 | 269 300 000 |
| Catchment area [$km^2$] | about 330 | 12 900 |
| Average inflow [$m^3 \cdot s^{-1}$] | 1.26 | 83.4 |
| Average outflow [$m^3 \cdot s^{-1}$] | x | 84.7 |
| Average retention time [day] | 55 | 36 |

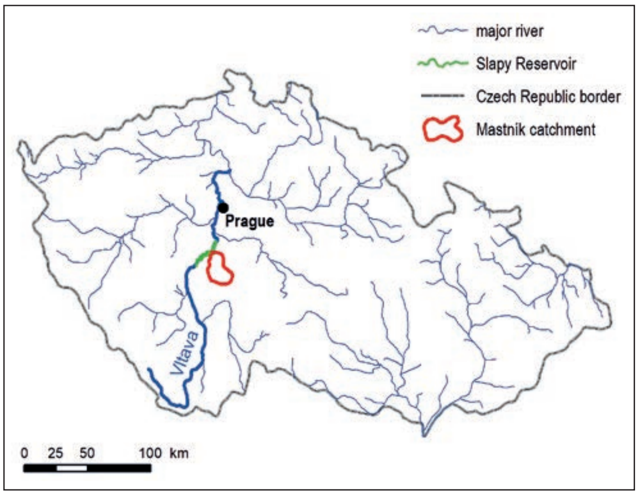


**Fig. 1** Location of the Mastník catchment and the Slapy Reservoir in Czechia.

about 230 m wide near its mouth to the main part of the reservoir. The volume of the bay is approximately 6 million $m^3$, depending on the water level of the reservoir. The Slapy Reservoir was built between 1949 and 1955 and is the 6th largest reservoir in Czechia. Flow velocity in the Slapy Reservoir is low and the average retention time is 36 days (Procházková et al. 1996). Limnological variables and characteristics of bay and reservoir are presented in Table 1.

## 2.2 Monitoring and dataset

Sampling in the field took place from May to October (growing season) from 2016 to 2018. A total of 160 water samples were collected from six locations selected in the Mastník bay. Each sampling location is shown in Figure 2 (S2–S7). Mixed samples were taken at every sampling location. A mixed sample is defined as a sample from the upper water layer of the bay (max. depth 1.2 m). At locations S3 and S4 vertical profiles from 5- and 10-meters depths were collected using a depth sampler, while at location S5 only 5 meters depth (the bay bottom) was sampled. At these three locations the mixed sample is denoted Sx-1, the sample from a depth of 5 m Sx-2, and the sample from a depth of 10 m Sx-3. Further details are given in Table 2.

The number of sampling cruises varied from year to year, with monthly observation of an entire growing season only in 2016 and 2018. In the field, the collected water samples were subdivided into plastic bottles and transported to the laboratory for analysis immediately. Sample analyses were performed in the Laboratory for Water Protection at the Institute for Environmental Studies of the Faculty of Science of Charles University and in Water management laboratories of the Vltava River Basin Authority. The largest number of parameters were analysis in 2018: $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, total nitrogen (TN), $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$, total phosphorus (TP) and chlorophyll-α (Chl-α). In contrast, in 2016 and 2017 the following parameters were analysed: $N\text{-}NO_3^-$, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$ and Chl-*α*. In most cases a YSI multiparameter probe was used to record basic physical characteristics such as water temperature (WT), dissolved $O_2$ (DO) and oxygen saturation (SO) throughout the water column. In several cases, the entire water column was not measured. Data with multiparameter probe were measured at 1 m intervals. Water transparency was measured using Secchi disc (SD), 20 cm in diameter and painted with contrasting black and white colours.

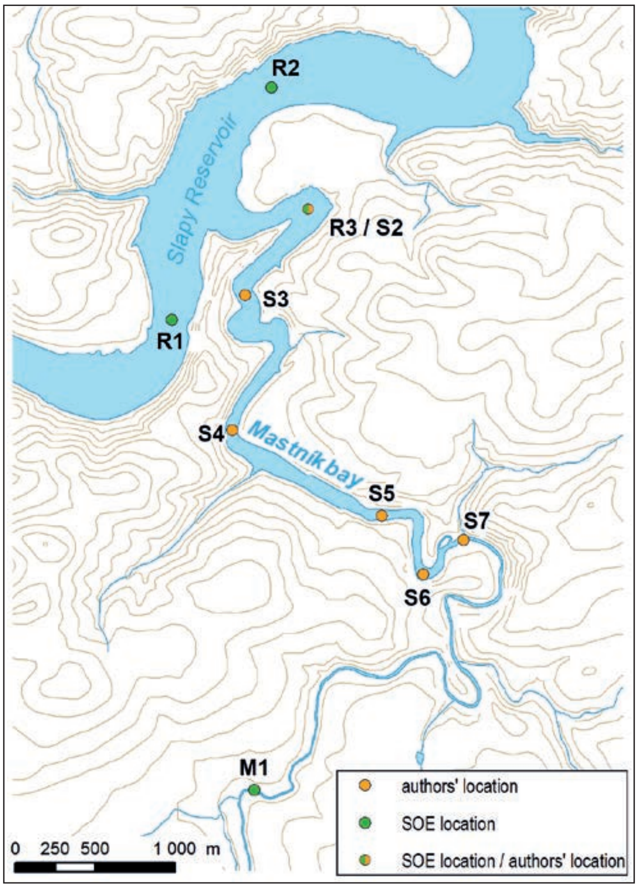


**Fig. 2** Sampling locations.

**Tab. 2** Information about each sampling points.

| Location name | Distance to mouth [km] | Width [m] | Average depth [m] | Samples |
|---|---|---|---|---|
| S2 | 0.55 | 249 | 25.0 | mixed sample from surface to 120 cm |
| S3 | 1.30 | 102 | 20.0 | mixed sample from surface to 120 cm, sample from a depth of 5 m, sample from a depth of 10 m |
| S4 | 2.30 | 74 | 13.0 | mixed sample from surface to 120 cm, sample from a depth of 5 m, sample from a depth of 10 m |
| S5 | 3.30 | 54 | 5.0 | mixed sample from surface to 120 cm, sample from a depth of 5 m |
| S6 | 4.00 | 54 | 1.5 | mixed sample from surface to 120 cm |
| S7 | 4.30 | 30 | 0.7 | mixed sample from surface to 120 cm |
| M1 | 8.10 | 3 | Dataset from Vltava River Basin Authority (SOE) | |
| R1, R2, R3 | | | | |

The authors' dataset was extended with data provided by the Vltava River Basin Authority (SOE), which included vertically resolved sampling at three locations within the Slapy Reservoir, as well as on the last sampling location on the Mastník stream before it enters the Mastník bay (M1). One of the sites at the reservoir (R3) corresponds to the authors' location S2; the other sites (R1 and R2) are located up and downstream along the longitudinal axis of the reservoir (see Fig. 2). Data from SOE were available from 2005 to 2016 at monthly intervals from April to October. For reservoir locations, data from the entire water column and mixed samples (upper layer to max. depth of 2 m) were available. Unfortunately, the SOE dataset did not form a continuous series, and the number of monitored parameters varied by year.

## 2.3 Assessment of water quality

Monitored water quality parameters in the Mastník bay were evaluated based on concentrations along longitudinal and vertical profiles. Emphasis was placed on ascertaining change in concentrations of nutrients and chlorophyll-α over time, enabling comparisons between the monitored years, especially between 2016 and 2018.

For the overall assessment of water quality, it is recommended to classify the results for two years. From the measured concentrations, the mean, median and characteristic value of C(90), which is defined as the value with a no-overrun probability of 90% were calculated. This value is based on the Czech Standard Classification of Surface Water Quality (ČSN 75 7221). In the case of evaluation of location M1, R1, R2 and R3, the two years 2015 and 2016 were used. There were 14 determinations available at location R1, R2 and R3. That mean the characteristic value was the second-highest when sorting concentrations in ascending order. In the case of dissolved oxygen, the series was formed in descending order. At a frequency of 24 or more values over the evaluated period (as at location M1), the value of C (90) was calculated according to the equation 1:

$$C(90) = (d_{90} \cdot C_{k-1}) + (1 - d_{90})\, C_k \qquad (1),$$

where
$C_k$ = $k$-th value in descending order (for DO ascending),
$C_{k-1}$ = $(k - 1)$-th value in descending order (for DO ascending),
and
$d_{90}$ = variable value, calculated according to the equation 2:

$$d_{90} = (k - 10)/100 \cdot (n + 0.4) - 0.3 \qquad (2),$$

where
$n$ = number of values (24 or more)
and
$k$ = variable value, which is calculated according to the equation 3:

$$k = 10/100 \cdot (n + 0.4) - 0.3 \qquad (3)$$

and rounded up to an integer.

The most commonly used method for classification and characterization of surface water trophic state is the trophic index. In this study, two indexes were used: Carlson's Trophic State Index (CTSI) and Trophic Level Index (TLI). These methods use Secchi disc transparency and chlorophyll, TP and TN concentrations. CTSI can be used for regional classification of all surface waters, including streams and rivers in temperate climate. TSI was calculated according to the following equation 4 (Carlson 1977):

$$CTSI = [TS(TP) + TS(Chl) + TS(SD)]/3 \qquad (4),$$

where
$TS(TP) = 14.42\mathrm{Ln}(TP) + 4.15$,
$TS(Chl) = 9.81\mathrm{Ln}(Chl\text{-}\alpha) + 30.6$,
$TS(SD) = 60 - 14.41\mathrm{Ln}(SD)$.

TLI, which also includes TN term, was calculated using the following equation 5 (Burns et al . 2005):

$$TLI = [TL(TP) + TL(TN) + TL(Chl) + TL(SD)]/4 \quad (5),$$

where
$TL(TP) = 2.92\log(TP) + 0.218$,
$TL(TN) = 3.01\log(TN) - 3.61$,
$TL(Chl) = 2.54\log(Chl\text{-}\alpha) + 2.22$,
$TL(SD) = 5.1 + 2.6\log(1/SD - 1/40)$.

Based on the calculated values, the monitored profiles were classified into trophic classes. Division into classes is given in Table 3.

The dependence of chlorophyll-α on TP concentration was calculated using the correlation coefficient (CC). Due to the low number of observations, the CC results could not be considered as statistically significant at a significance level of alpha = 0.05. Only 6 values are available it thy study. If the CC for 6 samples is higher than 0.7067, the dependence may be considered significant (Heo et al. 2008).

**Tab. 3** Classes of trophic index.

| TI classification | CTSI | TLI |
|---|---|---|
| Oligotrophic | 21 to 41 | 2 to 3 |
| Mesotrophic | 41 to 50 | 3 to 4 |
| Eutrophic | 51 to 60 | 4 to 5 |
| Supertrophic | | 5 to 6 |
| Hypertrophic | over 61 | 6 to 7 |

Tab. 4 Water quality of state sampling station M1 (2015–2016).

| Station | M1 | | |
|---|---|---|---|
| Component/Index | Mean | Median | C (90) |
| Water temperature [°C] | 11.21 | 11.50 | |
| Dissolved oxygen [mg l$^{-1}$] | 11.20 | 11.40 | 8.17 |
| Saturation $0_2$ [%] | 102.17 | 99.00 | |
| TN [mg l$^{-1}$] | 4.28 | 3.70 | 6.86 |
| N-$NH_4^+$ [mg l$^{-1}$] | 0.10 | 0.10 | 0.20 |
| N-$NO_3^-$ [mg l$^{-1}$] | 3.50 | 3.10 | 5.74 |
| N-$NO^{2-}$ [mg l$^{-1}$] | 0.04 | 0.00 | 0.07 |
| TP [mg l$^{-1}$] | 0.24 | 0.20 | 0.45 |
| Chlorophyll-α [ug l$^{-1}$] | 28.98 | 20.50 | 55.00 |

By comparison of datasets from the R1 and R2 locations, the possible effect of the Mastník stream on water quality in the Slapy Reservoir was evaluated. In the case of longer time-series datasets from the reservoir (i.e. R1, R2 and R3), the Mann–Kenndall statistical test (MKT) was used to evaluate the trend. Seasonal MKTs were performed on year time-series of concentrations for the R1, R2, R3 profile and to a monthly time-series of concentrations for the M1 for the period 1995–2016. The significance of the trend was tested at a level of alpha = 0.1.

## 3. Results

### 3.1 Surface water quality in the Mastník catchment area

The last sampling location on the Mastník stream before it enters Mastník bay is the Radíč station (M1). This station represents the catchment load and yields concentrations of pollutants coming from most of the catchment area (approximately 81% of the catchment area). Because of high concentrations of chlorophyll-α and total phosphorus, the water at this sampling location is identified as highly polluted (Mrkva 2018). The concentrations of all monitored parameters between 1995 and 2016 decreased. For selected parameters, this trend was confirmed by the MKT test, which showed a significant downward trend in the case of TP, N-$NH_4^+$, N-$NO_3^-$ and N-$NO^{2-}$. Only in the case of chlorophyll-α a slight increase was observed, with the average concentration being 20.12 μg l$^{-1}$ in 2002 and increasing to 28.9 μg l$^{-1}$ in 2016. However, the results could not be considered significant. Also, in the case of surface water temperature, an increase in the average value was observed, from 9.9 °C in 1997 to 11.2 °C in 2016. WT varied between 10.6 °C and 20.2 °C in the growing season of the monitored period. The average water temperature during these growing seasons was 15.9 °C. During investigated growing seasons the average contribution of TP to the bay was 278 kg per month. In contrast, the long-term average TP load, which is based on concentration from year-round measurements, was 845 kg per month. Contribution of TN was 1450 kg per month during investigated growing seasons. These values were calculated based on the concentrations reached at the M1 station.

### 3.2 Seasonal variations of different water quality parameters in Mastník bay

#### 3.2.1 Water temperature and oxygen regime

WT varied between 5.1 and 26.1 °C during the growing season in the monitored period. The coldest year was 2016, in which the surface layer water temperature varied between 10 °C in May and 21 °C in August. In 2017 and 2018 water temperatures exceeded 20 °C from June to September. The August maxima exceeded 23 °C in 2017 and 25 °C in 2018, respectively. The minimum values for water temperature were recorded in October.

Vertical profiles at S1–S5 show significant temperature stratification. In the summer months of 2018,

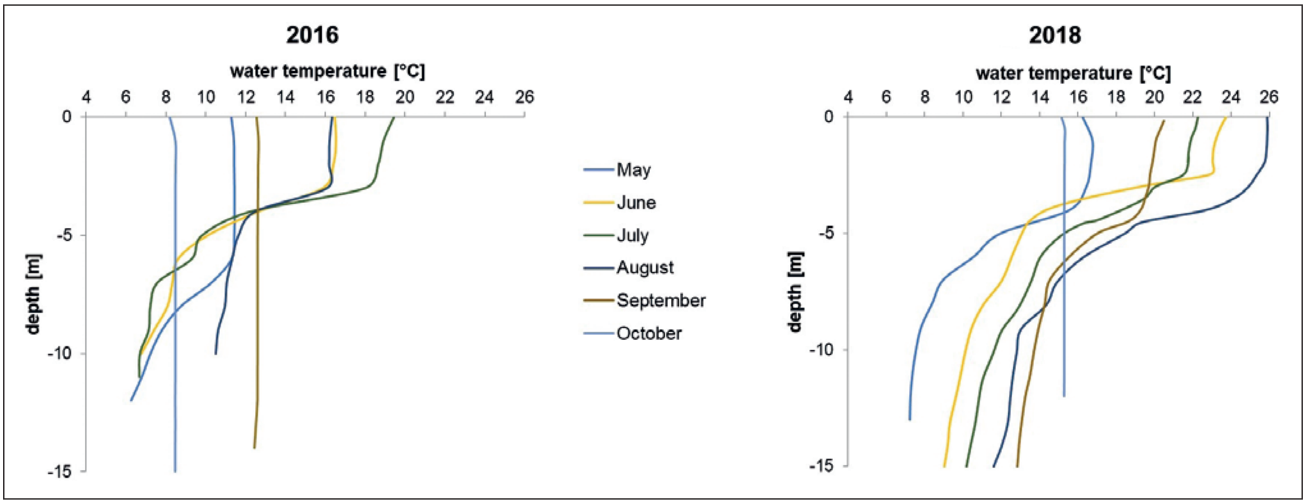


Fig. 3 Thermal stratification – vertical profiles at S3 (2016, 2018).

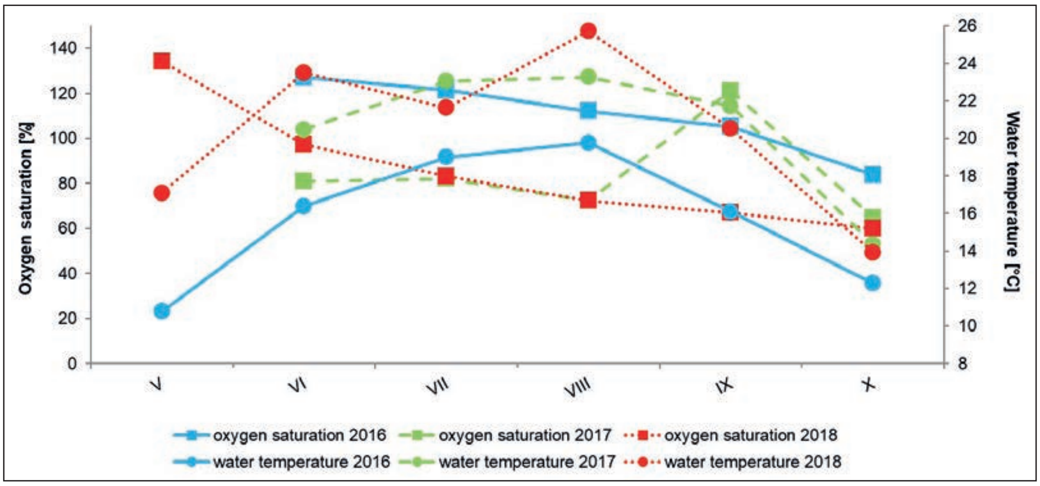


**Fig. 4** Water temperature and oxygen saturation (comparison of growing periods, 2016, 2017 and 2018).

water temperature in the epilimnion was approximately 26 °C, compared to a water temperature of approximately 14 °C in lower layers of the bay. Comparison of stratification development during the growing season is shown at S3 for both years in Figure 3. As can be seen from the figure, the thermocline started during the summer at a depth between 4 and 5 meters. In September and October of 2016 and October of 2018, the temperature profile showed uniformity throughout the water column at ~12 °C and ~15 °C. However, it is necessary to include the effect of reservoir water level manipulation in interpreting these results, since in October the water level in the reservoir decreases every year. While the sampling campaign started in April each year, the end of the spring circulation was not observed. In terms of longitudinal temperature development in bay, the difference between station S7 and S2 ranges from 1 to 2 °C in mixed samples. Towards to station S2 the temperature increases.

The solubility of oxygen in water is affected by temperature, with the solubility of oxygen decreasing as water temperature increases. Figure 4 compares the average monthly OS and WT values of all monitored stations in the growing season for the years 2016, 2017 and 2018. From these average values, it is evident that the highest saturation values were reached in 2016, when the lowest water temperatures occurred. The years 2017 and 2018 showed very similar patterns of relationship between these two parameters.

In the Mastník bay, oxygen concentration varied greatly from year to year. In 2016, there was adequate oxygen in the upper layer of bay water, compared to other monitored years. DO concentrations of 2016 were usually higher than 7.5 mg $l^{-1}$. In 2016, oxygen deficits occurred at greater depths, as shown in stratification diagram (Fig. 5). For example, the oxygen concentration S33 samples, taken from depth of 10 meters concentration decrease during the summer

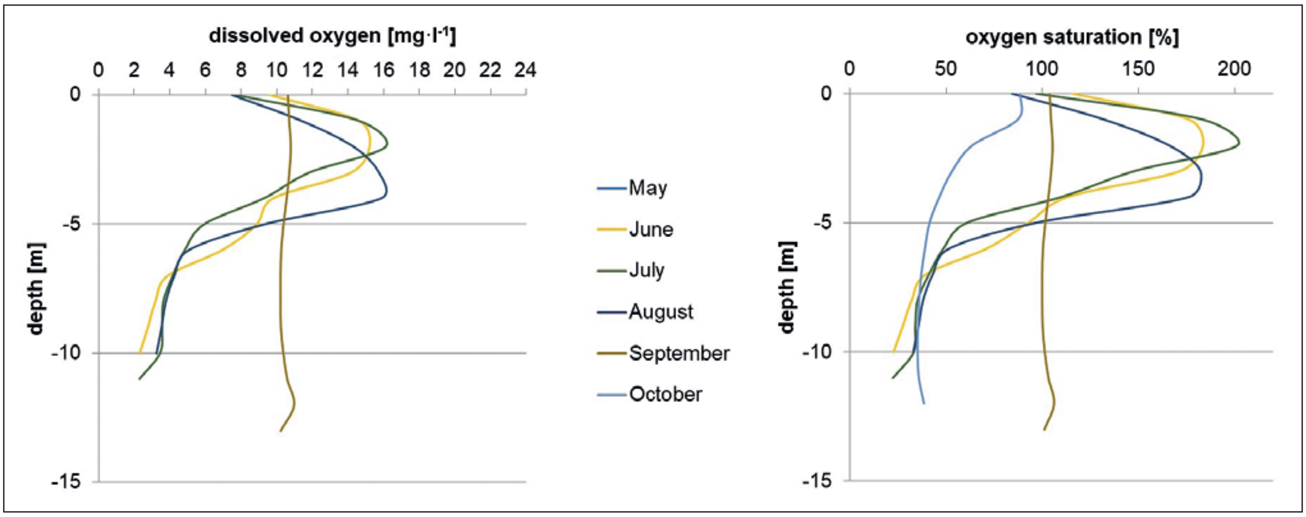


**Fig. 5** Stratification of dissolved oxygen and oxygen saturation: vertical profiles at S4 in 2016.

**Tab. 5** Dissolved oxygen concentration and oxygen saturation in Mastník bay.

| | 2016 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **V** | | **VI** | | **VII** | | **VIII** | | **IX** | | **X** | |
| Station | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] |
| S2 | x | x | 9.29 | 109.80 | 9.31 | 115.30 | 7.65 | 87.30 | 9.76 | 94.60 | 7.00 | 63.90 |
| S3-1 | x | x | 9.28 | 109.30 | 9.36 | 116.50 | 7.20 | 78.80 | 10.26 | 99.80 | 10.24 | 92.80 |
| S3-2 | x | x | 8.76 | 89.30 | 6.82 | 68.90 | 9.00 | 91.30 | 7.76 | 75.70 | 4.36 | 39.80 |
| S3-3 | x | x | 5.23 | 53.80 | 6.49 | 60.30 | 3.40 | 33.60 | 7.52 | 73.30 | 3.87 | 35.40 |
| S4-1 | x | x | 9.62 | 115.80 | 7.70 | 96.70 | 7.49 | 84.10 | 10.63 | 103.90 | 9.80 | 88.50 |
| S4-2 | x | x | 8.87 | 92.70 | 5.95 | 60.70 | 9.34 | 96.70 | 10.38 | 101.50 | 4.55 | 41.40 |
| S4-3 | x | x | 2.31 | 22.70 | 3.45 | 33.10 | 3.26 | 32.80 | 10.37 | 101.20 | 3.88 | 35.20 |
| S5-1 | x | x | 12.32 | 150.60 | 9.21 | 116.40 | 13.79 | 161.40 | 10.76 | 105.40 | 10.11 | 90.00 |
| S5-2 | x | x | 7.57 | 90.60 | 2.36 | 25.30 | 9.49 | 102.80 | 12.26 | 116.10 | x | x |
| S6 | x | x | 9.71 | 118.80 | 13.68 | 175.30 | 15.10 | 173.60 | 11.80 | 112.00 | x | x |
| S7 | x | x | 13.12 | 160.00 | 10.29 | 130.10 | 7.69 | 86.80 | 13.59 | 126.20 | x | x |
| | **2017** | | | | | | | | | | | |
| **Month** | **V** | | **VI** | | **VII** | | **VIII** | | **IX** | | **X** | |
| Station | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] |
| S2 | x | x | 6.75 | 75.30 | 4.70 | 54.90 | 5.68 | 66.90 | 6.49 | 74.23 | 6.09 | 60.80 |
| S3-1 | x | x | 7.21 | 80.60 | 5.49 | 64.60 | 4.21 | 49.70 | 6.17 | 70.57 | 6.95 | 69.30 |
| S3-2 | x | x | 7.98 | 76.00 | 5.89 | 59.50 | 3.64 | 39.20 | 7.26 | 75.10 | 6.14 | 61.30 |
| S3-3 | x | x | 8.84 | 79.40 | 6.90 | 64.80 | 3.54 | 35.60 | 7.68 | 76.80 | 6.19 | 61.70 |
| S4-1 | x | x | 8.13 | 91.00 | 5.87 | 68.70 | 5.13 | 60.50 | 5.13 | 58.68 | 6.13 | 61.20 |
| S4-2 | x | x | 8.87 | 83.50 | 6.39 | 65.10 | 3.79 | 42.30 | 7.91 | 82.40 | 6.17 | 61.60 |
| S4-3 | x | x | 9.60 | 87.00 | 7.94 | 74.50 | 3.51 | 35.00 | 8.63 | 86.30 | 6.28 | 62.50 |
| S5-1 | x | x | 9.16 | 102.10 | 7.53 | 88.20 | 6.89 | 80.60 | 10.17 | 114.27 | 6.79 | 67.60 |
| S5-2 | x | x | 11.93 | 115.80 | 7.65 | 84.10 | 7.13 | 81.90 | 5.54 | 61.56 | 7.22 | 69.00 |
| S6 | x | x | 7.93 | 88.00 | 10.62 | 122.80 | 11.23 | 80.30 | 8.17 | 93.45 | 8.30 | 78.30 |
| S7 | x | x | 5.22 | 57.00 | 10.43 | 120.20 | 12.14 | 140.10 | 13.69 | 152.11 | 6.84 | 62.90 |
| | **2018** | | | | | | | | | | | |
| **Month** | **V** | | **VI** | | **VII** | | **VIII** | | **IX** | | **X** | |
| Station | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] | DO [mg $l^{-1}$] | OS [%] |
| S2 | 12.59 | 129.60 | 6.72 | 79.10 | 3.57 | 40.90 | 5.33 | 65.80 | 4.81 | 53.80 | 5.60 | 52.40 |
| S3-1 | 12.90 | 132.90 | 7.78 | 92.10 | 4.39 | 50.50 | 6.35 | 78.10 | 5.43 | 60.30 | 3.80 | 38.00 |
| S3-2 | 15.72 | 145.90 | 6.93 | 65.90 | 5.82 | 57.80 | 6.40 | 68.30 | 6.49 | 67.20 | 3.85 | 38.40 |
| S3-3 | 17.35 | 144.90 | 7.01 | 62.30 | 6.50 | 59.80 | 7.42 | 70.10 | 6.96 | 66.80 | 3.86 | 38.60 |
| S4-1 | 12.36 | 134.20 | 9.32 | 110.40 | 7.24 | 82.60 | 4.81 | 59.40 | 6.25 | 69.80 | 4.49 | 44.90 |
| S4-2 | 13.91 | 134.40 | 8.25 | 79.30 | 7.76 | 77.60 | 8.42 | 89.50 | 6.75 | 71.80 | 4.65 | 46.40 |
| S4-3 | 17.56 | 148.70 | 8.75 | 77.70 | 8.20 | 75.20 | 9.87 | 93.20 | 7.93 | 77.00 | 4.57 | 45.50 |
| S5-1 | 15.45 | 158.20 | 8.24 | 98.20 | 8.63 | 97.90 | 10.98 | 134.90 | 6.86 | 76.20 | 4.80 | 46.70 |
| S5-2 | 12.95 | 125.20 | 6.15 | 61.10 | 8.45 | 94.10 | 13.69 | 149.20 | 7.43 | 80.60 | 5.44 | 50.30 |
| S6 | 10.95 | 116.00 | 8.01 | 94.40 | 8.64 | 97.70 | 3.44 | 42.00 | 7.80 | 86.20 | 12.40 | 117.20 |
| S7 | x | x | 10.17 | 117.40 | 11.60 | 129.60 | x | x | x | x | x | x |

to value below 4 mg $l^{-1}$. All concentrations lower than 4 mg $l^{-1}$ are highlighted in the Table 5. The table also shows higher oxygen concentrations in the part of the bay furthest away from the reservoir, which is the result of the inflow of fresh water from the basin and higher biological activity. In deeper zones, OS may remain below 100% due to the respiration of aquatic organisms and microbial decomposition. Additionally, these deeper levels of water often do not reach 100% oxygen saturation because they are not affected by waves and photosynthetic at activity near surface. The observed oxygen concentration in August of 2017 fell below 40% oxygen saturation.

An example of oxygen stratification is represented in Figure 5. These diagrams show stratification in 2016 during growing season at sampling location S4.

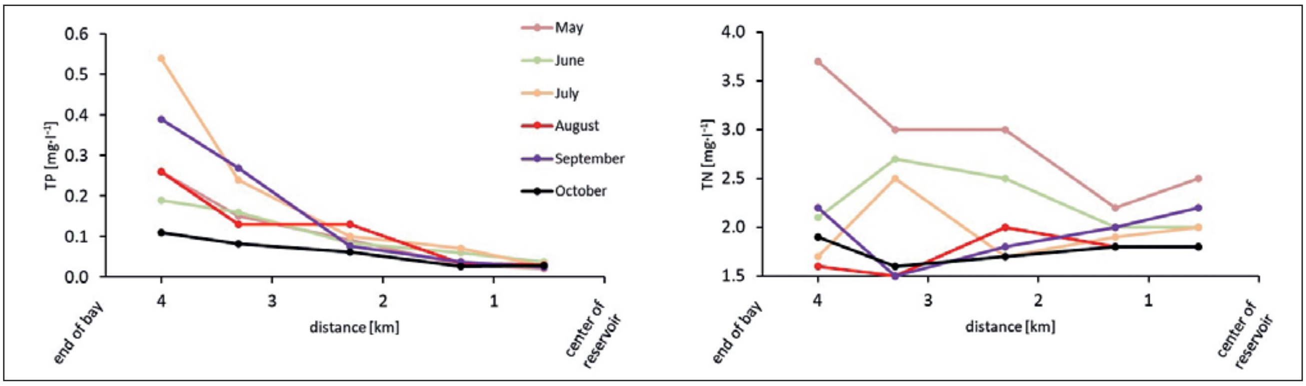


**Fig. 6** Longitudinal profiles of TP and TN concentrations along Mastník bay in 2018 (mixed samples).

The curve trend shows clustering of photosynthesizing algae at depth of 3–5 m, resulting in an oxygen saturation higher than 100%. A low oxygen zone (DO concentration below 4 mg $l^{-1}$) in the lower part of the sampling profile (under 7 m) is also apparent. This can partly be explained by sinking of organic material produced in the epilimnion to the thermocline, where oxidation reduces DO and oxygen saturation is about 50%. This low oxygen condition occurred in 2016 in S3, S4 and S5 profiles. However, much higher amounts of oxygen in the epilimnion were observed during whole growing season 2016, which suggests high biogenic production by phytoplankton. In 2017, the low oxygen zone at the bottom was observed only in August, and in 2018 there were no observed low oxygen conditions at the bottom at all, with the exception of October, which was affected by the reduction of the water level by more than 1 m.

### 3.2.2 Nutrients concentration

Nutrients are primarily compounds of nitrogen, phosphorus and silicon. In this study, the effect of silicon was not considered. An average TP concentration of 0.34 mg $l^{-1}$ and TN concentration of 3.88 mg $l^{-1}$ at the M1 station were measured. In the case of TP, this value is similar to the concentrations in the upper part of the bay, i.e. location S6 and S5. The concentrations ranged between 0.02 and 0.54 mg $l^{-1}$. The maximum concentrations were found in July 2018. In the case of TN, the maximum concentrations were in May and June, when the concentrations exceeded 4 mg $l^{-1}$. TN concentrations ranged between 1.6 and 4.5 mg $l^{-1}$. Higher TN values were found at greater depths. In the case of ammonia N, highest concentrations were found in September, when the concentrations exceeded 0.6 mg $l^{-1}$ along the entire longitudinal profile of the bay. In the case of TP concentrations gradually decreased in direction to the reservoir. Concentration changes from monthly observations along the longitudinal profile during 2018 are shown in Figure 6, which shows that the highest entering concentrations were observed in July. Except for May and June, an increasing trend in the longitudinal profile can be seen in the case of TN. Concentrations of TN ranged from 1.5 to 2.5 mg $l^{-1}$.

Because high amounts of phosphorus increase growth of algal biomass (eutrophication process), the dependence of chlorophyll concentrations on TP was calculated using the correlation coefficient. Results calculated for each station in 2018 are given in Table 6; results from mixed samples are highlighted. Due to the low number of observations, the correlation coefficient (CC) results could not be considered as statistically significant. The required value is only significant for chlorophyll concentration at station S4, because CC is higher than 0.7067 (Heo et al. 2008). All CC values for mixed samples showed positive correlation but were insignificant.

### 3.2.3 Chlorophyll-α concentration and trophic indexes

In the summer months, high levels of phytoplankton activity are clearly visible in the Mastník bay. Measurements of chlorophyll-α concentrations were used to estimate the total phytoplankton biomass. This method is simpler and faster than phytoplankton sampling and counting. However, as chlorophyll

**Tab. 6** Significance of TP concentration and Chl-α concentration for 2018.

| Station | CC | Significance |
|---|---|---|
| S2 | 0.28 | x |
| S3-1 | 0.56 | x |
| S3-2 | −0.10 | x |
| S3-3 | 0.11 | x |
| S4-1 | 0.87 | yes |
| S4-2 | 0.56 | x |
| S4-3 | −0.23 | x |
| S5-1 | 0.70 | x |
| S5-2 | −0.33 | x |
| S6 | 0.49 | x |

**Tab. 7** Trophic index for the Mastník bay in 2018.

| Station | Components average value | | | | Trophic index | | | |
|---|---|---|---|---|---|---|---|---|
| | SD [m] | TN [mg $l^{-1}$] | TP [mg $l^{-1}$] | Chl-α [μg $l^{-1}$] | CTSI | | TLI | |
| S2 | 2.08 | 2.05 | 0.03 | 27.50 | 53.60 | eutrophic | 5.20 | supertrophic |
| S3 | 1.50 | 1.95 | 0.04 | 41.33 | 58.15 | eutrophic | 5.51 | supertrophic |
| S4 | 0.98 | 2.12 | 0.09 | 84.00 | 66.11 | hypertrophic | 6.09 | hypertrophic |
| S5 | 0.81 | 2.13 | 0.17 | 152.83 | 71.31 | hypertrophic | 6.45 | hypertrophic |
| S6 | 0.37 | 2.20 | 0.29 | 211.60 | 79.13 | hypertrophic | 6.96 | hypertrophic |
| Overall total trophic index of Mastnik bay | | | | | 65.66 | hypertrophic | 6.04 | hypertrophic |

concentration assumes all phytoplankton to have the same levels of chlorophyll-α, it provides only a rough estimate of biomass, and cannot be used to identify specific species. Chlorophyll concentration changes during the growing seasons of 2016 and 2018 along the Mastnik Bay can be displayed by sorting measured values of chlorophyll concentration into 5 categories. Figure 7 shows a schematic of chlorophyll concentrations divided into 5 classes based on values from mixed samples at different location. The schemes show that the upper part of the bay had much higher concentrations than elsewhere in the bay. Chlorophyll concentrations in the upper part of the bay exceeded 100 μg $l^{-1}$ (represented in red), and at some location were above 500 μg $l^{-1}$, as seen during July and August 2016. In 2018, lower values were observed at the same station. A maximum Chl-α concentration of 280 μg $l^{-1}$ was reached in August at S6. During the growing seasons in 2016 and 2018 the pattern of areal distribution (Fig. 7) was similar, showing

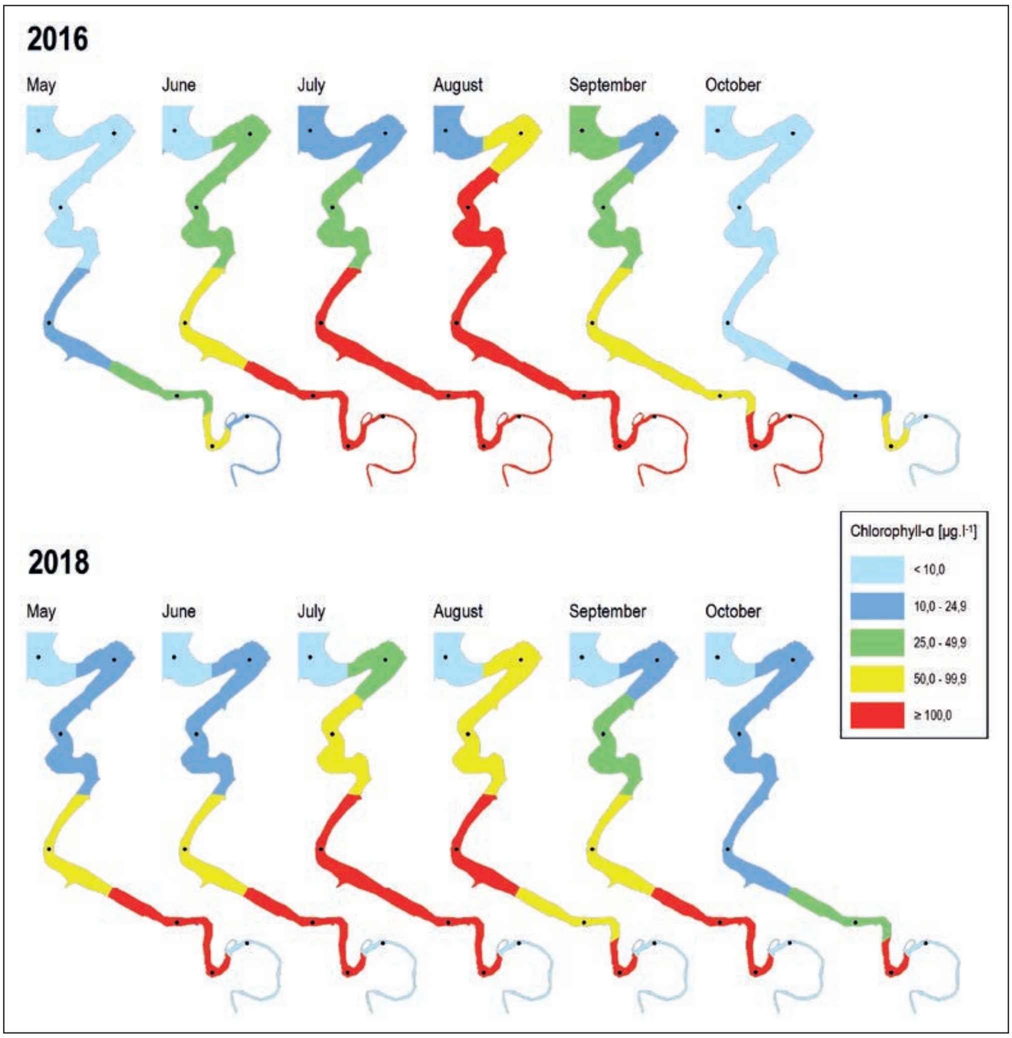


**Fig. 7** Classification according to chlorophyll concentration along the longitudinal profile of the bay during the growing season (comparison 2016–2018).

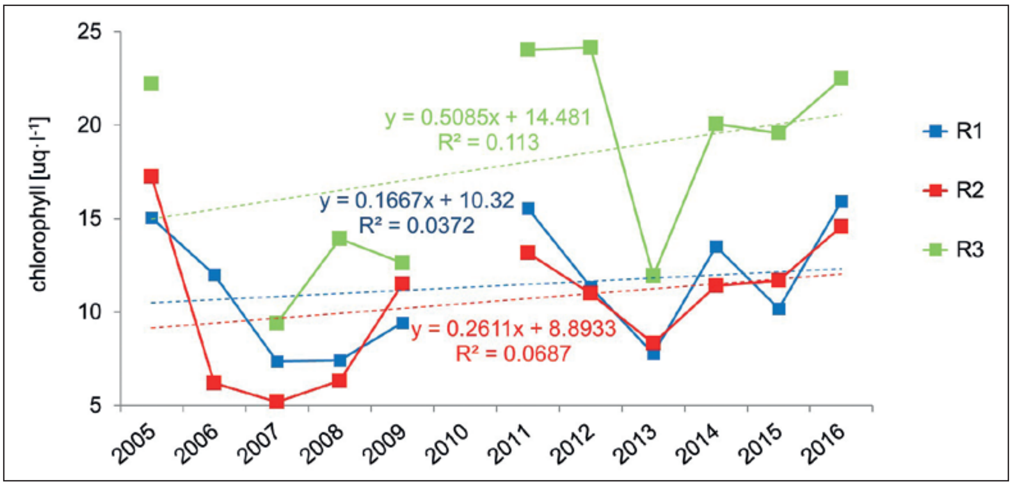


Fig. 8 Average chlorophyll-α concentration (2005–2016) at selected profiles in the Slapy Reservoir.

decreasing concentrations in the direction of the reservoir.

The numerical trophic index values for the Mastník bay are given in Table 7. All indices clearly show the hypertrophic conditions of the bay. Hypertrophic refers to high levels of biological productivity characterized by frequent and severe algal blooms and low water transparency. The average CTSI value for the bay was 65.66, indicating that the bay is at a hypertrophic level (Table 3) and ranged between 53.6 (eutrophic) at station S2 to 79.13 (hypertrophic) at S6. The average TLI value was 6.04 and varied from 5.2 (supertrophic) to 6.96 (hypertrophic).

### 3.2.4 Effect of nutrience of the Mastník bay on the Slapy Reservoir water quality

It is obvious from the results, that eutrophication problems in the summer months are more intense in the bay than in the reservoir. Based on data from 2015 and 2016 for profiles (R1, R2) located on free water surface in the Slapy Reservoir, the difference in concentrations of parameters during the observed period is marginal (Table 8). Station R3 is very similar to R1, with the only differences concerning the chlorophyll concentrations, which are higher in R3 (Tab. 8). This fact has no impact on the profile R2, which is located just behind the mouth of the Mastník stream into the Vltava river. For example, in 2016 average chlorophyll concentrations in stations R3, R1 and R2 were 22.05 µg $l^{-1}$, 15.9 µg $l^{-1}$ and 14.6 µg $l^{-1}$ respectively.

Development of average chlorophyll concentration in mixed samples from Slapy sampling location during the growing season (May–October) is shown in Figure 8. The diagram shows that average concentrations increase over the years at each profile. The linear trend has a slight positive slope. This increase is also confirmed by the value of the MKT. However, except for July on the R1 and R3 profiles, this trend is not significant at the alpha = 0.1 level (Tab. 9). There is also a considerable variation between the years.

The numerical values of the trophic index for the Slapy Reservoir are given in Table 10. All indices show different conditions. The CTSI value was 52.43, indicating that the reservoir is at a eutrophic level (Table 3), meaning a water body with high biological

Tab. 8 Water quality of sampling location at the Slapy Reservoir (mixed samples for growing season 2015–2016).

| Station | R1 | | | R2 | | | R3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Component/index | Mean | Median | C (90) | Mean | Median | C (90) | Mean | Median | C (90) |
| Water temperature [°C] | 17.22 | 18.00 | | 16.96 | 17.95 | | 17.25 | 17.95 | |
| Dissolved oxygen [mg $l^{-1}$] | 10.20 | 10.40 | 8.10 | 9.96 | 9.70 | 9.40 | 10.69 | 10.65 | 8.60 |
| Saturation $0_2$ [%] | 105.27 | 109.00 | | 101.69 | 105.00 | | 110.51 | 112.50 | |
| TN [mg $l^{-1}$] | 2.31 | 2.35 | 3.00 | 2.39 | 2.45 | 3.20 | 2.31 | 2.30 | 3.20 |
| N-$NH_4^+$ [mg $l^{-1}$] | 0.04 | 0.03 | 0.06 | 0.04 | 0.03 | 0.06 | 0.04 | 0.03 | 0.06 |
| N-$NO_3^-$ [mg $l^{-1}$] | 0.02 | 0.02 | 2.70 | 0.02 | 0.02 | 2.50 | 0.02 | 0.02 | 2.70 |
| N-$NO^{2-}$ [mg $l^{-1}$] | 1.98 | 2.00 | 0.03 | 1.99 | 2.00 | 0.01 | 1.86 | 1.80 | 0.04 |
| TP [mg $l^{-1}$] | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.05 | 0.05 | 0.04 | 0.07 |
| Chlorophyll-α [µg $l^{-1}$] | 13.05 | 8.05 | 35.00 | 13.13 | 7.40 | 40.00 | 21.03 | 20.50 | 50.00 |
| Fe [mg $l^{-1}$] | 0.04 | 0.03 | 0.08 | 0.04 | 0.03 | 0.06 | 0.05 | 0.04 | 0.07 |

**Tab. 9** Trend analysis in time series using the MKT (2005–2016).

| Station | R1 | | | | | | R2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | Average vegetation period | | July | | August | | Average vegetation period | | July | | August | |
| Parameter | MKT | S. | MKT | S. | MKT | S. | MKT | S. | MKT | S. | MKT | S. |
| Temperature [°C] | −1.17 | x | 1.35 | x | 1.35 | x | −0.62 | x | 0.81 | x | 0.00 | x |
| Dissolved oxygen [mg l⁻¹] | 0.75 | x | 0.54 | x | 0.81 | x | 0.07 | x | 0.54 | x | 0.45 | x |
| N-NH4 [mg l⁻¹] | 1.44 | x | 1.34 | x | 1.04 | x | 0.21 | x | −1.39 | x | 1.18 | x |
| TP [mg l⁻¹] | −0.48 | x | 0.54 | x | 0.00 | x | −0.62 | x | 0.09 | x | 0.18 | x |
| Chl-α [μg l⁻¹] | 0.89 | x | 2.60 | YES | 1.35 | x | 1.17 | x | 0.99 | x | 1.25 | x |

| Station | R3 | | | | | |
|---|---|---|---|---|---|---|
| Period | Average vegetation period | | July | | August | |
| Parameter | MKT | S. | MKT | S. | MKT | S. |
| Temperature [°C] | −1.30 | x | 1.35 | x | 0.36 | x |
| Dissolved oxygen [mg l⁻¹] | 0.89 | x | 0.00 | x | −0.63 | x |
| N-NH4 [mg l⁻¹] | 1.43 | x | −0.70 | x | 0.35 | x |
| TP [mg l⁻¹] | 1.43 | x | −0.20 | x | 0.99 | x |
| Chl-α [μg l⁻¹] | 1.03 | x | 1.79 | YES | 0.45 | x |

productivity, that can support an abundance of aquatic plants. The average value of TLI was 5.14, indicating a supertrophic water body.

To assess longitudinal changes in concentrations of observed parameters in two vertical profiles (R1, R2) at the Slapy Reservoir and for the effect of the Mastník catchment on reservoir water quality, diagrams of average concentrations of observed parameters (2005–2016) with depth interval of 5 meters were used (Figure 9). Diagrams show identical changes of average concentrations also in vertical profile. TP and $NNO_3^-$ concentrations show minor differences.

These data confirm the negligible effect of the Mastník stream and dominance of internal water quality development in the bay. By the wide mouth of Mastník bay, water masses mix only minimally due to low velocities. In summer months, under mean hydrological conditions, the Slapy reservoir water mass behaves as a "dam", which retains the hypertrophic waters of the Mastník stream in its bay. During summer eutrophication development proceeds intensively (Mrkva 2018).

The average water retention time in the Slapy Reservoir is 36 days, while the retention time in Mastník bay is 55 days. However, the retention time can vary greatly depending on the inflow. For example, in the summer of 2018, the water level on the M1 profile was below 90 cm several times. This water level means the drought at this location (Czech Hydrometeorological Institute). This level corresponds to a discharge of 0.06 $m^3 s^{-1}$. The average inflow in 2018 in the growing season was only 0.15 $m^3 s^{-1}$, which is a very low value compared to the long-term average discharge (1.26 $m^3 s^{-1}$). Under low flow conditions, retention period would be 454 days.

## 4. Discussion

The physical and chemical indicators investigated in this research have been used to assess the water quality of the Mastník bay and to assess its impact on the Slapy Reservoir, a reservoir on the Vltava River in Czechia. Poor water quality of the Mastník catchment manifests itself in the Mastník bay. Significant phytoplankton development has been observed during the growing season (Mrkva 2018) Due to the low water velocity in the bay the water exchange with the Vltava

**Tab. 10** Trophic index for the Slapy Reservoir in 2016.

| Station | Components average value | | | | Trophic index | | | |
|---|---|---|---|---|---|---|---|---|
| | SD [m] | TN [mg l⁻¹] | TP [mg l⁻¹] | Chl-α [μg l⁻¹] | CTSI | | TLI | |
| R1 | 2.17 | 2.47 | 0.03 | 15.91 | 51.86 | eutrophic | 5.09 | supertrophic |
| R2 | 2.24 | 2.54 | 0.02 | 14.50 | 49.80 | mesotrophic | 4.96 | eutrophic |
| R3 | 1.87 | 2.51 | 0.05 | 22.50 | 55.63 | eutrophic | 5.37 | supertrophic |
| Overall total trophic index | | | | | 52.43 | eutrophic | 5.14 | supertrophic |

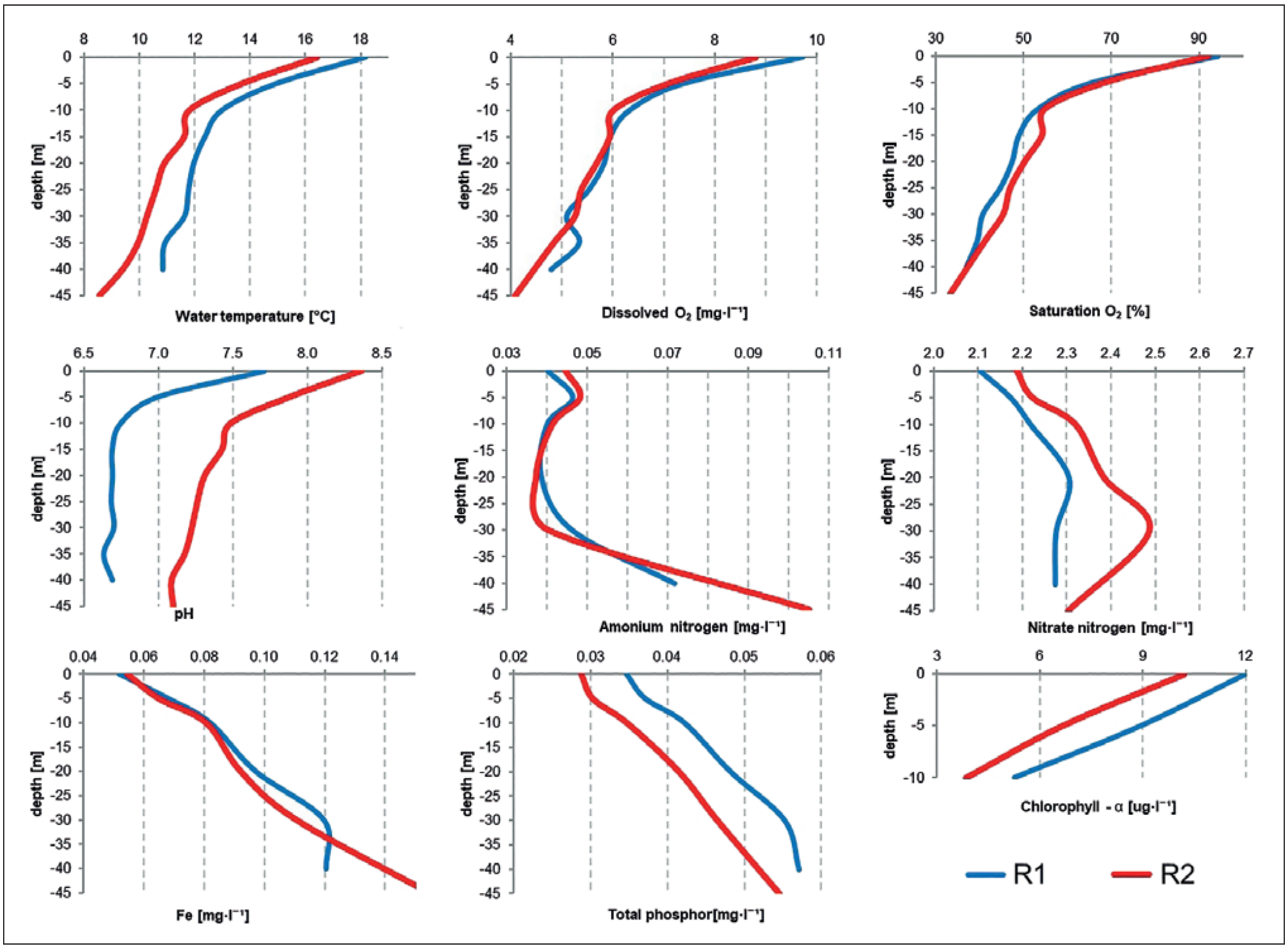


**Fig. 9** Comparison of stratification of different parameters at R1 and R2 locations of the Slapy Reservoir (average from 2005 to 2016).

river is limited, resulting in favourable conditions for eutrophication.

Temperature is an important factor to consider when assessing water quality. Temperature can alter the physical and chemical parameters of surface waters. It affects the metabolic rate and biological activity of aquatic organisms, the concentration of DO in water and the toxicity of compounds (Wetzel 2001). Photosynthesis and thus the reproduction of phytoplankton accelerates by heat until a certain optimum. In July and August between 2016 and 2018 the surface water temperature in the Bay ranged from 21 °C to 25 °C. These summer surface water temperatures are similar to the average water temperatures of lakes in much warmer latitudes, such as Lake Hawassa, Ethiopia, where the average water temperature is 21.23 °C (Worako 2015), Lake Timshah in the Suez Strait, which averages 22 °C (El-Serehy et al. 2018) and Xinlicheng Reservoir with an average summer value of 22.6 °C (Guo et al. 2018). Minimum temperatures were found in May and October, falling down to 5 °C. In the summer months, significant temperature stratification was confirmed with temperature difference in the water column reaching 12 °C.

In the case of large and rapid death of phytoplankton, there may be a significant reduction in $O_2$ concentration at greater depths due to the consumption of $O_2$ during microbial decomposition of dead matter, often leading to low oxygen zones near the bottom. This may be the reason for the observed vertical differences of oxygen in the Mastník bay. Waters with lower $O_2$ saturation are usually below the thermocline, where the oxygen content is not affected by surface waves and photosynthesis. In contrast, supersaturation can often occur near the water surface due to high levels of photosynthesis or a significant change in temperature (Weitkamp, Katz 1980). This condition becomes evident in summer (Figure 5). At a depth of 2 m, both the highest phytoplankton concentration and the highest $O_2$ saturation occur, while below the thermocline at water depth of more than 5 m the saturation decreases to 50%. The measured oxygen saturation is also affected by the time of sampling, because in summer a strong change in temperature between day and night occurs, while at the same time change in radiation effect the photosynthetic activity of the algae. The largest production of oxygen by phytoplankton is in the morning. Overall, the measured data show that highest $O_2$ concentrations and oxygen saturations are observed in stations S7, S6 and S5. This is attributed to a nearby tributary to the bay, which provides nutrients for the growth of phytoplankton.

This view is supported by data on phosphorus and chlorophyll concentrations in this part of the bay. An average concentration of DO for the whole monitored period was 8.4 mg $I^{-1}$. In different reservoirs, for example in the Xinlicheng Reservoir in China, where the average concentration was 8.45 mg $I^{-1}$. The summer average in this reservoir was 1 mg $I^{-1}$ lower than average of the Mastnik bay (Guo et al. 2018). In the Feitsui Reservoir in Taiwan, which is located in an area with a subtropical oceanic climate, its mean DO value 7.14 mg $I^{-1}$ (Chen 2014).

According to both indices of the trophic state, the state of the Mastník bay is hypertrophic. The profiles on the Slapy Reservoir show a better classification concerning the degree of trophy, with CTSI evaluating it as eutrophic and TLI evaluating it as supertrophic. It should be noted that the overall condition of the bay is distorted by the profiles at the top of the bay. In the case of stations S2 and S3, the results are comparable to the Slapy Reservoir itself. Eutrophication is more pronounced in upper part of the Mastník bay due to its shallowness and the longer water residence time might also support eutrophication. The most important parameter affecting the evaluation of the trophic state of this bay appears to be chlorophyll, in contrast to the results of other investigations. For example, in the case of Lake Hawassa in Ethiopia, the TSI is 73, but the average chlorophyll concentration is 28 µg $I^{-1}$, as compared to the average of the bay in this study (103 µg $I^{-1}$). However, Hawassa has significantly higher concentrations of TP (Worako 2015). Xinlicheng Reservoir has been reported to have an average TSI value of 50.65, which indicates that the reservoir is generally in a eutrophic state (Guo et al. 2018). Lake Timsah has a TSI of 60 and a TLI of 5.2, and significantly lower concentrations of Chl-α (20 µg $I^{-1}$). However, it has also higher concentrations of TP (0.48 mg $I^{-1}$) and TN (7.2 mg $I^{-1}$) (El-Serehy et al. 2018) when compared to average concentrations (TP: 0.125 mg $I^{-1}$; TN: 2.09 mg $I^{-1}$) of the Mastník bay. The Feitsui Reservior has average TP concentration 0.21 mg $I^{-1}$ and CTSI is in the range of mesotrophic and eutrophic (Chen 2014). In New Zealand (NZ) lakes TLI values are significantly lower than values in the Mastník bay, averaging about 4.0, which ranks the lakes between mesotrophic and eutrophic. In addition to the significant difference in Chl-α concentrations between the Mastník bay and NZ lakes, there is also a large difference in transparency, which averages 5 m are in NZ lakes (Burns et al. 2005) when compared to the Mastník bay average of 1.15 m. Reservoirs on the Paranapanema River in Brazil showed similar indices as the Mastník bay, although different trophic indices have used for reservoirs in tropical and subtropical areas (Pomari et al. 2018). Assessment of the trophic condition of a lake are often directly linked to water quality. However, in some cases, this is very inappropriate, since there are naturally eutrophic water bodies. It is therefore necessary to consider this information before directly relating trophic status in direct to water quality (Parparov 2010). Naturally eutrophication is not related with the Mastník bay, where eutrophication is affected by human activity and the pollution of the Mastník stream is the result of human activities.

In the case of TP, a slight predominance of point sources of pollution is observed in the Mastník river basin (Mrkva 2018). The concentration of TP discharged into the Mastník recipient does not change significantly during the year. Thus, the benefit of TP from the river basin is not as crucial as its supply of TP in sediments that form throughout the season and especially at high flows, when the capabilities of WWTPs are reduced. In a relatively shallow bay, TP sediment is more readily available phytoplankton than in the deep reservoir itself. But the results of some studies demonstrate that sediment-derived P stimulates phytoplankton growth, but that its effect on phytoplankton dynamics is modulated by other factors, such as light (Cymbola et al. 2008).

## 5. Conclusion

High water residence times in the Mastnik Bay favour algal growth, especially during the growing season. Water quality parameters, which involved nutrients and oxygen concentrations, water temperature and phytoplankton biomass in the Mastník bay was investigated over three growing seasons (2016–2018) to describe the trophic state and water quality of the Mastník bay and ascertain its effect on the Slapy Reservoir. Based on trophic indices, the bay can be classified as hypertrophic while the Slapy Reservoir itself is eutrophic. Total phosphorus concentrations in the bay are still high, even though the supply of phosphorus from the Mastník catchment area is decreasing. An increase of eutrophication and thus chlorophyll concentration can also be associated with increasing surface water temperatures and stronger thermal stratification, or by releasing TP from the sediment. However, the effect of the Mastník catchment on the concentration of the monitored substances of the main water body of the reservoir could not been proven.

Nevertheless, a small change in the quality of surface water in a river basin can cause a change in the ecological characteristics of the whole stream and its surroundings. In the case of the Mastník bay, it is necessary to reduce phosphorus inputs into the reservoir to prevent eutrophication. Improvement of WWTP efficiency and reduction of diffuse sources seem to be suitable measures. In the coming decades, water flows could be more affected by changing climate, as already observed in 2018. Rising air temperatures and changes in precipitation may result in deterioration of surface water quality despite all measures and investments made so far. It is necessary to continue devoting attention to this issue.

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# Land use and land cover change-induced landscape dynamics: a geospatial study of Durgapur Sub-Division, West Bengal (India)

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**ABSTRACT**
This article examines the factors and process of change in the land use and land cover change-induced landscape dynamics in the Durgapur Sub-Division region of West Bengal in 1989, 2003, and 2018 by employing the satellite imageries of Landsat 5 (1989 and 2003) and Landsat 8 (2018). The images of the study area were categorized into seven specific land use classes with the help of Google Earth Pro. Based on the supervised classification methodology, the change detection analysis identified a significant increase in built-up land from 11% to 23% between 1989 and 2003 and from 23% to 29% in 2003 and 2018. The areas under fallow land and vegetation cover have mainly decreased, while the areas of industrial activities and urbanization expanded during the study period.

**KEYWORDS**
change detection; geospatial; landscape dynamics; land use and land cover

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## 1. Introduction

Landscape of a region is subject to modifications and changes caused by various factors and processes occurring thereon. Almo Farina states that "[L]andscape dynamics involve properties of the landscape, such as stability, persistence, resistance, resilience, and recovery, that operate along a broad range of temporal and spatial scales, such as shifting mosaic steady-state, and equilibrium spatial properties" (Oxford Bibliographies 2017). Studying earth's surface and environment has been one of the central themes of geographical research. Dynamics in landscape indicate to the fact that any land is not static forever; rather it is changeable at different scale and pace. Similarly, surface of the earth has been changing since its origin. Various types of external and internal factors play their role in such a change. The landscapes include the numerous features on the earth like forest land, water bodies, built-upland (all type of settlements, roads etc.), agricultural lands etc.

Land use and land cover are two separate terminologies which are often used interchangeably (Dimyati et al. 1996). In particular, land use and land cover (LULC) changes in tropical regions are of major concern due to the widespread and rapid changes in the distribution and characteristics of tropical forests (Myers 1993; Houghton 1994). However, changes in land cover and in the way people use the land have become recognized over the last 15 years as important global environmental changes in their own right (Turner 2002).

Recent research on land use and land cover change detection has drawn attention of many researchers (Liang et al. 2002; Ayele et al. 2016). Change detection has emerged as a significant process in managing and monitoring natural resources and urban development mainly due to provision of quantitative analysis of the spatial distribution of the population of interest. There are a lot of available techniques that serve purpose of detecting and recording differences and might also be attributable to change (Singh 1989; Yuan et al. 1999).

The land use and land cover changes play an important role in the study and analysis of global changed scenario today as the data available on such changes is essential for providing critical input to decision-making of ecological management and environmental planning for future (Zhao et al. 2004; Dwivedi et al. 2005; Erle and Pontius 2007; Fan et al. 2007). The accurate and timely land use and land cover maps derived from remotely sensed images are the keys for monitoring and quantifying various aspects of global and local climate changes, hydrology, biodiversity conservation, and air pollution (Sellers et al. 1995; Bonan 2008; Butchart et al. 2010; Schröter et al. 2010). Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth – system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn 1996).

## 2. Objectives

The present study addresses the following major objectives: i) To study land use and land cover changes and their impact on landscape dynamics in the Durgapur Sub-Division by comparing three-time period of year 1989, 2003, and 2018; and ii) To examine and detect factors of change of land use and land cover during study period and resulting conditions in the Durgapur Sub-Division.

## 3. Study Area

The study area of Durgapur Sub-Division lies in the eastern part of the Paschim Barddhaman District of West Bengal (shown in Figure 1). It is lies between 23°26′ N to 23°48′ N and 87°8′ E to 87°32′ E. The area of Durgapur Sub-Division is 771.28 km$^2$. The total population of the region is 1,209,372 as per the Census of India 2011. In this area the major city is Durgapur. This is an industrial city of eastern India and the second planned city (1955) of India after Chandigarh. It consists of four Community Development Blocks: Durgapur–Faridpur; Kanksa; Andal; and

**Tab. 1** Showing administrative units and demographic profile of Durgapur Sub-Division.

| Region | C.D. Bock / M.C. | Panchayat | | | Mouzas | Inhabited Village | Population |
|---|---|---|---|---|---|---|---|
| | | Samity | Gram | Gram Sansad | | | |
| Durgapur Sub-Division | Andal | 1 | 8 | 146 | 14 | 12 | 186,915 |
| | Faridpur-Durgapur | 1 | 6 | 88 | 54 | 48 | 115,924 |
| | Pndabeswar | 1 | 6 | 112 | 17 | 14 | 161,891 |
| | Kanksa | 1 | 7 | 132 | 86 | 77 | 178,125 |
| | Durgapur (MC) | – | – | – | – | – | 566,517 |

Source: http://www.sdodurgapur.org/blocks.php; and Census of India, 2011.

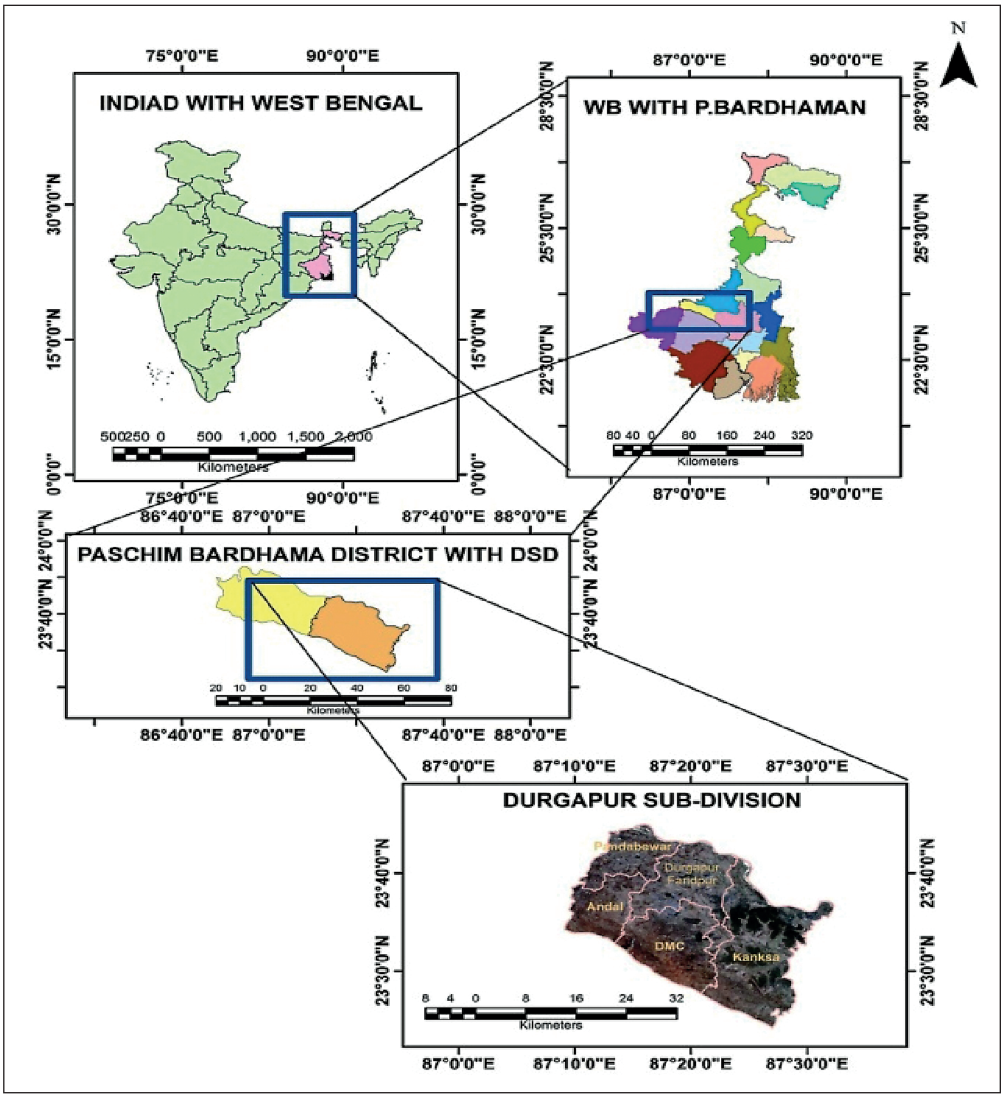



**Fig 1** Location map of the study area.

Pandabeswar and a Durgapur Municipal Corporation as shown in the Table 1. In Durgapur Subdivision, Durgapur Municipal Corporation is the only statutory urban area that comes within the ambit of the Asansol-Durgapur Planning Area (ADPA).

## 4. Material and Methods

The present study is based on a secondary source of database. The research database here involves the use of various methods, techniques and tools for the study of land use and land cover to make a wider sense of landscape dynamics of the region. Geographic Information System and Remote Sensing tools are used to collect, organize and analyze the spatial data. Remote Sensing has greatly opened new vistas in deriving factual information on natural and human resources by virtue of its synoptic overview, multi-spectral and multi-temporal coverage of the earth's surface. The Table 2 and Table 3 show the types of data, sources, satellite imageries and data sensors used in the present research.

The matter of the fact is that remote sensing platforms is a system used for collecting and analyzing space features. It includes space-borne (satellite imagery), air-borne (aerial photographs, thermal, radar images, etc.) and ground-based techniques as tools for the location and identification of the

**Tab. 2** Showing data types and sources for the study.

| Category | | Data type | Data source | Time period |
|---|---|---|---|---|
| Secondary | Spatial | Satellite data | USGS | 1989, 2003, 2018 |
| | | Administrative map | Durgapur Sub-division website | 2018 |
| | Attribute | Statistical | District Census Handbook, A-series – General Population Table | 2011 |

Source: Prepared by the authors, 2019.

Tab. 3 Showing satellites and sensors data acquired for the present study.

| Sl. No | Satellite | Sensor | Date |
|---|---|---|---|
| 1 | LANDSAT 5 | Thematic Mapper (TM) | Dec 17, 1989 |
| 2 | LANNDSAT 5 | TM | Nov 15, 2003 |
| 3 | LANDSAT 8 | OLI-TIRS | Nov 18, 2018 |

Source: Prepared by the authors, 2019.

biological, ecological and cultural characteristics of various features of the earth surface. In order to identify the spatial pattern and the rate of change, it all requires data analysis over a considerable time period or of sometime junctures. For data analysis purpose the important software and tools used in the study include ARC-GIS and ERDAS imagine 14. The ARC-GIS software is used to complement the display and processing of the acquired data. The ERDAS Imagine 14 is used for 'image processing' (layer stack, subset, classification) purpose. For verification and accuracy purposes of satellite images used in the research, the Google Earth system also has been very useful in the present study. Through this, images are used for location identification and classification. The method adopted in the present study for a detailed analysis of the land use and its mapping is given in the flow chart as shown in Figure 2. The methodology of the present study comprises the use of Landsat-5 (TM), Landsat-8 (OLI-TIRS) data from USGS (The United States Geological Survey, https://earthexplorer.usgs.gov). Here supervised classification method is used with maximum likelihood algorithm for Operation Image Classification. In the supervised classification approach, select groups of training pixels are adopted to represent seven land use and land cover units of the study area. Supervised classification is more or less controlled by the analyst. In this process, the analyst selects training pixels that are representative of the desired land use classes. In the present study, for each class around 40 training samples are taken into account. SPSS 22 is also used for analysis particularly Pearson's product-moment correlation coefficient (r) and Multiple Linear Regression to understand the relationship among the classes.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (1)$$

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_p x_{ip} + \epsilon \quad (2)$$

where, for $i = n$ observations,
$y_i$ = dependent variable,
$x_i$ = expanatory variables,
$\beta_0$ = y-intercept (constant term),
$\beta_p$ = slope coefficients for each explanatory variable,
$\epsilon$ = the model's error term (also known as the residuals).

The description of classified seven land use and land cover categories and their properties are provided in the below given Table 4. It provides a features description of the concerned classes.

The interpretation keys are chosen based on the classification of Landsat-5 and Landsat-8 images. Bhatta notes that "the criterion for identification of an object with interpretation elements is called an interpretation key" (Bhatta 2011). The seven major land use and land cover classes identified; the interpretation keys used for them are mentioned below in the Table 5.

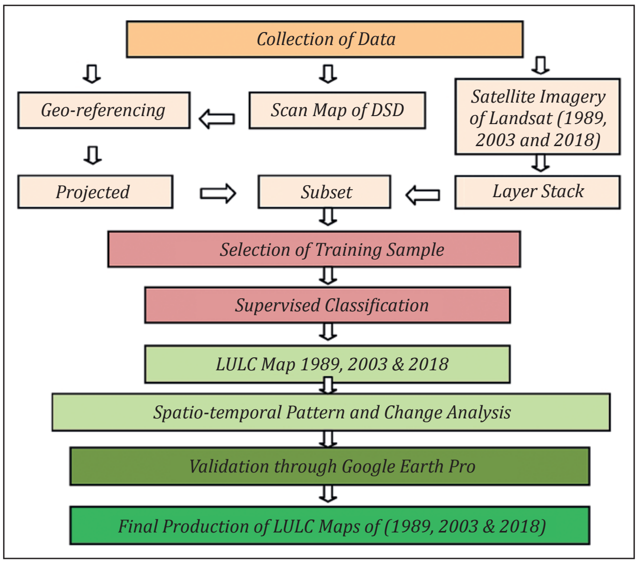



Fig. 2 Flowchart of methodology.
Source: Prepared by the authors.

Tab. 4 Land use and land cover classes of Durgapur Sub-Division.

| Land use / Land cover classes | Features description (Based on National Remote Sensing Centre, India, 2019) |
|---|---|
| 1. Built-up Land | Residential, Commercial and services, Industrial, Transportation, Communication and Utilities, Mining – Active, Mining – Abandoned, Quarry. |
| 2. Crop Land | These are the areas with standing crop as on the date of Satellite overpass. Such as Cultivated Land, Plantation, Garden. |
| 3. Fallow Land | Without Crop Land which are taken up for cultivation but are temporarily allowed to rest. |
| 4. Vegetation | Deciduous Forest Land, rivers in the buildings, in the agricultural fields and gardens, Mixed Forest Land, Shrubs vegetation along the roads. |
| 5. Barren Land | Gullied, Ravinous, Barren Rocky/Stony Waste |
| 6. Water Bodies | River/Stream/Canals, Ponds, Reservoirs |
| 7. Sandy Areas | Riverine or inland areas. Riverine sands are those that are seen as accumulations in the flood plain as sheets which are the resultant. Due to river flooding. |

Source: Prepared by the authors, 2019.

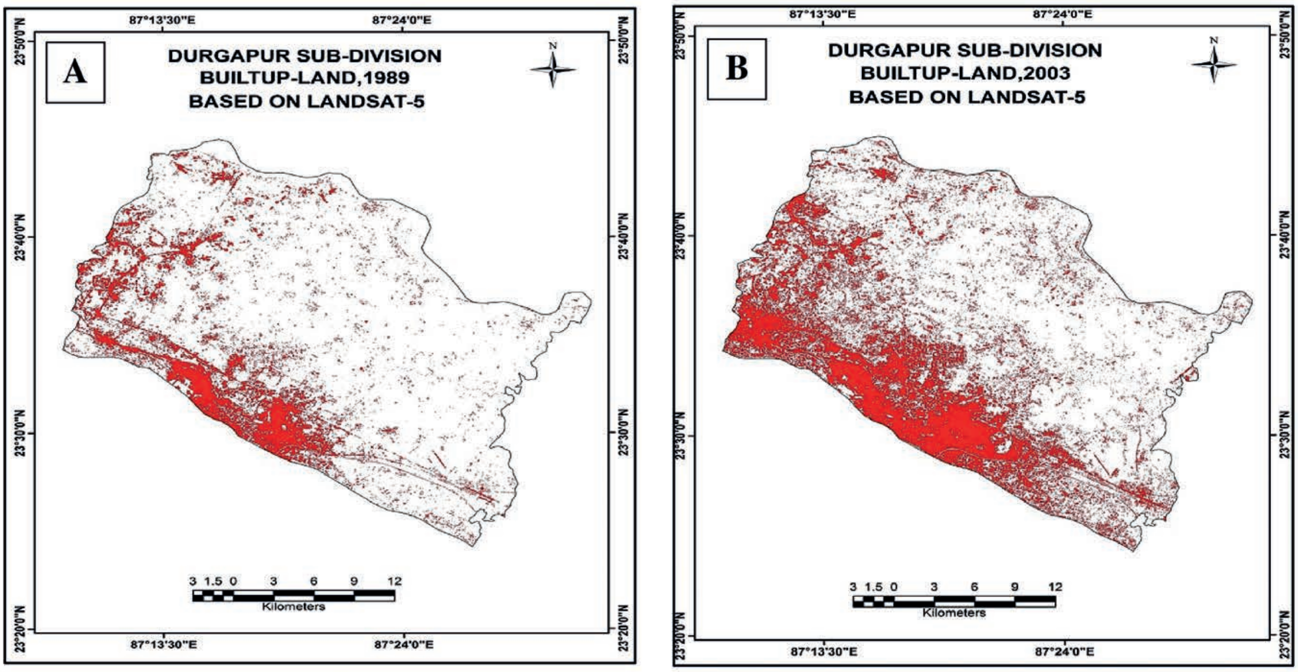
**Tab. 5** Showing interpretation keys for the study region.

| Land use / Land cover classes | Characteristics of False Color Composite (FCC) of Landsat-5 Landsat-8 |
|---|---|
| 1. Built-up Land | Bluish |
| 2. Cropland | Dull red and smooth appearance |
| 3. Fallow Land | Grey with smooth texture |
| 4. Vegetation | Dark red with rough texture, Dull red to Pinkish |
| 5. Barren Land | Bluish/greenish grey with smooth texture and yellowish |
| 6. Water Bodies | Dark blue to light blue, accordingly depth |
| 7. Sandy Area | White with smooth texture |

Source: Prepared by the authors, 2019 (Based on Document Control Sheet, NRSC, India).

## 5. Results and Discussion

The study reveals that area is largely agrarian in character except few urban centers and industrial clusters located in the Durgapur Sub-Division. There has been accelerated spatial change under two prominent land uses i.e. built-up land and cropland. This pinpoints to the fact that the region being agriculturally prominent, the cropland has increased drastically more than the built-up area in the region. Therefore, spatial changes including surface organization of the land use and land cover and their inter-relationship with a focus on direction and spread are well explained.



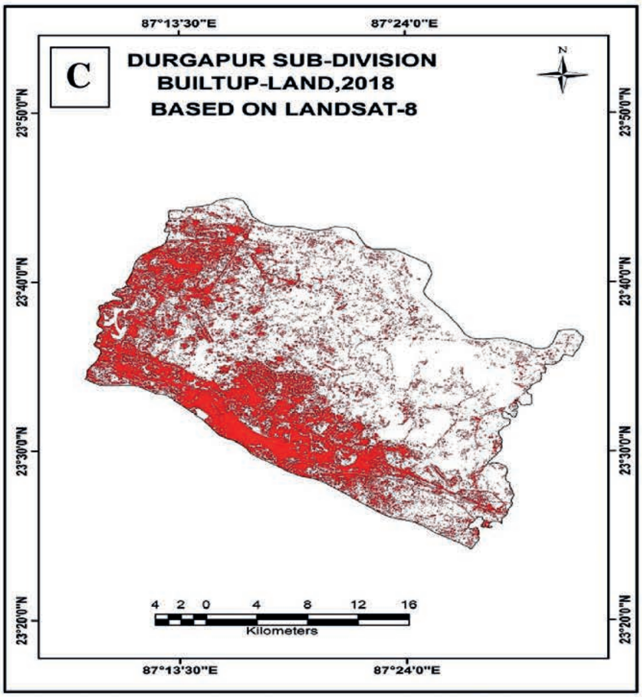
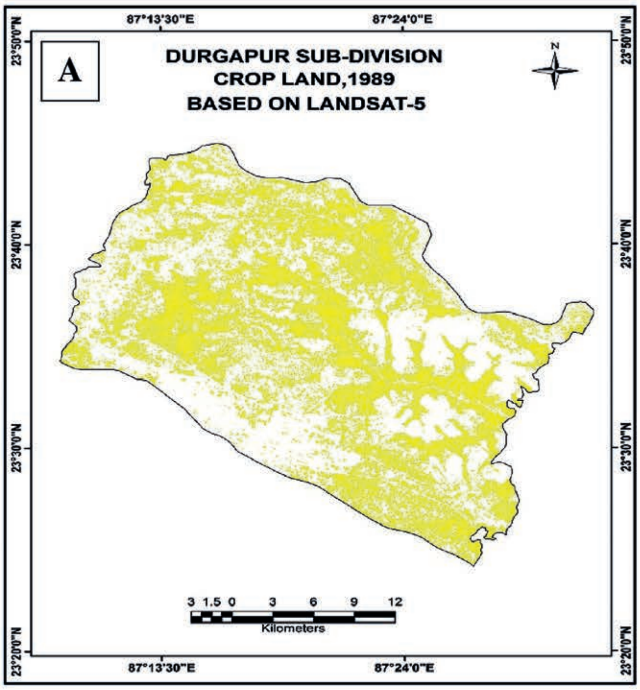
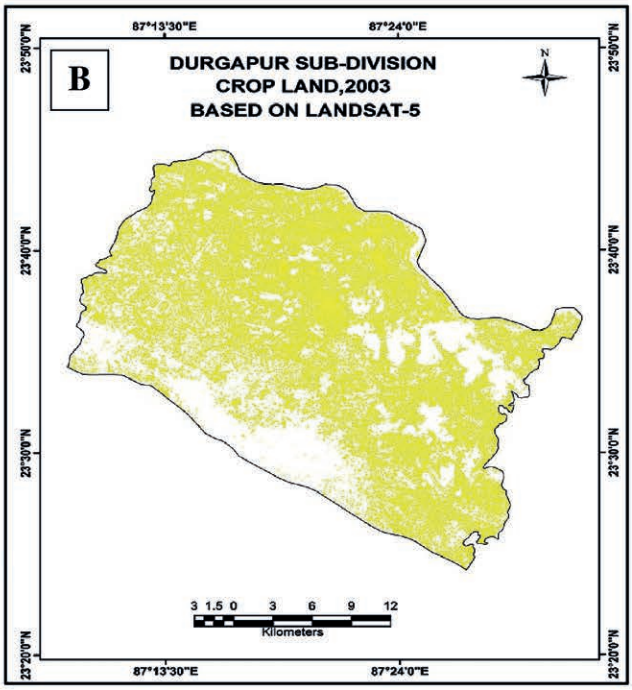




**Fig. 3** Land use and land cover maps showing Built-up Land (A) 1989, (B) 2003, (C) 2018.

(i) **Built-up land.** It is covered 87.2302 km$^2$, which constituted 11% of the total geographical area in the year 1989. What is importantly observed is that most of the built-up land area is found in the South Central and West, South–West portions in Figure 3. In the year 2003, in a span of fourteen years, the built-up land covered 174.5542 km$^2$ which accounted for 23% of the total area. During this period major built-up land areas are Durgapur Municipal Corporation, Andal, and Pandabeswar mining clusters. By the year 2018, the built-up area further grew to 221.4387 km$^2$ accounting for 29% of the total area of the region (Table 6). During this phase, major concentrations are found in South Central and Western portions of the Sub-Division.

(ii) **Crop Land.** As seen from classification image cropland is found to be a dominant land use class in the area. It covered 203.3873 km$^2$ constituting 27% of the total area in 1989. Cropland covered 189.2033 km$^2$ constituting 24% of the total geographical area in 2003 (Table 6). Rice, wheat, vegetables, etc. are the main crops of the region. By 2018 the cropland is found to increase to 36% of the area. The cropland is seen all over the region, mostly in Central and Northern, South-East parts. There is the presence of a canal system in the Southern portion and along the Southern boundary flow the Damodar River



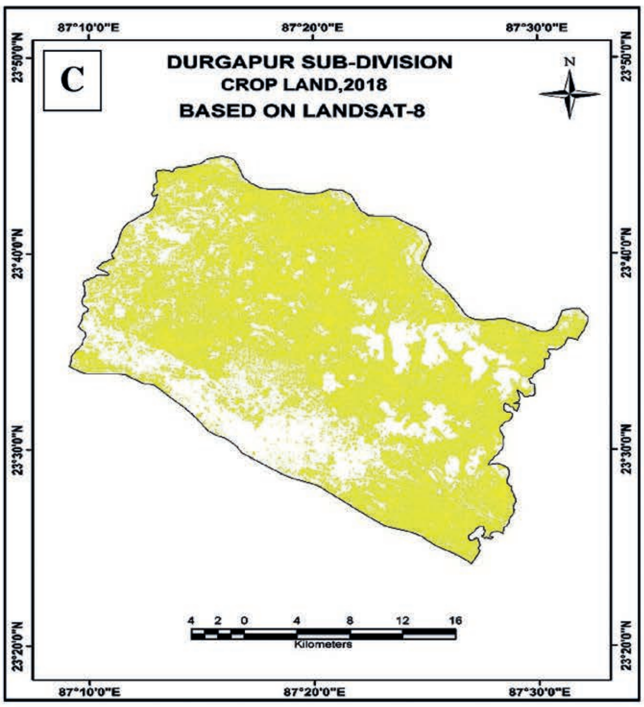
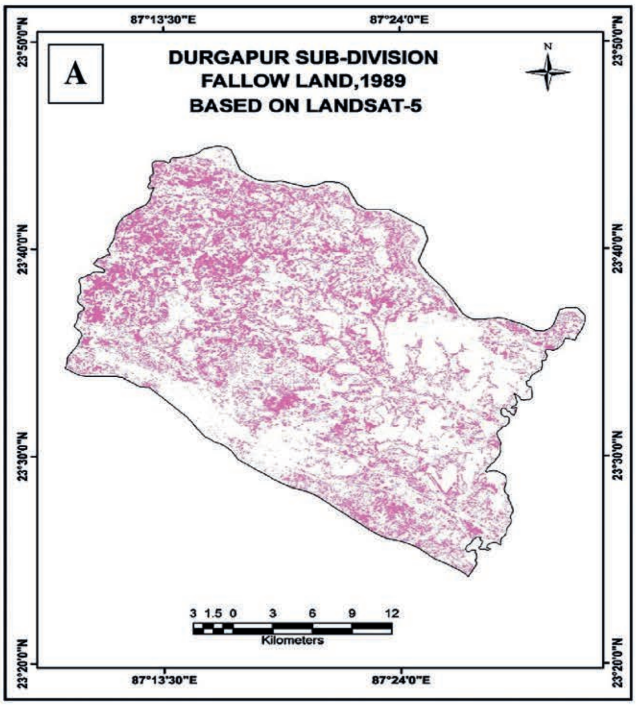



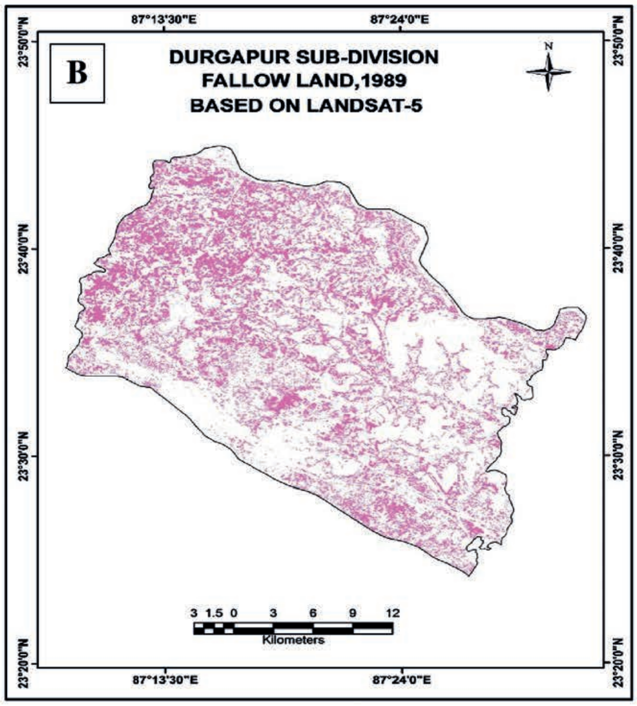

**Fig. 4** Land use and land cover maps showing Crop Land (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

**Tab. 6** Showing area profile of different land use and land cover of the study region.

| Sl. No | Land use / Land cover classes | 1989 | | 2003 | | 2018 | |
|---|---|---|---|---|---|---|---|
| | | Area (km²) | % | Area (km²) | % | Area (km²) | % |
| 1 | Built-up Land | 87.2302 | 11 | 174.5547 | 23 | 221.4387 | 29 |
| 2 | Crop Land | 203.3870 | 27 | 189.2033 | 24 | 273.6386 | 36 |
| 3 | Fallow Land | 185.3955 | 24 | 195.9534 | 25 | 95.6295 | 12 |
| 4 | Vegetation | 207.3816 | 27 | 162.6660 | 21 | 119.0188 | 15 |
| 5 | Barren Land | 61.3674 | 8 | 27.9828 | 4 | 29.4435 | 4 |
| 6 | Water Bodies | 16.8129 | 2 | 15.6402 | 2 | 13.8159 | 2 |
| 7 | Sandy Area | 9.7254 | 1 | 5.3001 | 1 | 18.3150 | 2 |
| **Total** | | **771.30** | **100** | **771.30** | **100** | **771.30** | **100** |

Source: Prepared by the authors, 2019 (Based on satellite imageries).



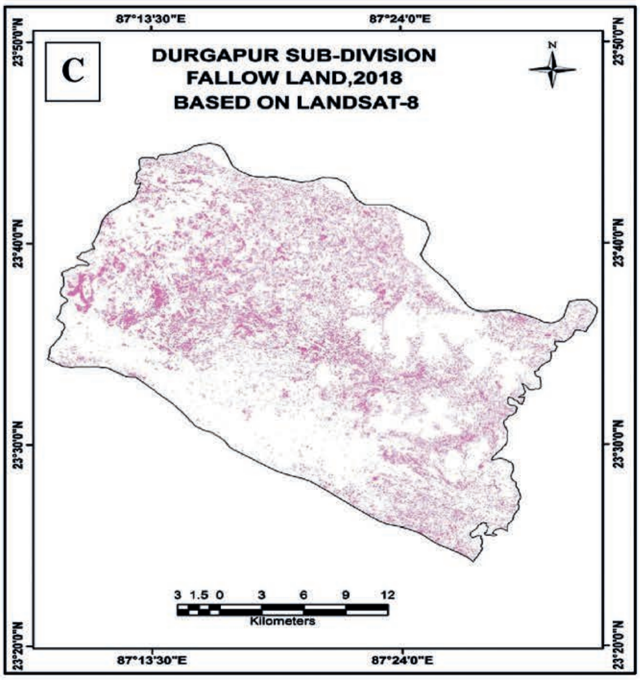
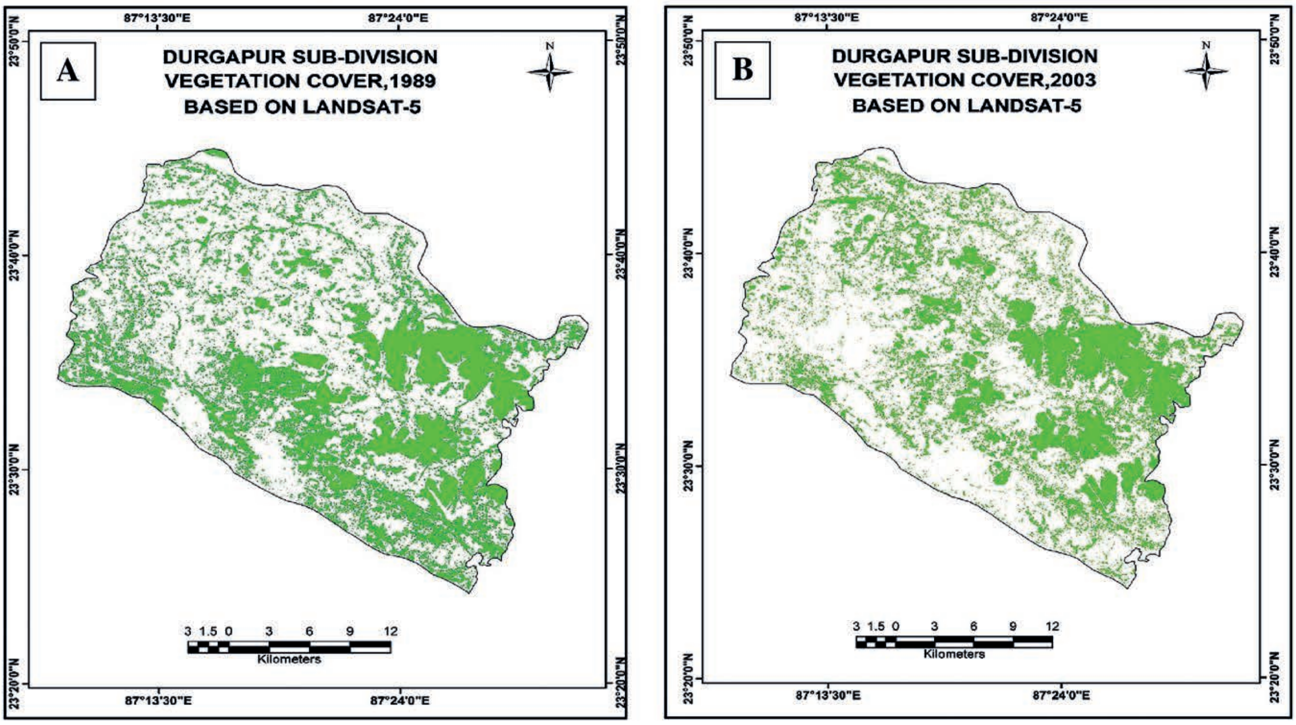




**Fig. 5** Land use and land cover maps showing Fallow Land (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

which is the major source of irrigation in the region (Figure 4).

(iii) **Fallow Land.** In Durgapur Sub-Division the 'fallow land' is the area that is without any crops and it is mostly open land. It covered 185.3955 km$^2$ which accounted for 24% of the total area in the year 1989 and in 2003 it grew to 195.9534 km$^2$ accounting for 25% of the total geographical area. By 2018, the fallow land has decreased to 95.6295 km$^2$ area which is 12% of the total geographical area (Table 6). This sharp decline in the area is mainly observed in the middle portions along with agricultural land and near the northern ends. Some patches are also seen in South-East, North-East parts, Western parts, and few dense patches are seen in the South- West, Central parts of the region (Figure 5).

(iv) **Vegetation.** Dense vegetation can be observed in the East, North-East, South-East parts of the region. Some patches of forest cover seen in the Central and North-West parts. The vegetation area was 207.3816 km$^2$ constituting 27% of the total area in 1989. In 2003, this was 162.666 km$^2$ which is 21% of the total geographical area. It is mainly found in North-East, East Central and some patches of North-West



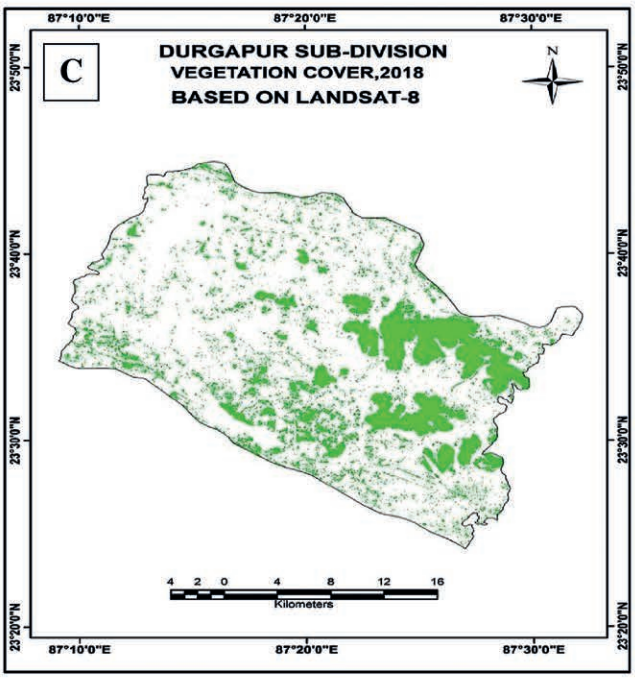




**Fig. 6** Land use and land cover maps showing Vegetation Cover (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

and southern parts. By 2018 the vegetation cover is seen in North-East and Eastern parts of the regions where many plantation sectors coming along the river and in Durgapur Municipal Corporation. Now this covers 119.0188 km$^2$ areas which are 15% of the total geographical area (Figure 6).

(v) **Barren Land.** It is found in the Central and the North-Western parts of the region. Some patches are seen in the North-East portion of the study area. The area included in this category was reported about 61.3674 km$^2$ which accounted for 8% of the total area of the region in 1989. In the year 2003, the Barren Land covered 27.9828 km$^2$ of the region which is half of that found in 1989. 2018, this land-use covers 4% of the total geographical area and largely found in the Central parts and rest is fragmented all over the region (Figure 7).

(vi) **Water Bodies**-In the study area water bodies mainly consists of rivers, canals, reservoirs, ponds, tanks, etc. Two major rivers flow in the region: one is on the northern side the Ajoy and the other is the Damodar towards the southern boundary. A canal is seen in the southeastern region. Many tanks and ponds are also found in the region (Figure 8). In 1989, the

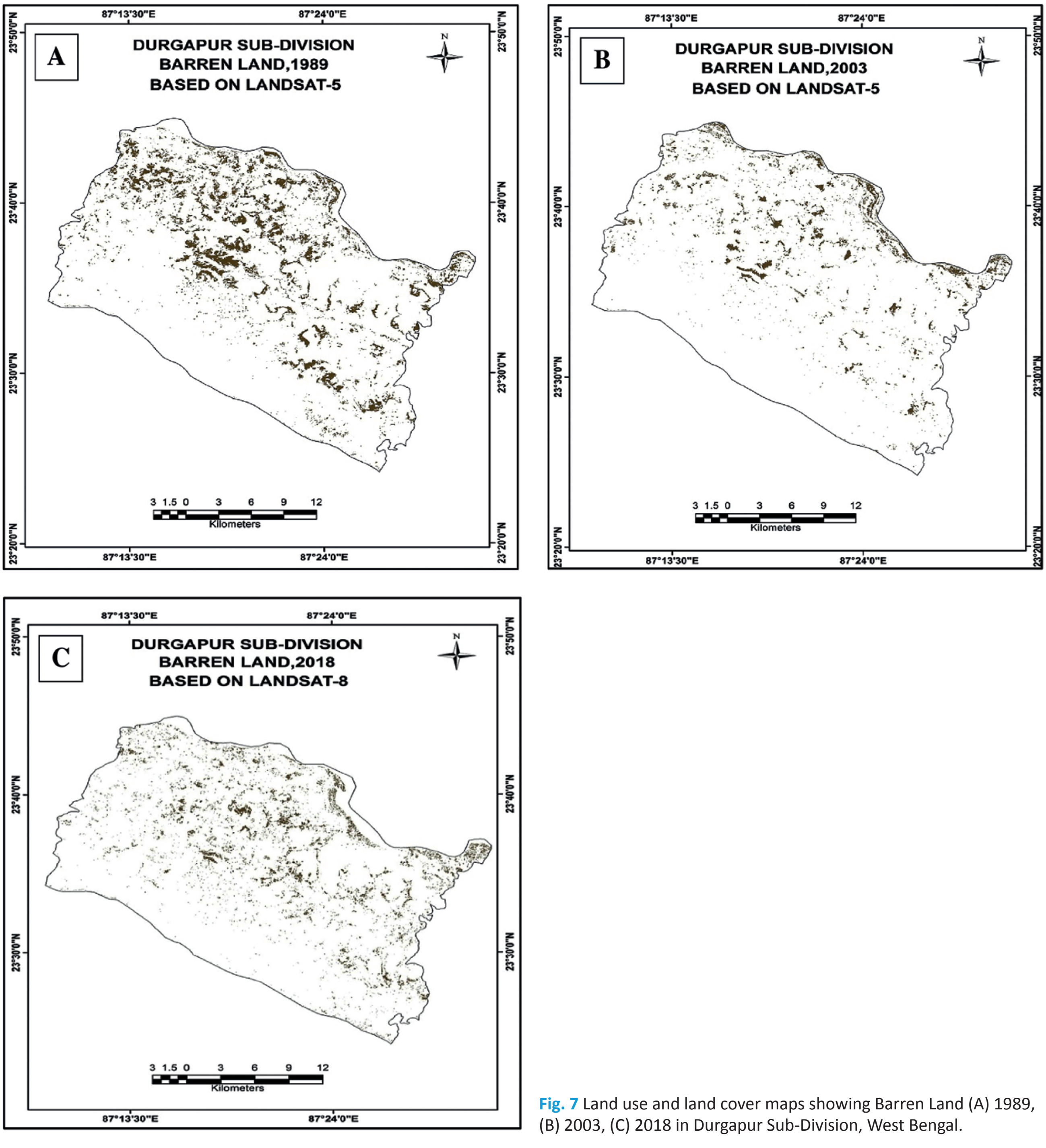



Fig. 7 Land use and land cover maps showing Barren Land (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

area included in this category was 16.8129 $km^2$ which accounts for 2% of the total area and 15.6402 $km^2$, in 2003 and 13.8159 $km^2$ in 2018.

(vii) **Sandy Area.** Sandy area is mostly found in the northern side in the Ajoy river flood plain. Some patches are found in southern parts of the Damodar river basis. In 1989 sandy area consisted of 9.7254 $km^2$ area which was 1% of the total area. In 2003, the water bodies covered about 15.6402 $km^2$ area accounting for 2% of the total geographical area and sandy area 5.3001 $km^2$ which is 1% of the total geographical area. In 2018, the water bodies covered 13.8159 $km^2$ of the area of the region accounting for 2% and the sandy area was 18.3150 $km^2$ with 2% of the total geographical area of the Durgapur Sub-Division region (Table 6). By 2018 the sandy area is mostly seen in the northern region along the bank of the Ajay River. Few dense patches are also seen in the Southern region along the bank of the Damodar River (Figure 8).

Pearson's Product Moment Correlation coefficient (r) technique is applied here to exhibit the association among the Land use/Land cover classes. The value of 'r' lies between ±1. A value of r = +1.0 indicates a perfectly direct or perfectly positive correlation, and a value of r = −1.0 indicates a perfectly inverse

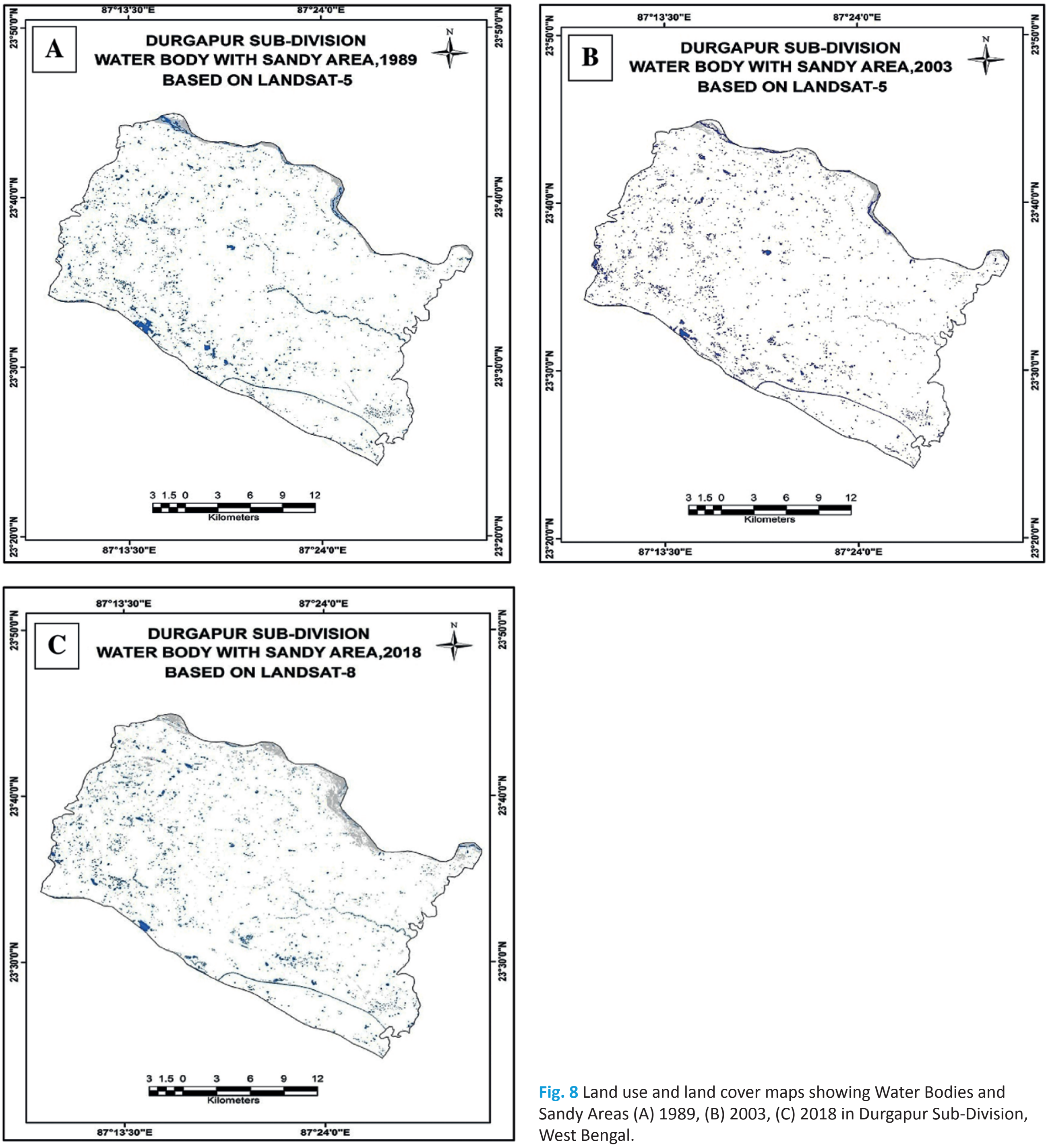



Fig. 8 Land use and land cover maps showing Water Bodies and Sandy Areas (A) 1989, (B) 2003, (C) 2018 in Durgapur Sub-Division, West Bengal.

Tab. 7 Showing correlation coefficient (r) among the classified land use and land cover types of the Durgapur Sub-Division.

| Pearson Product Moment Correlation Coefficient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Land use/Land cover classes | | Built-up Land | Crop Land | Fallow Land | Vegetation | Barren Land | Water Bodies | Sandy Area |
| Built-up Land | Pearson Correlation | 1.000 | .657 | −.703 | −.986 | −.925 | −.956 | .509 |
| | Sig. (2-tailed) | | .543 | .504 | .105 | .248 | .189 | .660 |
| Crop Land | Pearson Correlation | .657 | 1.000 | −.998* | −.772 | −.322 | −.849 | .983 |
| | Sig. (2-tailed) | .543 | | .039 | .438 | .792 | .354 | .117 |
| Fallow Land | Pearson Correlation | −.703 | −.998* | 1.000 | .810 | .379 | .880 | −.970 |
| | Sig. (2-tailed) | .504 | .039 | | .399 | .752 | .315 | .156 |
| Vegetation | Pearson Correlation | −.986 | −.772 | .810 | 1.000 | .850 | .991 | −.644 |
| | Sig. (2-tailed) | .105 | .438 | .399 | | .354 | .084 | .555 |
| Barren Land | Pearson Correlation | −.925 | −.322 | .379 | .850 | 1.000 | .773 | −.143 |
| | Sig. (2-tailed) | .248 | .792 | .752 | .354 | | .437 | .908 |
| Water Bodies | Pearson Correlation | −.956 | −.849 | .880 | .991 | .773 | 1.000 | −.739 |
| | Sig. (2-tailed) | .189 | .354 | .315 | .084 | .437 | | .471 |
| Sandy Area | Pearson Correlation | .509 | .983 | −.970 | −.644 | −.143 | −.739 | 1.000 |
| | Sig. (2-tailed) | .660 | .117 | .156 | .555 | .908 | .471 | |

* Correlation is significant at the 0.05 level (2-tailed). Source: Calculated by the authors.

or perfectly negative correlation (Sarkar 2015). The Table 7indicates the positive and negative relationship among the LU/LC classes of the study period. It reveals that Built-up Land positively associated with the Crop Land and Sandy Area. The calculated value of these two classes is 0.657 and 0.509 respectively, on the other hand, a strong negative relationship with the vegetation and Barren land. The calculated value of these two classes is −0.986 and −0.925 respectively (Table 7)

## 5.1 Surface Change Detection

Change detection techniques for various studies have been reviewed by many researchers. Remote Sensing and Geographical Information System (GIS) based change detection (by using digital satellite imageries) is the process that helps in determining the change associated with land use and land cover properties with reference to geo-referenced multi-temporal data (Jensen 1996). From a policy and planning perspective, change detection in such cases helps in enhancing the capacity of local governments to implement sound environmental management practices (Prenzel and Treitz 2004).

Multiple linear regression (MLR), also known simply as multiple regression, is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. The goal of multiple linear regressions (Table 8) is to model the linear relationship between the explanatory (independent) variables and response (dependent) variable (Kenton 2019). Table 8 shows the linear relationship among the land use and land cover classes of the study region.

### (i) Land use and land cover change: 1989 and 2003

Table 9 shows the land use and land cover change during 1989 and 2003 under different classes. The composite land use and land cover of Durgapur Sub-Division are shown in Figure 9. The imagery which was taken from the Landsat-5 on Dec 17, 1989 (USGS), showed that the built-up land was 87.2302 $km^2$ accounting for 11% of the total geographical area. But the imagery captured on Nov 15, 2003 (USGS) showed the built-up area increased to 174.5542 $km^2$. This constitutes 23% of the total geographical area. The total change between the two time periods is 87.3240 $km^2$ and the percentage increase is 12%. This considerable change happened due to an increase in the mining area at Andal and Pandabeswar Block.

Above Maps depict spatial change with respect to different classes' categories of land use and land cover during 1989–2003. Higher change is witnessed under the built-up area which has registered a 12% increase in the discussed period. This may be associated with a decrease in cropland (−3%), vegetation (−6%) and barren land (−4%) in Table 9. Classified imagery showed that it is clear that there is growing more in urban and followed by rural settlements in the region. The new settlement is set up

**Tab. 8** Multiple linear regression model.

| Multiple linear regression model | R2 | Adjusted R square | Standard error of estimate | F | Standardized Coefficients (Beta) | t-value | sig (p-value) |
|---|---|---|---|---|---|---|---|
| **Buit-up Land (x1)** | | | | | | | |
| x2 | 0.432 | −0.135 | 72.57956 | 0.76100 | 0.657 | 0.873 | 0.543 |
| x3 | 0.494 | −0.13 | 68.54350 | 0.97500 | −0.703 | −0.987 | 0.504 |
| x4 | 0.973 | 0.946 | 15.84690 | 35.94800 | −0.986 | −5.996 | 0.105 |
| x5 | 0.855 | 0.711 | 36.62812 | 5.91600 | −0.925 | −2.432 | 0.248 |
| x6 | 0.914 | 0.829 | 28.20084 | 10.66700 | −0.956 | −3.266 | 0.189 |
| x7 | 0.259 | −0.482 | 82.91339 | 0.35000 | 0.509 | 0.591 | 0.660 |
| **Crop Land (x2)** | | | | | | | |
| x3 | 0.996 | 0.992 | 3.93607 | 262.90600 | −0.998 | −16.214 | 0.039 |
| x4 | 0.597 | 0.193 | 40.60682 | 1.48000 | −0.772 | −1.216 | 0.438 |
| x5 | 0.103 | −0.793 | 60.54609 | 0.11500 | −0.322 | −0.340 | 0.792 |
| x6 | 0.721 | 0.442 | 33.76055 | 2.58700 | −0.849 | −1.608 | 0.354 |
| x7 | 0.967 | 0.993 | 11.66295 | 29.05800 | 0.983 | 5.391 | 0.117 |
| **Fallow Land (x3)** | | | | | | | |
| x4 | 0.656 | 0.313 | 45.70929 | 1.90900 | 0.810 | 1.382 | 0.399 |
| x5 | 0.144 | −0.721 | 72.13830 | 0.16800 | 0.379 | 0.410 | 0.752 |
| x6 | 0.775 | 0.549 | 37.60922 | 3.43800 | 0.880 | 1.854 | 0.315 |
| x7 | 0.941 | 0.882 | 18.91180 | 15.99400 | −0.970 | −3.999 | 0.156 |
| **Vegetation (x4)** | | | | | | | |
| x5 | 0.722 | 0.440 | 32.94319 | 2.59700 | 0.850 | 1.612 | 0.540 |
| x6 | 0.983 | 0.965 | 8.21481 | 56.85400 | 0.991 | 7.540 | 0.084 |
| x7 | 0.414 | −0.171 | 47.81855 | 47.81855 | −0.644 | −0.841 | 0.555 |
| **Barren Land (x5)** | | | | | | | |
| x6 | 0.598 | 0.195 | 16.92628 | 1.48500 | 0.773 | 1.219 | 0.437 |
| x7 | 0.210 | −0.956 | 26.40610 | 0.02100 | −0.143 | −0.145 | 0.908 |
| **Water Bodies (x6)** | | | | | | | |
| x7 | 0.546 | 0.091 | 1.43962 | 1.20100 | −0.739 | −1.096 | 0.471 |

x1 = Built-Up Land, x2 = Crop Land, x3 = Fallow Land, x4 = Vegetation, x5= Barren Land, x6 = Water Bodies, x7= Sandy Area
Source: Calculated by the authors.

in the Durgapur Municipal limits and beyond and around the Andal town area that is identified from the classified imagery. In 2003, the built-up area is also seen as have increased in the South-East region (Figure 9).

### (ii) Land use and land cover change: 2003 and 2018

The imagery is taken from the Landsat-5 on Nov 15, 2003 (USGS) noted Built-upland 174.5547 km$^2$ or 23% but imagery taken on Nov 18, 2018 (USGS) the Built-up land reported about 221.4387 km$^2$ which is 29% of the total geographical area. The rapid growth up to 2018 has taken place due to the establishment of a new industrial parks and sectors along the NH2 in Andal to Panagarh (Figure 10). This also with a rapid increase of the population in the municipal area of the Durgapur (about 566,937 in 2011 census), Andal town (186,915), Pandabeswar (161,891). Under built-up category, the mining area also increased in 2018 compared to 2003 at Andal and Pandabeswar block. A newly setup Airport is seen near Andal (Waria) in 2018. An increase in cropland i.e. 12% took place simultaneously when there is a further decrease in fallow land (−13%) and vegetation (−6%) (Table 10). Anyhow, barren land, water bodies, and sandy areas remain intact. The fact is that there is an expansion of industrial activities in the virgin areas and follow up is the rise of urban areas and the growth of rural settlements as well. There are also linkages that with increase in population in the areas located in the region, there has been consistent pressure on land since the agriculture area has to be increased. This is resulting in a decrease in fallow land and vegetation cover in the Durgapur Sub-Division. Thus, the landscape of the region is changing by these activities that accelerated over the last few years.

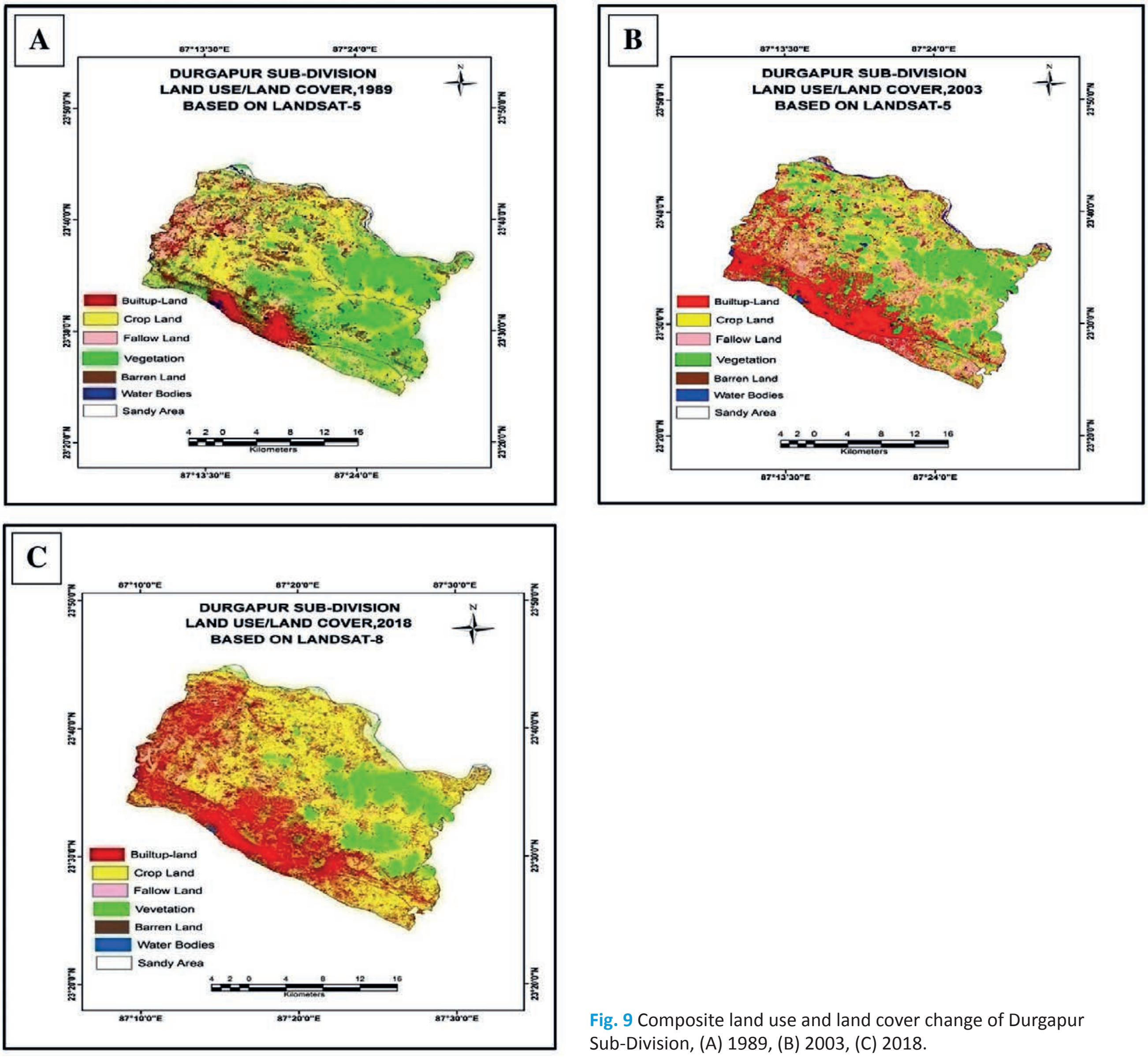



**Fig. 9** Composite land use and land cover change of Durgapur Sub-Division, (A) 1989, (B) 2003, (C) 2018.

During 2003-2018, this scenario is out passed by tremendous increase in crop land. The fact is that with the implementation of Damodar Valley Project, mono-cropped areas of the Paschim Barddhman district have been converted into multi-cropped lands. The industrial complex of Durgapur was established at the expense of forest in the mid-fifties and it has been growing further since then. Durgapur Sub-Division has experienced a drastic change in the landscape with expansion of urban, industrial, and mining activities at the cost of forest, pasture, and cultivated lands. According to District Census Handbook of

**Tab. 9** Land use and land cover change in Durgapur Sub-Division, 1989 and 2003.

| Land use / Land cover classes | 1989 | | 2003 | | Change | |
|---|---|---|---|---|---|---|
| | Area (km²) | % | Area (km²) | % | Area (km²) | % |
| Builtup-Land | 87.2302 | 11 | 174.5547 | 23 | 87.3245 | 12 |
| Crop Land | 203.3870 | 27 | 189.2033 | 24 | −14.1837 | −3 |
| Fallow Land | 185.3955 | 24 | 195.9534 | 25 | 10.5579 | 1 |
| Vegetation | 207.3816 | 27 | 162.6660 | 21 | −44.7156 | −6 |
| Barren Land | 61.3674 | 8 | 27.9828 | 4 | −33.3846 | −4 |
| Water Bodies | 16.8129 | 2 | 15.6402 | 2 | −1.1727 | 0 |
| Sandy Area | 9.7254 | 1 | 5.3001 | 1 | −4.4253 | 0 |

Source: Calculated by the authors based on satellite imageries 1989 and 2003.

**Tab. 10** Land use and land cover change in Durgapur Sub-Division, 2003 and 2018.

| Land use / Land cover classes | 1989 | | 2003 | | Change | |
|---|---|---|---|---|---|---|
| | Area (km²) | % | Area (km²) | % | Area (km²) | % |
| Builtup-Land | 174.5547 | 23 | 221.4387 | 29 | 46.8840 | 6 |
| Crop Land | 189.2033 | 24 | 273.6386 | 36 | 84.4353 | 12 |
| Fallow Land | 195.9534 | 25 | 95.6295 | 12 | −100.3239 | −13 |
| Vegetation | 162.6660 | 21 | 119.0188 | 15 | −43.6472 | −6 |
| Barren Land | 27.9828 | 4 | 29.4435 | 4 | 1.4607 | 0 |
| Water Bodies | 15.6402 | 2 | 13.8159 | 2 | −1.8243 | 0 |
| Sandy Area | 5.3001 | 1 | 18.3150 | 2 | 13.0149 | 1 |

Source: Calculated by the authors based on satellite imageries 2003 and 2018.

Barddhman, the percentage of urban share of population of the district has expanded from 36% in 2001 to 39.9% in 2011 of the total population (Census 2011). The Durgapur Sub-Division is second highest, after Asansol, urbanized division of the Paschim Barddhman district. This region has huge potential in the economic and industrial development and advancement of the district. Rapid increase in population and expansion of infrastructure and built environment are evidences of how landscape is changing. The major loss has been of fallow land in the study area as shown in the Figure 10.

## 6. Conclusion

The present study focused to analyze the landscape dynamics of Durgapur Sub-division during a long period covering years 1989, 2003 and 2018. Emphasis has been on the way spatial change occurring in the region with respect to bio-physical and socio-economic processes and associated factors. The major findings of the study are as follows:

- The dominant spatial change in the region is associated with the rapid increase in the built-up area in central and west, southwest parts and a similar rise in the cropland in central and northern, southeast parts since they are subject to human-induced intervention processes. The built-up land increased from 87.2302 km² (1989) to 174.5547 km² (2003) and further to 221.4387 km² (2018).
- The increase in industrial activities and mining i.e. western part of the region, expansion of urbanization, and growing human demands for agricultural products all have played a vital role in the landscape transformation.
- The share of biophysical elements including fallow land, natural vegetation, and barren land has been under pressure and consistently declining as is evidenced during the study period. The fallow land area increased from 185.3955 km² (1989) to 195.9534 km² (2003) but it decreased to 95.6295 km² (2018).
- Over the study found that the cropland area increased due to decrease of fallow land because of the rapid increase of population growth changes in the land use pattern from 1989, onwards till now.
- Water bodies are lost over the study period due to increase in built-up land, cropland, and sandy area. Here there is found a negative relationship among the water bodies and built-up land, cropland and sandy area.
- Most of these changes in land use or functional change are naturally unsustainable and may affect the environmental setting of the region.

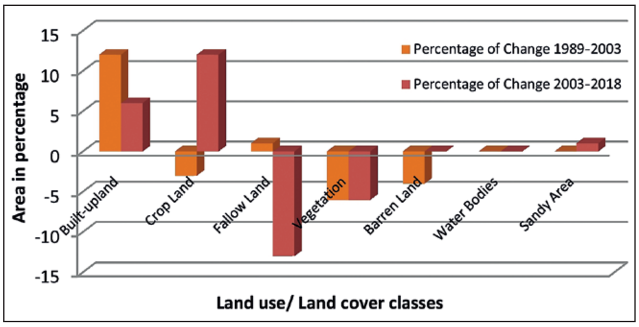



**Fig. 10** Land use and land cover change between 1989 and 2003 and between 2003 and 2018.

It is pertinent to mention that changes in land use and land cover, the timely remedial measures are important for optimum and sustainable utilization of land resources and prevention thereof from further undesirable deterioration. There is further scope for research in this arena to look into agricultural changes, cropping pattern, productivity and fertility of the region. This may be further studied in relation to overall biophysical and human-induced changes in the region.

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# The consequences of armed conflicts on life paths of Bosniaks from Eastern Bosnia

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**ABSTRACT**

This article sets out to describe the individual mobility of persons affected by the war in former Yugoslavia from a long-term, biographical perspective. It evaluates how the conflict and post-conflict conditions limit or enhance the spatial range of individual activities. The time-geographical approach is applied through the usage of spatio-temporal records of the war and post-war life. Thirty-two respondents from Bosnia and Herzegovina were interviewed, and asked to generate an "ex-post facto" open time-space activity diary. The article demonstrates the usefulness of the time-space activity diary usage as a significant instrument for a sensible analysis of life-paths.

**KEYWORDS**

life paths; time-geography; time-space activity diaries; biographies; war conflict; post-war situation; Eastern Bosnia and Herzegovina

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## 1. Introduction

Every war and armed conflict in the history was accompanied by inhuman treatment, violence, atrocities and killings, which imprints deep mark on all members of the society regardless of their gender, age, education, cultural background, nationality or religious membership. War kills and its consequences go beyond its end and are profound for future development. The breakup of Yugoslavia in the nineties of the 20th century was not an exception.

Violence and wars did not have impact only on the economy but also on social structures within the territory of former Yugoslavia. It also affected the large migratory movements that emerged towards the end of the 20th century. Armed conflicts lead to forced migration and long-term refugee problems. As Ljuboja (2015) mentioned, relocations caused by violence and wars or displacements of citizens belonging to different ethnic or religious groups by the state authorities certainly represent the biggest and the most obvious movements of people in relatively short periods of time. Significant changes, caused by the conflicts at the end of the last century, occurred in the inner structure of the populations of Croatia, Bosnia and Herzegovina and Serbia. They represent the most recent examples that have remained etched in the collective memory of the nations in question.

In the eyes of the outside observers the Yugoslav social model has been a relatively successful symbiosis of different cultures and traditions, but the period of extreme political tensions, growth of nationalist forces and escalating national conflicts in a number of the republics in the late 1980s, culminated into several wars in the early 1990s. The beginning of the 1990s pointed to the future development of events. Most of the republics, Slovenia, Croatia, Bosnia and Herzegovina and Macedonia proclaimed independence after the dissolution of Yugoslavia in early 1992.

Despite the centuries of the co-existence within the multicultural society, Bosnia and Herzegovina experienced a bitter transition from the communist era to independence. The war from 1992 to 1995 in Bosnia and Herzegovina resulted in huge direct and indirect demographic changes in this former Yugoslav republic. The initial period of the post-war recovery was characterized by a massive devastation, dislocations and deaths. Nowadays post-war Bosna and Herzegovina consists of two entities based on its constitutional and administrative structure: the Federation of Bosnia and Herzegovina (FBiH) and Republika Srpska (RS) and Brčko District (self-governing administrative unit).

In order to understand and explain armed conflicts, the breakdown of the state and post-conflict development and to place these events in a theoretical plain, the wide range of theories tends to describe inter alia the issues of ethnicity, nation, nationality, interactive processes between events and personal motives for expressing intolerance, as far as conflicts, violence, ethnic cleansing, and other (e.g. Horowitz 1985; Kaplan 1994; Connor 1994; Hutchinson, Smith 1996; Collier 2000; Sekulić et al. 2002; Collier, Hoeffler 2004; Blagojević 2009; Beširević 2010; Jesse and Williams 2011). Societies in the post-conflict time (as it was in some former republics of Yugoslavia) and the processes of renewal and development on almost all of its levels are also becoming the subject of special researchers' interest (Blagojević 2004; Lambourne 2004). In connection with the studied issues, the theories focused on the migration (Drbohlav, Uherek 2007) and its determinants (e.g. Drbohlav 2011) are also important. Victims of civil war and forced displacement in former Yugoslavia constitute an important form of forced migration. Forced migration is the result of a string of connected emergencies and is an integral part of international (regional) relationships and societal crises (Castles 2003).

All significant human interactions in the conflict and post-conflict societies can be seen from the geographical (time-space perspectives), especially from the behavioural geography and time-geography point of view. Behavioural geography studies human space-time activities as the outcome of decisions made by individuals within the constraints set by the society and the environment and according to their perception and understanding of the situation. Behavioural geography is not based on an abstract model of rational behaviour, but is focused on what people do and why they do it (Castree et al. 2013). Behavioural approach in geography recognizes that people live simultaneously in a subjective environment of values, meanings and perceptions and in an objective physical environment. Current behavioural geographical approaches include both, qualitative and quantitative methods (Golledge, Stimson 1990; Golledge 2008; Gold 2009). Behavioural geography was also critically used to study individuals' space-time actions, in choosing whether to stay or to move, along with their perceptions of extreme events (conflicts). Behavioural geography continued to expand into various areas including potential and real ethnic and religious tensions and war conflicts and tensions (e.g. Ira 1997; Jacobson 2006; Uher 2018; Uher, Ira 2019). Many life stories of the 20th and 21st century in the areas affected by the war conflict have similar mixtures of individual lives, network building and the intervention of authorities. But the lack of information, specific social and family life relations existing in certain time and in certain cultural conditions can be considered as a factor influencing their social and spatial mobility. Time geography, as outlined first by Torsten Hägerstrand, is an approach aimed at the clarification of the constraints to objects and individuals in their search for slots in the time-space continuum. Hägerstrand (1970) builds on everyday experience and the bounding capacity of time and space. Every individual follows a trajectory (observed paths) in time-space. Time-geography studies a broad spectrum of own concepts (Ellegård 1999 and 2019; Lenntorp 1999; Ira 2001; Lundén 2003; Schwanen 2009; Schwanen, Kwan 2012). The individual human being is an integer unit of existence. The life paths of individuals are influenced by biological needs and by societal factors, among other political regulations (Kleinepier et al. 2015). The life trajectory of a person whose demands do not comply with the political environment will search for refuge domain, either as a permanent solution in full or partial accord with her or his demands, or as a stepping-stone in the search for full satisfaction. Planning his or her day, year and life, the individual has to utilize and accommodate to all the networks and structures available (Lundén 2003).

The aim of this article is to analyse how the complex and often changeable and unpredictable conditions surrounding thirty two individuals from Eastern Bosnia, who were affected by war, limit or enhance their range of activities in the conflict and post-conflict space and how they are manifested in their life-paths formed by their time-space behavioural patterns. The paper gradually introduces brief theoretical and methodological framework, the studied area with its short history and the data and methods used. Furthermore, the results of spatio-temporal research of life paths conducted among selected sample of Bosniaks are presented, followed by a discussion and conclusion.

## 2. Material and methods

### 2.1 Study area

Our research, applying a time-geographical approach using spatio-temporal records of a rich complexity of war and post-war life, took place in the post-war Bosna and Herzegovina consisting of two entities based on its constitutional and administrative structure: the Federation of Bosnia and Herzegovina (FBiH) and Republika Srpska (RS) and Brčko District – Fig. 1.


**Fig. 1** Bosna and Herzegovina: administrative structure and study area.

Bosnia and Herzegovina (total area 51,129 km$^2$) is home to members of numerous ethnic groups and around 60% of the population is rural. According to the Ministry for Human Rights and Refugees of Bosnia and Herzegovina (2006), from the beginning of the three-year war until signing the Dayton Agreement, about 2.2 million persons, which makes almost a half of the pre-war domicile population, were forced to leave their homes and move. Out of that number, more than a million people were displaced within Bosnia and Herzegovina and around 1.2 million people have sought the refugee protection abroad. In the early post-war years, estimates of the number of the victims in the civil war oscillated between a wide range of 25,000–329,000 (Tabeau, Bijak 2003), but most often in the range between 200,000–250,000. About 15,000 persons were recorded as missing (Ministry for Human Rights and Refugees 2006). According to later estimates, the number of victims oscillates approximately around 100,000 (Tabeau, Bijak 2005). A comparison of the 1991 and 2013 censuses shows that the absolute population of all ethnic groups decreased by almost 0.8 million (from 4.377 million to 3.531), with the share of Bosniaks increasing by 6.6% and the share of Serbs, Croats and others declining. (Institute for statistics of FB&H 2016).

The research of the life paths of the examined group of Bosniaks concerns the territory of the former Yugoslavia, the area in which all respondents lived, migrated or were forced to move before the period of armed conflict, during the war events or after the end of conflict.

The study area in which structured interviews were carried out is in the northeast Bosnia (Fig. 1), a part of territory called Podrinje in village Mihatovići near city of Tuzla. In Mihatovići there is one of the refugee centres, mainly for Bosnian Muslims, and probably the largest one in the canton of Tuzla. During the war, the city of Tuzla has never been seriously attacked and was a rare oasis of "normality" in the Bosnian war. When the Bosnian war ended, the return process was agreed, although there remains a significant number of displaced persons, refugees and other conflict-affected persons of concern who are in need of durable solutions. In this mountainous area, about 10 kilometres outside the city of Tuzla, transport options to the camp are limited. A narrow road leads to the collective settlement that was built mostly from sources of the Norwegian People's Aid at the beginning of the war (Lisica 2013). The refugee camp Mihatovići is situated on a hill and was designed for the temporary housing units. Officially in 2016, there were still 161 residents living in this camp (Catholic Relief Services 2016) and according to the City Administration,

**Fig. 2** Refugee houses in Mihatovići.

**Fig. 3** Primary school in Mihatovići.

in 2018 there were 286 residents (http://www.tuzla.ba). Many of the residents who still live in the run-down refugee camp are relatives and survivors of the 1995 genocide in Srebrenica. These people mostly came from Srebrenica but also from the nearby settlements such as Bratunac, Zvornik or Vlasenica.

Besides the refugee houses (Fig. 2), the refugee camp Mihatovići has two little grocery shops and one primary school (Fig. 3). The Service for Veterans' and Disability Protection, Residential Affairs and Return of the City of Tuzla is in charge of the collective centre. According to data available in 2015, the government representation planned to close the "collective settlement" of Mihatovići in 2017. But since then, the refugee camp Mihatovići provided services for some marginalised social-economic group which struggles with poverty.

## 2.2 Data and methods

In this paper we study the activity patterns of a selected group of 32 displaced individuals who were directly affected by war while preserving the individualities of the group members.

Only 6 men but many more women (26) were represented in this group. This disparity resulted from a real situation among displaced persons, as a significant number of men died either during the defensive war or were later killed. We followed their life-paths starting from the pre-war period (1990) to the year 2018. From the total number of 32 respondents we selected 5 persons (3 females and two males) with different life destinies and on the example of their life-paths we analysed in more detail the complexity of their behavioural patterns (3D graphs in Figs. 2–6). The data allowed us to gain a new insight to the behaviour of these individuals before, during and after the war. It contributes to understanding of activities of people affected by war conflicts in physical space and chronological time in specific political, economic, socio-cultural, institutional, and geographical contexts. Also, we can compare similarities and differences in the life of our respondents.

In order to collect survey data, the time-geographical approach based on records of activities in time-space was applied. The time-space activity diary is a significant instrument for a sensible analysis of life-paths of individuals. The use of time-space diaries expanded after the introduction of Hägerstrand's time geography into human geography (Hägerstrand 1970). The development of geographic information systems (GIS) and computational capabilities in the last few decades expanded possibilities in time-geographic research (Kwan 2004) and facilitated the analysis of time–space diaries (Couclelis 1999). Activity diaries collect information on the activity content: the time that an activity episode starts and ends (when), the geographical context, i.e. the spatial location where the activity takes place (where), the social context, i.e. the person(s) involved in the event (with whom), and the use of transportation mode(s) enabling access the place where the activity occurs (how). There are several additional dimensions for which information is collected, e.g. the respondent's feelings and emotions during activities (Schwanen 2009). This method recording individuals´ activities and movement in time and space may facilitate reflections on changes in the patterns of activities and may enable a deeper understanding of relationships in community (Díaz-Muňoz 1999; Ellegård 1999). It illustrates practices and activities in geographical and social context. The diary method provides an effective approach to collect data that enables the systematic study of activities of individuals and was applied in several scientific disciplines (e.g. Couclelis 1999; Schwanen 2009 and Miller 2017).

Data collection for this research was organized in April 2018. Respondents were interviewed and asked to generate an "ex-post facto" open time-space activity diary. One of the key challenges within the mixed methods research is the successful integration of quantitative and qualitative data during analysis and interpretation. The integration of the qualitative and quantitative data can bring a different perspective to the research and can contribute to the understanding of complex research problems (Tariq and Woodman 2013). We have used 3D maps to visualize the trajectories of individuals during the period of less than three decades. We also conducted in-depth interviews with the same individuals in which they expressed their responses to the questions. Oral history interviews may concern a very specific subject or cover an entire lifespan or trace a complex issue that unfolds over time offering the geographers the opportunity to examine the complexities and intricacies of place (George, Stratford 2010). This method is especially applicable to the study of memory and place, but can be useful to geographers in many sub-fields of the discipline (Ward 2012).

Nationality, internal displacement and housing in the territory of former Yugoslavia in the pre-war period were included in the selection criteria for the group of respondents. The main challenge associated with the data collecting was to reach a desired group of people. This was possible using the snowball sampling, which works as a chain referral (e.g. Goodman 1961; Cohen, Arieli 2011; Rochovská et al. 2014). It helped to develop a research sample. In this method, the sample group grows like a rolling snowball. It has been very useful in investigating a wide variety of specific population (for example marginalised), and thus it is possible to agree with Cohen, Arieli (2011) who are claiming that the snowball sampling is useful in collecting data in conflicting environments. We realize that this relatively small set of respondents does not make it possible to generalize the interpretation of behavioural patterns of internally replaced persons in Bosnia and Herzegovina. However, it allows us to better understand the extreme complexity and emotional impact of the war and post-war situation on the example of individuals who have so far failed to cope with the return to the post-war conditions of everyday life.

## 3. Results

The analyses of in-depth interviews and time-space diaries helped us better understand importance of life-paths and their bonding with life activities of people affected by war conflicts in a physical space and chronological time in concrete economic, geographical, socio-cultural, institutional, and political contexts.

In-depth interviews were useful when we wanted to know detailed information about a person's thoughts and behaviours or to explore new issues in depth (related to war and post-war events). Interviews were used to provide context to other data (time-space activity diaries), offering a more complete picture of what happened in the life of the respondents and why.

Records in time-space diaries of our respondents contained six groups of data. The first group refers to *time, the date*. The individual described the path starting at the point of birth till 2018. The second group refers to *activity* (e.g. study, employment, military service or escaping the war conflict locality). The third set of data (*geographical context – place*) identifies the *geographical location* where the activity took place (e.g. Srebrenica, Potočari, Kladanj, Tuzla, etc.). The fourth describes *social context* – with whom they did that activity specified in terms of their relations with the respondent (e.g. family members, friends, and partners). The fifth data set referred to the *transport* mode (walking, using tractors, lorries or cars, etc.). And the sixth data set contained *some notes* such as getting married or involvement in violence, explanation of feelings in specifics situations. This helped us discover their influence upon and relations with any other event. The basic time unit was one month, but in case of forced and urgent migration we used even a day as a basic unit. The time-space diary technique/method has been complemented by audio recording. The interviews were structured to be compatible with the time-space diaries. However, the respondents had the opportunity to answer freely in their own words without significant interference from the person who conducted the interview.

The diaries that we have analysed were based on personal histories of 32 respondents (6 males and 26 females), which we collected during April 2018 and then recorded their trajectories. In one-to-one personal interviews, respondents were questioned retrospectively about their personal history, starting at the point of birth through the time of armed conflicts till present. All of them are Bosniaks by nationality, Muslims by religion and with Bosnian-Herzegovina citizenship. The average age of interviewees is 51.2 years. Among all respondents 12 of them completed the elementary/basic school of 8th grades, but most of them have not completed it and reached only a few levels of the primary or secondary education. Only 5 persons completed secondary school. There was also one respondent who had no education. Thirty respondents are in age group considered economically productive and only two respondents are in the post-productive age (working age population 15–64). Of all respondents only two persons are self-employed in their own shops in the camp. The rest of them depend upon state compensation for displaced persons or some of them occasionally work. They came from Republic of Srpska, but after the ethnic cleansing in 1995 they were forced to move to the Federation of Bosnia and Herzegovina.

Before the war their households were mostly in rural areas around Zvornik, Bratunac, Srebrenica or Vlasenica in highlands where the economically active population was employed in agricultural sector.

According to the widespread norms, with regard to woman's role and her behaviour, girls were required to skip attending school classes and to stay at home and help with household duties and farming until they reached a "marriageable age". When they leave the family and get married little is expected to change in the new family. Men have been encouraged to go out and seek jobs in order to support financially their families. The consequences of these traditional models manifested later in the post-war transition when they found themselves in an urban environment with lacking education and no work experience, and unable to adapt to the changing market conditions.

Important aspects of the time-space behaviour of all thirty two interviewed are presented in Tab. 1. Almost three decades of our analysis were divided into three periods: pre-war period in *Bosnia and Herzegovina* (1 January 1990 – 6 April 1992), war times (7 April 1992 – 14 December 1995) and post-war period (15 December 1995 – 16 April 2018) ending in the time when survey was conducted. It is evident from Table 1 that war and post-war period is characterized by complicated life-paths in some cases with numerous movements and shorter or longer stays in places (stations). During analysed war-period, ten of the twenty-six interviewed women experienced/underwent five or more relocations in order to save their own lives and the lives of family members, especially children. In the post-war period, the number of relocations decreased. Only in five records of activity diaries we can find five or more movements. A specific case is a man (42 years old) who worked as a construction worker in 10 localities (apart from Bosnia and Herzegovina, also in Slovenia, Italy, Austria, and Germany). During movements apart from overcoming relatively long distances on foot, they used various (sometimes unusual such as tractors and lorries/trucks) transportation means to reach stations where they could survive for some time. Stations in terms of the time-geographical terminology are spatial locations (places) where activities between relocation periods took place. The most of respondents were forced to migrate by war and post-war events. Records in time-space diaries also enabled us to analyse motivations to move or stay. Pre-war motivations to move were induced by family reasons and job opportunities especially for male population. Motivation factors changed during the war. Apart from the fact that several respondents were motivated to join their families, several war-endangered persons were forced to leave their homes and directed by domestic and international institutions to new localities.

A qualitative data collection method, in-depth interviews, offered the opportunity to capture rich, descriptive data about interviewees' behaviour, attitudes, perceptions and experience from the pre-war to post-war period, and the complex processes in between. All our respondents in the Mihatovići camp have been exposed to multiple pre-and post-migratory traumatic experiences, it was therefore essential for us to be aware and respectful for their vulnerability. The total number of questions in this in-depth interview was 27 and most of questions were related to the key aspects of their lives.

**Tab. 1** Spatial behaviour of respondents from Eastern Bosnia (1990–2018): movements and stations.

| Respondents (Age-Gender) | Number of movements / Number of stations (places) | | |
|---|---|---|---|
| | 1 January 1990 – 6 April 1992 | 7 April 1992 – 14 December 1995 | 15 December 1995 – 16 April 2018 |
| 84-F | 0/1 | 7/8 | 0/1 |
| 68-F | 0/1 | 3/4 | 1/2 |
| 63-F | 0/1 | 3/4 | 6/5 |
| 60-F | 0/1 | 2/3 | 1/2 |
| 59-F | 0/1 | 6/5 | 2/2 |
| 58-F | 0/1 | 6/8 | 1/2 |
| 58-F | 0/1 | 2 /3 | 0/1 |
| 57-F | 0/1 | 5/6 | 1/2 |
| 56-F | 0/1 | 7/8 | 1/2 |
| 55-F | 1/2 | 3/4 | 0/1 |
| 55-F | 0/1 | 4/5 | 2/3 |
| 51-F | 1/2 | 3/4 | 0/1 |
| 52-F | 0/1 | 4/5 | 0/1 |
| 47-F | 0/1 | 6/7 | 1/2 |
| 46-F | 1/2 | 5/6 | 1/2 |
| 46-F | 0/1 | 10/9 | 4/3 |
| 45-F | 0/1 | 2/3 | 0/1 |
| 44-F | 0/1 | 4/5 | 1/2 |
| 44-F | 0/1 | 5/6 | 9/6 |
| 43-F | 0/1 | 3/4 | 7/8 |
| 40-F | 0/1 | 1/2 | 6/5 |
| 40-F | 0/1 | 2/3 | 3/4 |
| 39-F | 0/1 | 6/7 | 1/2 |
| 38-F | 0/1 | 4/5 | 1/2 |
| 31-F | 0/1 | 1/2 | 1/2 |
| 30-F | 0/1 | 3/4 | 3/4 |
| 64-M | 0/1 | 1/2 | 7/5 |
| 62-M | 0/1 | 5/4 | 3/3 |
| 59-M | 0/1 | 3/4 | 1/2 |
| 59-M | 0/1 | 7/5 | 1/2 |
| 42-M | 0/1 | 1/2 | 11/10 |
| 40-M | 0/1 | 2/3 | 3/3 |

Prior to the conflict, only one respondent had the opportunity to witness a case where members of a particular nationality or religion were preferred. The other 31 respondents answered negatively. Only less than a tenth of respondents experienced personally some inconvenience before conflicts in the 1990s due to nationality or religion. One of these answers was: yes, from neighbours in 1992 saying, we Muslims have caused the war and wanted the war. This did not imply our decision to move. Until they started killing, no one left their home.

All respondents agreed that if there were no armed conflicts, they would still remain in the original region/ place of residence. Nearly two-thirds of respondents think that the propaganda of some nations affected the development of the conflict in the former Yugoslavia. On the contrary, one-fifth of the respondents answered no. Most of the questioned Bosniaks (two thirds) believe that the faith, religion in the milieu in which they formerly lived, played a very important role. Opinions on whether official attitudes of church leaders played an important role in promoting their own interests and contributing to the spread of conflicts were different. In thirteen cases the answers were positive, twelve respondents answered no and seven did no comment or were not sure. It is evident from the positive answers that the church leaders did not make sufficient efforts to calm the situation and promote reconciliation. A large number of respondents (24) believe that political leaders abused religion in their favour. The war conflict also had an impact on marriage. Five respondents also reported ethnically mixed marriages in their neighbourhood that have ended in a divorce after the war conflic began.

The vast majority of respondents said they did not intend to return to localities where they used to live before the war. The main reasons were as follows: their homes and properties were either burned or taken away. Over time some of them managed to sell what they owned before the war. The important reason why they plan to stay at the place of their present stay is a feeling of security. And it has often been accounted that those places have no more importance for them than they had before the war. These reasons suggest that the move was provisionally terminated with the prospect of settling permanently.

The interviewees also expressed their views on the conditions under which they would return to live in the environment they came from. Less than a third would return if they had a house, less than a third, assuming there were schools, job opportunities, shops, doctors, better conditions. The retreats gave the following reasons: “if my husband was not killed”, “if my relatives were alive”. Less than a third is determined to never return.

Moving away is associated not only with the changes in housing and employment, but also with coming into a different cultural, social and economic environment that had a significant impact on the lives of the respondents. Nearly two-thirds reported a very negative impact, especially a deteriorated state of health (i.e. mental illness, diabetes, heart disease, and so on). For many, the beginning after war was very difficult (frequent moves) and in some cases the family is still not together.

Nearly two-thirds of respondents feel safe when they visit their former country/region, respectively, they moved out from. More than a third does not feel safe. According to the Bosnian respondents, the relations among neighbours in the domestic community before the war were good (21) and very good to excellent (11). Most of the participants in the interviews (31) would support changes in the place they came from, mainly political and economic changes (one third), some (7) would promote social, cultural and community changes (changes in local environment).

As an example of visual interpretation of time-space diaries in 3D graphs we have selected five respondents from Kostijerevo (Fig. 2), Pribidoli near Srebrenica (Fig. 3), Radovčići near Srebrenica (Fig. 4), Liplje (Fig. 5), and Vlasenica (Fig. 6). A selected group

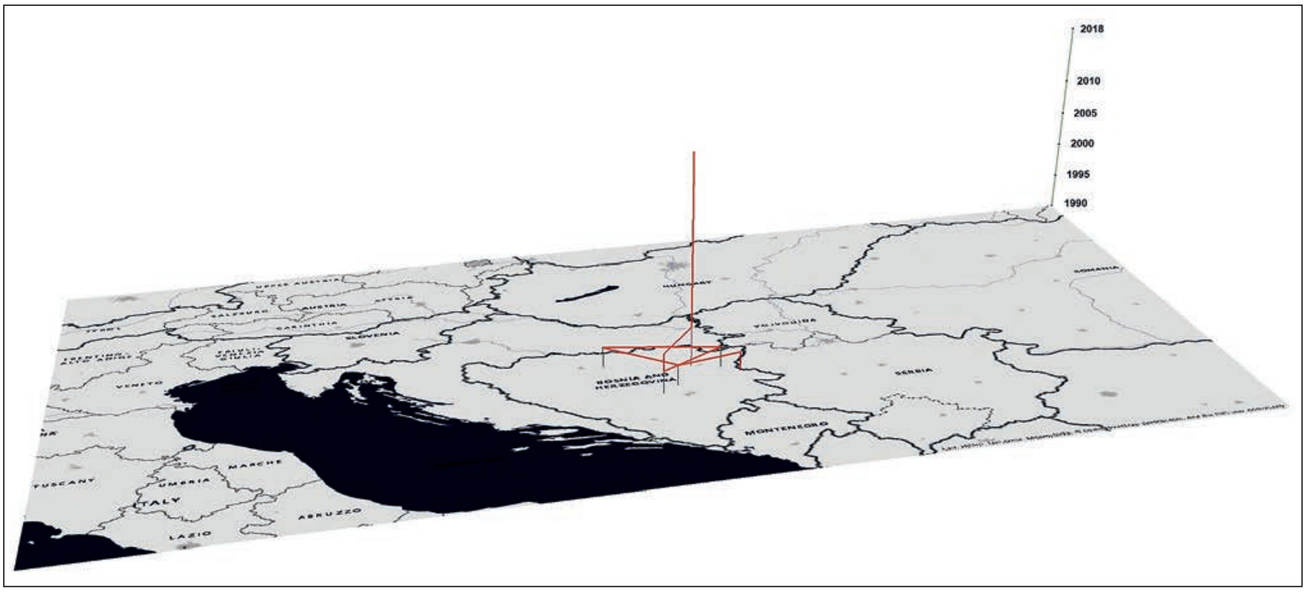


Fig. 4 Life-path of 84 years old female living in Mihatovići camp.

of 5 respondents, represented by 3 women and 2 men, shows different types of life paths influenced by different life situations and different factors Vertical line in the graph represents the time context, duration of some activity in certain geographical space of one individual. Every interruption or diversion meant change of direction of the movement of time axis and its duration. Time span used in the construction of 3D graph is from 1990 until 2018. Before the war there were no important changes in place of living recorded i.e. if not for the war, the female respondents would have lived all their lives in the places they were driven out of. But because of the war they had to hide and often change their accommodation until they settled in Mihatovići camp.

The oldest respondent, 84 years old female from the village of Kamenica, a woman who did not attend school, represents the type of Muslim female population of Bosnia of the older generation (Fig. 4). She is a widow, mother of 9 children, three of whom died during the civil war in the Srebrenica area. Until July 1992, she lived with her family in Kostijerevo. In July and August 1992, she and her family were forced to leave their homes. On foot, through the mountainous forests, they fled north to the village of Kiseljak. They spent more than 2 years there in the detention centre. In June 1995, she has been internally displaced to the refugee centre (community/collective centre) Mihatovići. From that time until the date of the interview, she spent almost 23 years in that facility.

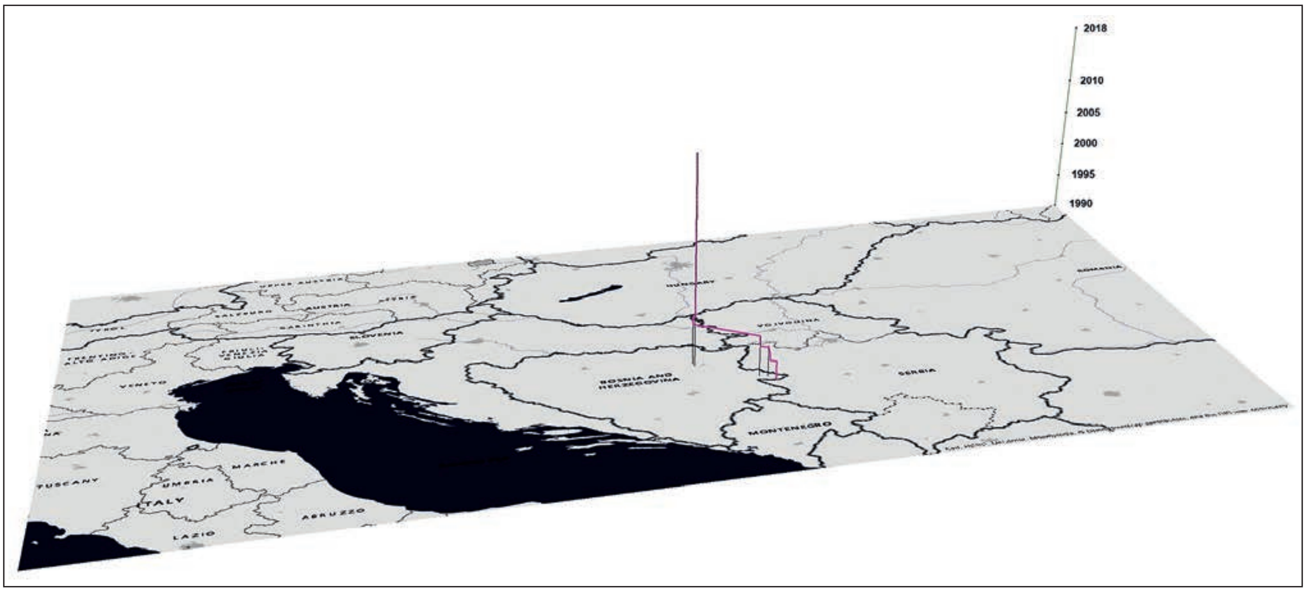


Fig. 5 Life-path of 56 years old female living in Mihatovići camp.

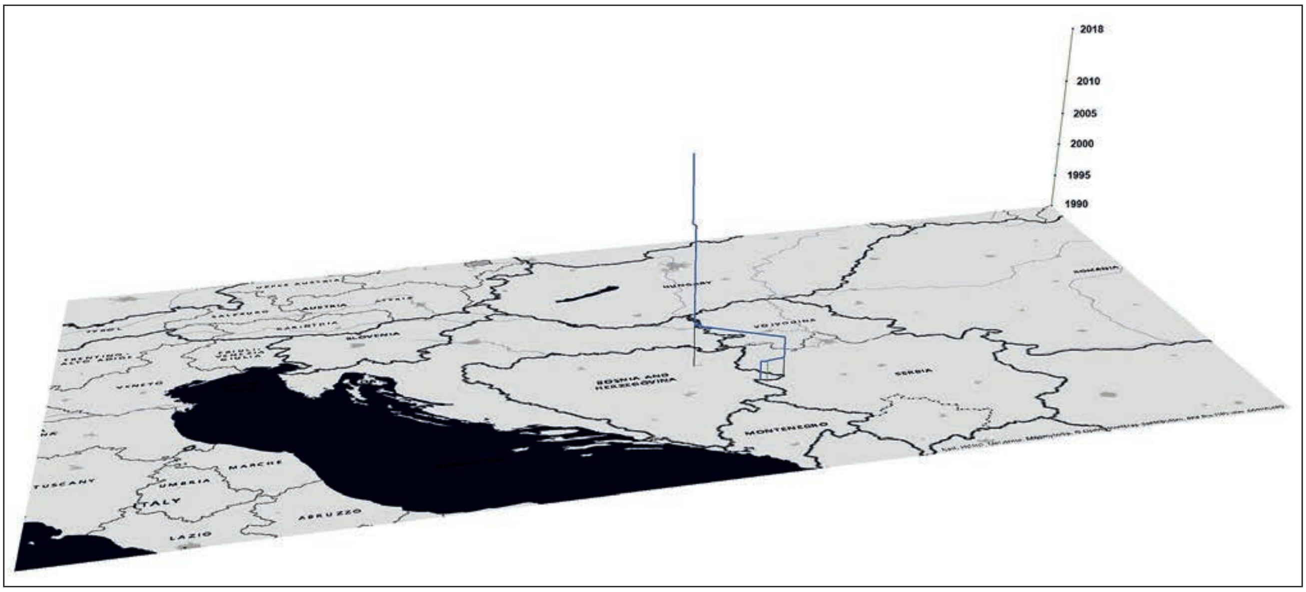


Fig. 6 Life-path of 58 years old female living in Mihatovići camp.

Another Muslim woman aged 56, born in the village of Pirići, with incomplete primary education (4 years of primary school), a mother of three children (Fig. 5). In April 1992, at the beginning of the conflict in Bosnia, she left the village of Pribidoli and after short stays in several localities she got to Srebrenica with her family (husband, children and mother-in-law). During the war she became a widow – her husband died there). After almost two years spent in Srebrenica they were forced to move on foot and bus to Potočari (north of Srebrenica). After more than a year spent in detention centres, gets together with children to the refugee centre (community/collective centre) Mihatovići.

The life-path of a 58 years old Muslim woman with completed primary education, a widow with 2 children begins in the small settlement of Delić near Srebrenica (Fig. 6). After being married, she starts a family in the village of Radovíći. She left their home in June 1992 and hid with her family and neighbours in the mountains for two months. From August 1992 to July 1995 they live in the village Petriča (on the border with Serbia) together with their relatives. In July she lost her husband (shot in Potočari near Srebrenica). After three months in the Ši Selo near Tuzla, she leaves with children and some relatives in Bukinje near Tuzla, where they lived until May 2009. From there, she moves with one son to the refugee centre (community/collective centre) Mihatovići.

Differences between movements in the case of two men (62 and 59 years old) were that before the war the older (62) Bosnian Muslim (Fig. 7), father of two

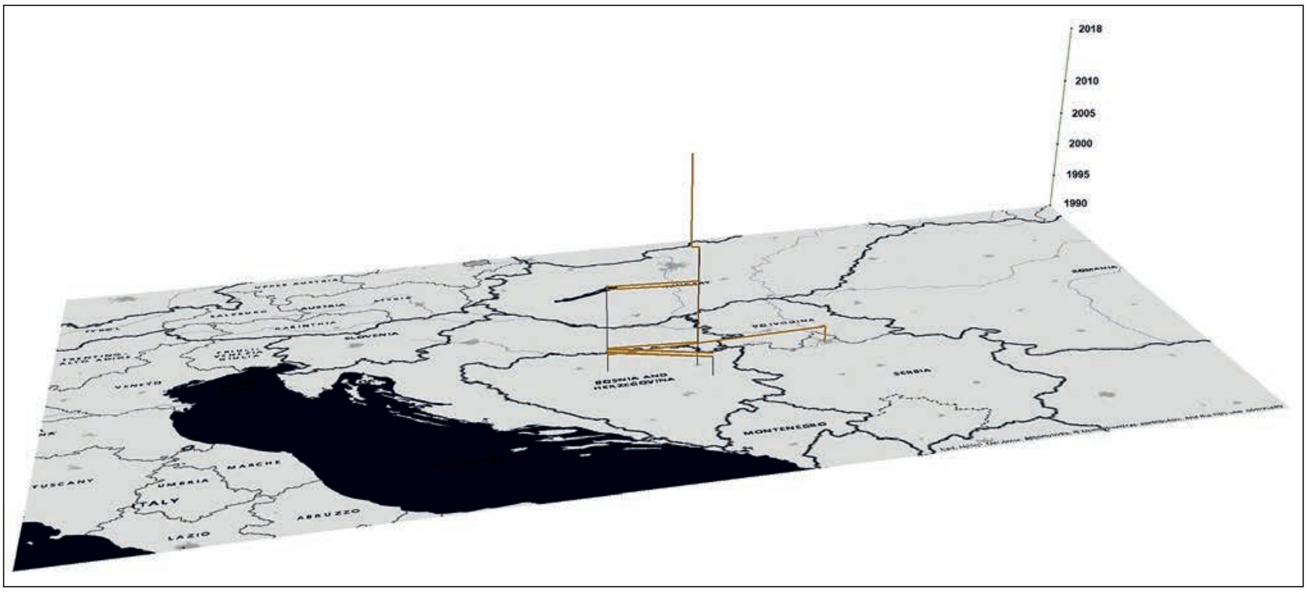


**Fig. 7** Life-path of 62 years old male living in Mihatovići camp.

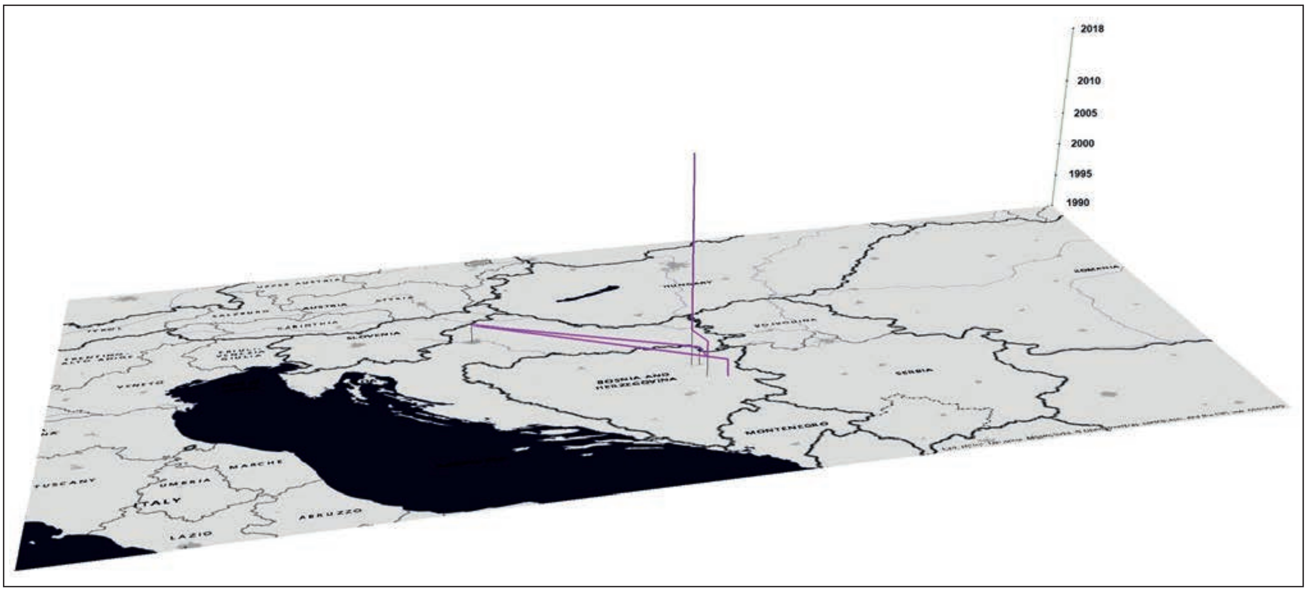


**Fig. 8** Life-path of 59 years old male living in Mihatovići camp.

children was long-term employed in Belgrade and younger (59), also Bosnian Muslim (Fig. 8), father of two children in his home town of Vlasenica. At the beginning of the war in 1992 both of them were in their home towns and became soldiers of the territorial defence. During this period, 59 years old Bosniak was sent to the military training in Zagreb and after that he joined the army in Tuzla and took part in the fighting around Tuzla. In 1995, he was demobilized and since then he changed two localities of his accommodations before he entered Mihatovići camp in the last part of 1995. Older respondent of Bosnia origin (62) was demobilised also in 1995 and since then he spent more than 6 years in Tuzla. After that, for couple of months he returns to Liplje, but because of lack of financial sources he left his birthplace Liplje for Tuzla. Since April 2006 he was replaced together with his wife and children to Mihatovići camp.

## 4. Discussion

In our empirical research we applied the time-geographical approach which seems to be a convenient foundation for mapping and modelling migration processes and patterns of individuals in the conflict and post-conflict time. The methodological concept is based on works of Torsten Hägerstrand which state that in time-space the individual describes a path starting at the point of birth and ending at the point of death (Hägerstrand 1978). Every form of human meeting is preceded and succeeded by movement in space. Four dimensional view of the world is a view which conceptually respects the continuity and interdependence of matter, space and time (Pred 2005). The essential module of time geography is placed on individuals' mobility, that is, the *life-path* in which people connect with each other in couples or groups at various points and for various purposes. The life-path can be understood in a variety of temporal and spatial scales, from a day-path to a lifetime. The time-space diaries helped us to create a more complex picture of how individuals interacted with each other in a life affected by war conflicts and post-war difficult situations. Detailed records made it possible to identify some social and economic contexts in which our respondents lived before the war comparing to their present situation (Schwanen 2009).

The use of a data set from a longer period (a biographical time scale) leads to some differences with respect to how the time-space paths should be interpreted compared to short period (e.g. daily trajectories). Our results are consistent with Frändberg's statement: "When the time scale is years and decades rather than hours and days, the representation of movement is by necessity very selective" (Frändberg 2008: 19).

The GIS as information technology is placed at the intersection of several different views of space and time (Couclelis 1999). New perspectives on space and time in a war and post-war life of affected population were added to the traditional ones, the cognitive and the socio-cultural. It seems to be very efficient and the question of space and time in the analyses of the complicated life-paths (formed by external circumstances) is becoming more complex.

Wars have long term effects not only on the populations in the conflict zones, but also on populations beyond these territories (e.g. through the flight of refugees and by the economic impacts). The landscapes of war zones are well marked, on the one hand by damaged buildings and infrastructure, destroyed landscape icons (such as churches and mosques), ravaged cities, abandoned lands, on the other hand by various new elements which appeared in the landscape during post war rebuilding. Much of the post-conflict geographical research is focused on the political, social and economic consequences of wars (O'Loughlin 2009). Growing attention is now being given to the number of behavioural geographical aspects (e.g. distribution of refugees and forced migrants near conflict zones, long distance migration and refugee flows, large and diverse populations in poor regions involved in a struggle over power, representation, and resources such as food, employment, education, and healthcare).

There are an increasing number of time-geographically-inspired studies on lives of people in vulnerable situations, studies carried out in various academic disciplines, such as human geography, sociology, political science, social change studies, psychology, psychiatry, social work and occupational therapy (Ellegård 2019). Many of these applications, as well as the application in our study, using the time-geographic concepts and visualizations can help to understand the life situation of these people. There is a potential to combine time-geographic diaries with "the post-war treatment programmes" and discussions on motivation to realize changes in order to get better quality of their lives.

## 5. Conclusion

The results of the analysis of the group of respondents in our study have, on the one hand, a limited informative value, on the other hand they describe in more detail the difficult situation of a selected sample of the population of war and post-war Bosnia and Herzegovina. As far as the time-space behaviour patterns of studied group of Bosniaks are concerned, in pre-war period it was a traditionally conservative population characterized by significantly different time-space behaviour of male and female population. Women were mostly not used to moving or migrating far from the place of their birth (or stay), except for marriages. In many cases, men migrated more often, with job opportunities being the main motive.

Unfortunately, the war became the main push and pull migratory factor, which forced to them to escape the war zone and became long term internally displaced persons. We have paid special attention to the geographical, social and other contexts recorded in their time-space diaries because they are very important for a deeper understanding of behaviour of individuals affected by war not only in time of conflict but also in post-conflict period. Thirty two men and women with complicated and disturbed life trajectories survived sudden and unwanted changes of locations. In particular, they had in common the history of former Yugoslavia although their experiences of the war conflict and post-war events have been different and subjectively experienced and perceived in different ways. With the ever changing relations in the war and post-war environment they got into trouble. Similarly as Lundén (2003) we can state that the real individual reasons for their life-choices at different situations will never be completely clear. Community and family relations, personal economic situation, religion and ethnicity may have in certain cases more impetus than political situations in war and post-war periods.

The collection of time–space diaries was tailored to specific research questions focused on people struggling with difficult life circumstances. It was part of strategy for our research with a particular interest in the multiplicity and particularity of people's experiences of life in the conflict and post-conflict environment. It was based on a systematic ex-post record of the person's use of time over the period lasting almost three decades including the spatial coordinates of their activities locations. The method of diary supplied information for the analysis of life paths of studied Bosniaks, who to these days have not found a way to deal with the consequences of the war and integrate into the newly formed post-war Bosnian society. This kind of research is considered to be absent, so the research presented in this paper could be perceived as one of the first studies with an original empirical material which could serve for the development of more complex interdisciplinary research projects combining theories of war and post-war marginalization and integrating experiences of people in war-induced marginalized groups with time-geography.

We can state, similarly as Ellegård (2019), who mentions in her publication on concepts, methods and applications in time geography, that the individual life-path concept also helps reveal what consequences arise for other individuals in life-threatening situations from one individual's decisions to act in a certain way. In-depth structured interviews and the visualizations of life-paths offered the possibility to generate questions which could be posed thanks to detailed information about the life constraints and experience of people affected by the war. Time-geographic analyses can be useful to show to authorities (even international) that the rules and programmes they have set up in post-conflict territories are not always functional.

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# Application of potential accessibility models in decision-making on HSR routing: the case of Rapid Connections in Czechia

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**ABSTRACT**

The aim of this article is to discuss regional impacts of high-speed railways on transportation accessibility. It investigates the potential changes in the transportation accessibility of Czech municipalities due to the planned construction of high-speed rail lines in Czechia. It considers two currently discussed variants of the high-speed rail line between Prague and Brno. We discuss the model of potential transportation accessibility and discuss its usability in the preparation and construction of high-speed rail line structures, and how it would affect the optimal route selection. We also present different methods of accessibility analyses in GIS applied to the case of Czechia and their presentation through map outputs.

**KEYWORDS**

high-speed railway; Czechia; regional and local impacts; potential accessibility

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## 1. Introduction

Transport accessibility is considered one of the basic conditions for the development of a region's economy and also demonstrates the quality of the region's involvement in the labor market (Sands 1993; Gutiérrez 2001 or Chen, Hall 2012). The quality of transport accessibility is also irreplaceable in performing other activities of human life, such as commuting to health care, education, and cultural institutions, but it also plays a role in the development of tourism, etc. "Transport accessibility, along with population density, affects the efficiency of serving the territory and the population" (Maier et al. 2007: 6).

In an elementary manner, transport accessibility can be understood as the ease or difficulty of reaching a place or service from other places. Accessibility can be expressed in terms of the distance traveled or the travel costs or travel time expended (Clark 1990). It can be "defined as the ease of reaching a certain location in space" (Giuliano 1995 in Hudeček et al. 2011: 1). It is in transport geography that one can most often encounter the expression of transport accessibility based on the time needed to cover a given distance. The term accessibility usually refers to the concept of a proximity of two points in space, to the simplicity of spatial interactions, or to the potential of contacts with different types of services and functions (Michniak 2002). Accessibility, however, can also be understood as a chance to enable a person occupying a certain space to utilize different types of activities (Taylor 1997), i.e. "the potential of opportunities for interaction in space" (Hansen 1959 in Hudeček et al. 2011: 1).

Moreover, in transport geography, great attention is paid to the study of accessibility as one of the key concepts. Today, the most frequently monitored are accessibilities from peripheral areas to core areas, whether by public or individual transport. Due to the fact that transport accessibility is one of the most significant manifestations of changes in the transport network, the concept of accessibility is used to express changes in the territory that will be caused by the construction of new transport roads.

Given that accessibility is an issue affecting different fields (transport, spatial planning, marketing, etc.), it does not necessarily always work with only a temporal dimension. GIS integrated tools have also brought new opportunities for study. In addition to *time accessibility*, for example, *cumulative accessibility* is also analyzed, which is expressed as the number of certain activities attainable from a particular location at a particular time. An example would be the number of jobs available per hour of driving from the municipality of residence (ESPON TRACC project). Accessibility may therefore include not only spatial dimensions but also social or economic dimensions such as population size, unemployment rate, etc. (Salze et al. 2011). While a simple expression of temporal accessibility involves only the aspect of distance and cumulative accessibility distance and a certain activity, both expressions lack the aspect of the center's location relative to others and do not take into account their differentiated meaning. Equally large headquarters located at the same distance from Brno or from Karlovy Vary will have differentiated position potential due to differences in the importance of Brno, respectively Karlovy Vary. This problem involves the concept of *potential accessibility*, which is essentially a derivative of the gravitational model.

The potential as an index of geographical availability has been used in geography for quite some time (Rich 1980). Originally, population potential was understood as a measure of a geographical change in the vicinity of all or part of a country's population. Later, this concept was extended to reflect the proximity of job opportunities, the availability of services, etc. (Guy 1983).

Basic services such as shops, banks, post offices, medical facilities, but also job opportunities are less easily accessible from rural or peripheral areas than in large cities. Thus, some people may be twice disadvantaged – they do not have a sufficient choice of services or employment opportunities, and they live far from the desired service (Haynes et al. 2003). It is with regard to the attractiveness of the services in question that we cannot only consider the temporal dimension in such a case. That is why we include the potential of the service or job opportunities in the transport accessibility research.

Another example might be to find an answer to the question "What is the accessibility of a particular business to a potential employee?" (Van Wee et al. 2001: 3). Generally, it can be assumed that only people with certain temporal accessibility (e.g. 30 minutes) will be included as potential employees of the company. However, given that we cannot only consider the temporal dimension of commuting, but also the attractiveness of a given job opportunity or regional unemployment rate, it is necessary to include these in the form of the weight of centers in the accessibility calculations. In this case, we also work with the so-called potential accessibility. Similarly when assessing alternative solutions to transport systems (e.g. different routing of rail connections), it is important not only to consider the aspect of time accessibility but also to consider potential accessibility, which will comprehensively assess the location of settlements in the newly proposed infrastructure.

This paper aims to present the advantages of potential accessibility models use in decision-making on routing the high-speed rails. We will demonstrate the model's use on the case of Czech HSR plans called the Rapid Connections and will assessed two variants of tracing between Prague and Brno by potential accessibility concept.

## 2. A tool for modeling potential accessibility: network dataset and parameters of network analysis

The key source of the GIS accessibility model is, besides the timetable, a sufficiently accurate map background.

### 2.1 Creation the network dataset in GIS

The model is characterized by a GIS network data set (NDS) of digital vector data representing the transport network (in this case the railways) and containing, apart from the lines and nodes, also adequately selected attributes. These are average train speed and hence the time needed to cover the given distance. These attributes will ultimately enable the specific software to find, for example, the shortest path or to construct isochrons (e.g. Hudeček et al. 2011) by a gradual cumulation of the travel time between the individual inter-nodal sections. The weight of the nodes could be added as well, e.g. population size, number of jobs available, and other. Final created Network Dataset (NDS) contains all railway line's sections needed and their junctions (centroids of settlements connected to stations and stops, ends of tracks or sections, and their crossings). The advantage of time-demanding creating the NDS is its variability for different destinations – once an accessibility model is compiled it can then be used to analyze the accessibility of any point in the network (or multiple points at once).

In the model used in this research, all rail tracks in operation were included and future HSR track were digitalized according to current plans of Ministry of Transportation of Czechia. Each section of the railway line has the specific time needed to pass the section either by local train (Os in Czech terminology) or by express train (R) or by higher quality train (IC/EC) calculated in the attribute table. The time required to pass a given section represents the fastest possible connection in the train in the categories mentioned according to the timetable. Speeds of the planned HSR sections were taken from strategic materials of the Ministry of Transport of the Czech Republic. The times of transfers between individual lines and the time of train stay at the station are not consider in this analysis. It would not even be useful to include the time of transfer between individual trains in the calculations, as this may change with a change in train transport concept or with the positioning of individual trains within the timetable.

Then, the ArcGIS tool, the Network Analyst with Python SW extension, was used for calculation time and potential accessibility. The *time accessibility* was expressed between each pair of stations/municipalities in the regional model and between the fast-train stations in the long-distance model. So, each network section was given the time spent on the train.

The resulting time distances, in this case, are therefore partly theoretical, even though the speed has been optimized on the basis of a real timetable. The difference between theoretical and real-time can be explained by the following effects: the vectorized railway network is slightly generalized, the accessibility model does not allow for waiting at the station, and the speed was primarily determined by the typology of the tracks and later adjusted to the timetable. Although the distortion is minimal with regard to the national level of assessment, it is therefore important to consider model distortion when interpreting the results. The time calculated from the model may be slightly lower than real-time, however, this detail is sufficient for the purpose of expressing the changes caused by the construction of HSR.

### 2.2 Calculation of potential accessibility

To calculate the potential accessibility of all municipalities in Czechia served by rail transport on the basis of the population, the authors' script was used. Potential accessibility $A_i$ for specified point layers with $i$ (origins) and $j$ (destinations) was expressed according to the formula:

$$A_i = \sum_j Weight_j^{\alpha} \times exp(-\beta \times TravelTime_{i,j}) ,$$

where $Weight^{\alpha}_j$ determines the importance (weight) of locality $j$, here it represents the population, coefficient α adjusts the weight of the centers (not considered in this case), $TravelTime_{i,j}$ represents the travel time (time accessibility) between nodes $i$ and $j$ and the coefficient $\beta$ is an argument of the exponential function, which is used here as the distance impedance (resistance). The value β determines how strict the weight reduction of the centers will be with respect to the time distance (see below).

Specifically, the following inputs were used to calculate potential accessibility:

1) Origins – this is a point layer of municipalities in Czechia from the ArcČR 500 geodatabase version 2.0 by ARCDATA Praha, s. r. o., to which we count the potential accessibility. Abput concerning the fact that there is no railway line to each municipality in Czechia, only the municipalities served by the railway were selected.
2) Destinations – this is the same layer with "origins", so potential accessibility is calculated for each municipality in the context of accessibility to all other municipalities in Czechia served by rail.
3) Network – the layer of the railway network. It consists of (i) the layer of stop trains with all the railway stops and the travel time of the stop trains and (ii) the layer of express connections, which contains only train stations of an IC and higher quality trains and future HSR trains.

4) Impedance – this is an attribute of the transport network; this is an exponential function of a travel time.
5) Weight – this is an attribute of the Origin/Destinations layer, in this case the population was of the municipality used.

The output of the analysis is a new attribute (in the attribute table of the point layer), which represents the value of the potential accessibility, expressed according to the formula above. This value was used for the subsequent visualization of this phenomenon in maps.

For the actual calculation of potential accessibility, determining the value of $\beta$, which affects the proportion of the municipality's population in our case is absolutely crucial. The value of the $\beta$ parameter is selected with concerning for to the selected accessibility model (long-distance, regional) and is determined according to the following formula:

$$\beta = -\frac{\ln(f(TravelTime_{i,j}))}{TravelTime_{i,j}} .$$

The main way to calibrate the model is to determine the so-called *median time value* (or: *halftime*). From the model supplemented data of the 2011 Population and Housing Census on the daily commute to work, it was empirically proven that half of the commuters in Czechia travel to work within 22.5 minutes, half more than 22.5 minutes. This means that we are looking for an exponential function that, for a travel time value of 22.5 minutes, would give such distant centers the weight of just one-half. This corresponds to a coefficient of $\beta$ = 0.030809. The exponential function in this form assigns a weight of three quarters at a time distance of 9.3 minutes and a weight of one-tenth (10%) at a distance of 74.7 minutes. These values can be considered as corresponding to reality (Marada et al. 2016). As this model case only deals with rail accessibility and train passengers are generally less sensitive to commuting time than car passengers, the halftime was rounded to 30 minutes for the regional model. Basically, points that will be within 30 minutes traveling from the origin municipality will be counted by their weight value more than the municipalities that are located at a time distance of more than 30 minutes within the network. This calculation, therefore, takes into account the fact that people travel shorter distances more than longer distances. In the case of a long-distance model, we applied analogously the halftime of 60 minutes. This

**Tab. 1** Determination of the $\beta$ parameter for individual values of "halftime".

| Halftime value $TravelTime_{i,j}$ (minutes) | $\beta$ parameter | $TravelTime_{i,j}$ (minutes) when f ($c_{ij}$) corresponds to | | |
|---|---|---|---|---|
| | | 0.75 | 0.25 | 0.1 |
| 5 | 0.138629 | 2.1 | 10.0 | 16.6 |
| 10 | 0.069315 | 4.2 | 20.0 | 33.2 |
| 15 | 0.046210 | 6.2 | 30.0 | 49.8 |
| 20 | 0.034657 | 8.3 | 40.0 | 66.4 |
| 30 | 0.023105 | 12.5 | 60.0 | 99.7 |
| 45 | 0.015403 | 18.7 | 90.0 | 149.5 |
| 60 | 0.011552 | 24.9 | 120.0 | 199.3 |

Source: Spiekerman (2012)
Note: From table 1 for the value of the median time ("halftime") 30 minutes, it follows that destinations exactly 30 minutes travel time apart from each other will be weighted at 50% of their value and correspond to a value of $\beta$ = 0.0223105. Using this value of the $\beta$ parameter will mean that targets 12.5 minutes from that point will be weighted at 75% of their value and targets 99.7 minutes will be weighted at only 10% of their value.

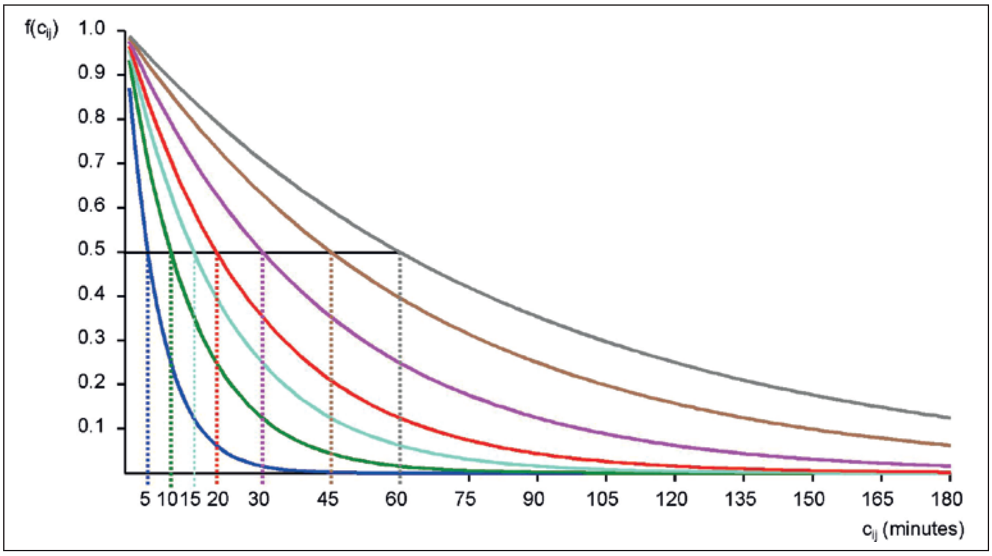


**Fig. 1** Weight curves for each accessibility model.
Source: Spiekerman (2012)
Note: The model in this article uses a median time (halftime) of 30 and 60 minutes.

value was determined with regard to the distance of the regional town of Jihlava as a city with significant potential for daily commuting to Prague and Brno (approx. 45–60 minutes from Prague or Brno). Specific values of travel time, in which the resistance is three quarters (0.75), a quarter (0.25), or one-tenth, are given in Tab. 1. The $\beta$-values used in regional and long-distance models are tinted. The graph in Fig. 1 below shows the resulting weight curves for 7 different halftime values, respectively values of $\beta$.

### 2.3 Variants of planned HSR under consideration

The case study was used for the routing of the high-speed rail called Rapid Connections in the Czech Republic (see e.g. https://www.szdc.cz/vrt/co-je-vrt/postup-pripravy-vrt). The two compared variants were the routing of the Rapid Connection 1 (RS1) in the Central Bohemian Region and the Vysočina Region (see Fig. 2). The RS 1 line will connect the two major cities of Czechia, Prague and Brno. To evaluate the advantages and disadvantages of the individual variants in a complex way, a method of comparing potential accessibility in both variants seems to be suitable.

The potential accessibility models were used to monitor the potential accessibility for three variants – the current state of the railway network respecting the almost completed network of transit railway corridors (maximum speed 160 km/h), furthermore, the state after the construction of the HSR with the RS1 line routing variant in the south direction (direction Benešov – Vlašim) and lastly the state after the construction of the HSR with the RS1 line routing variant in the east direction (direction Kolín – Havlíčkův Brod). Furthermore, two model variants were created for each of the three network variants based on a different concept of transport service. The first model always considered the so-called regional system of territorial service with a median time (halftime) of 30 minutes of train running. And the second model considered the so-called long-distance system of territorial service with a median time distance of 60 minutes of train running. Compared to the "classical" time accessibility calculations, the results of these analyzes present the mutual potential accessibility of all municipalities within the whole railway network, and therefore it is not only about accessibility to the capital city or vice versa.

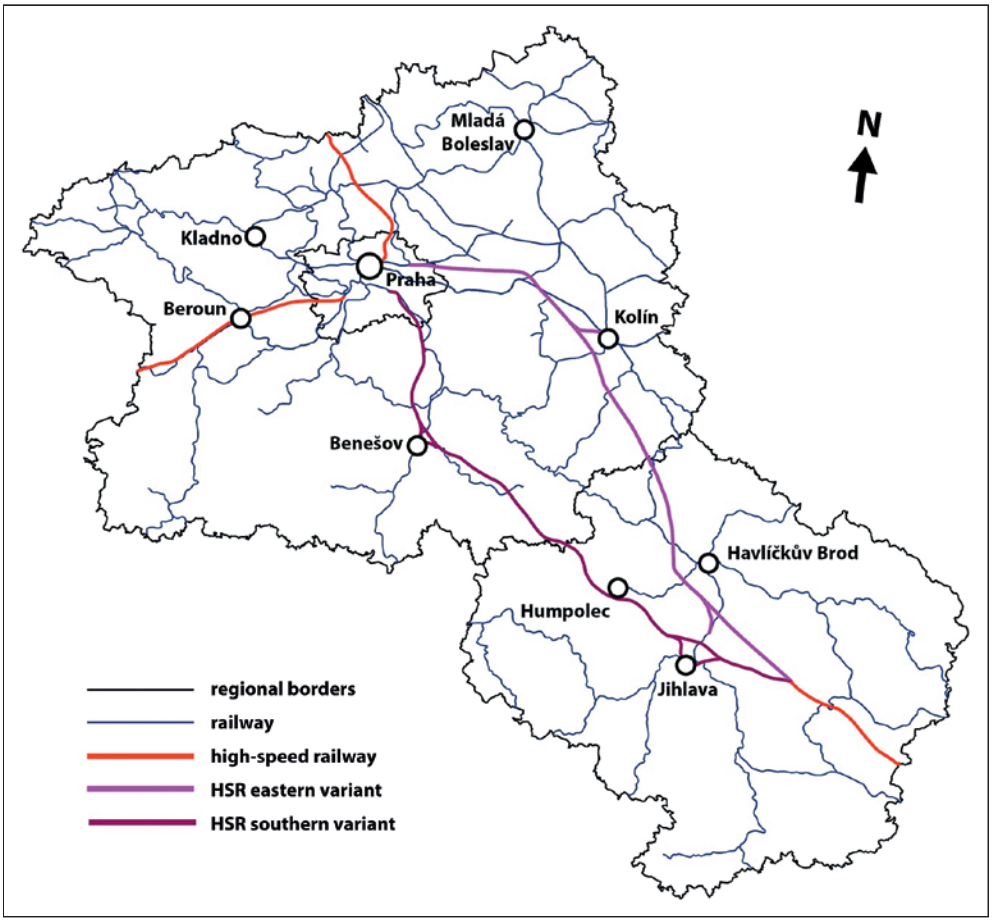


Fig. 2 HSR variant routing in the Central Bohemian Region and Vysočina Region.
Source: own work
Note: HSR = high-speed rail as part of the so-called Rapid Connections system

It should be pointed out that the potential accessibility values in the calculations take values in the order of ten million, so for the presentation in the tables, all results are divided by 1,000. For visualization in maps, relativization is used with the average value of potential accessibility per municipality in the null variant (current state, without HSR). This value is always stated in absolute terms in the map notes. The same average value of "null variant" was used as a 100% value for all other maps for comparability of individual analyzes. Indexes are used to compare different models. Since the calculations of potential accessibility are directly linked to specific points located on the transport network (in this case the railway), these are no results for the whole of Czechia, but only for municipalities with a railway station or stop.

**Tab. 2** Value of potential accessibility of regional cities and its change.

| City | Potential accessibility | | Potential growth |
|---|---|---|---|
| | regional model | long-distance model | |
| Prague | 82,124.23 | 82,849.16 | +0.87% |
| Pilsen | 81,312.67 | 82,384.74 | 1.32% |
| Karlovy Vary | 78,540.41 | 80,992.00 | +3.12% |
| České Budějovice | 78,550.65 | 81,141.20 | +3.30% |
| Ústí nad Labem | 80,501.89 | 82,030.83 | +1.89% |
| Liberec | 79,492.65 | 81,357.02 | +2.35% |
| Hradec Králové | 80,591.91 | 82,011.54 | +1.76% |
| Pardubice | 81,051.36 | 82,269.64 | +1.50% |
| Jihlava | 79,396.74 | 81,404.25 | +2.58% |
| Brno | 80,878.07 | 82,298.58 | +1.75% |
| Zlín | 79,363.48 | 81,475.80 | +2.66% |
| Olomouc | 79,629.44 | 81,438.17 | +2.27% |
| Ostrava | 79,188.89 | 80,312.55 | +1.41% |

Source: accessibility analysis, authors' calculation

## 3. Changes in potential accessibility after the construction of high-speed rail in Czechia

Potential accessibility analyzes were created for various types of area service, as well as for two different HSR routes in Czechia.

### 3.1 Potential accessibility of municipalities in Czechia by rail at present ("null variant")

Figure 3 illustrates the results of the potential accessibility model currently (2015), which considers the so-called regional transport model. The 100% value used to visualize the results is the average potential accessibility of all municipalities – 80,354.

It is clear from Figure 3 that, in the case of the regional model, the highest values of the potential accessibility of the municipality are reached in Prague and its hinterland. The high values of potential accessibility of Prague in all models are due to its relatively central location within the transport network. Municipalities in the hinterland of Prague then logically achieve higher values of potential

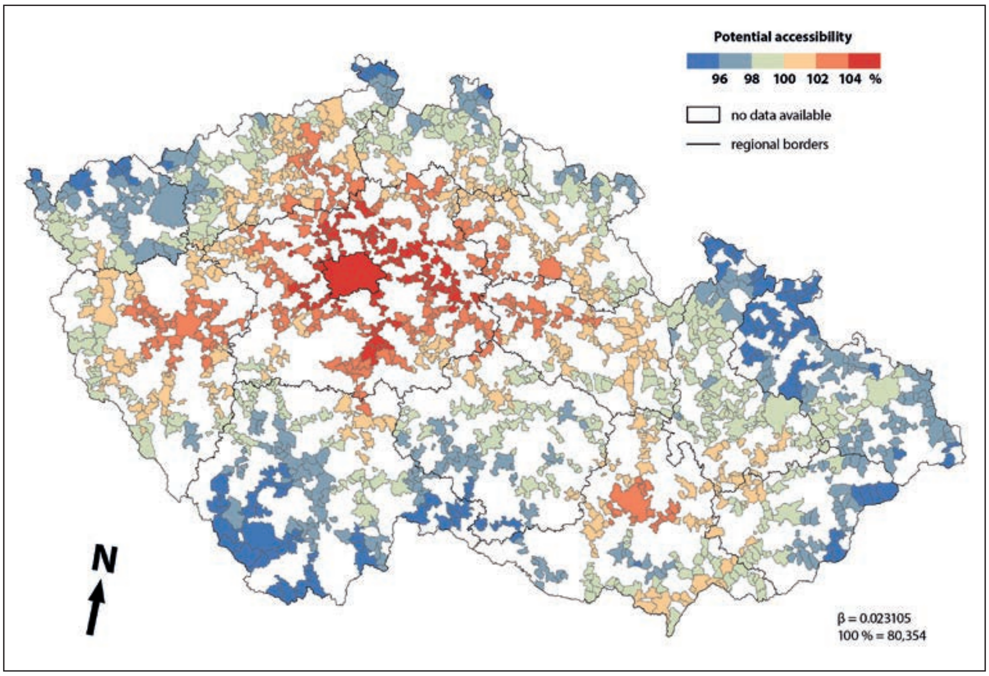


**Fig. 3** Potential accessibility of municipalities in Czechia in 2015 (regional model).
Source: accessibility analysis, authors' calculation

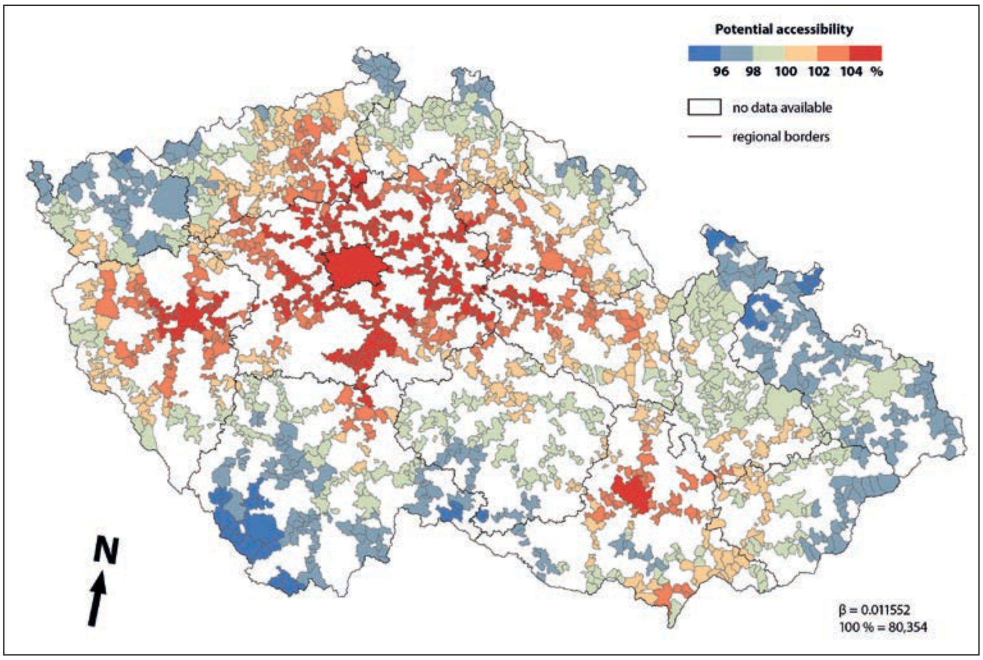


Fig. 4 Potential accessibility of municipalities in Czechia in 2015 (long-distance model).
Source: accessibility analysis, authors' calculation

accessibility precisely because of the high population size of Prague, but also because of their geographical proximity to the capital. These results also correlate to the fact that shorter-distance passengers travel more than longer-distance passengers, respectively the desire to travel decreases over time.

Figure 4 illustrates the results of the potential accessibility model at present (similar to Figure 2) but considers the so-called long-distance accessibility model. This model allows for faster long-distance transport – municipalities (or railway stations) with 60 minutes accessibility are then calculated at a value of 50% of their population size.

This model suggests that in the case of faster long-distance transport, the attractiveness of municipalities at a greater distance from Prague – the extensive areas of the north-east of the Central Bohemian Region, but also the Benešov Region – will increase. In terms of its location in the transport network and its population size also Pilsen and the municipalities in its hinterland are improved. We can observe the strengthening of the integration of the metropolitan areas in the northern "half" of Bohemia and the integration of the metropolitan area of Brno. An interesting phenomenon is that the potential accessibility of Ostrava is practically unchanged – this is mainly because it is, in terms of the Czech railway network, in a significantly eccentric position in relation to other large cities in Czechia.

Table 2 above and the cartograms (see Figures 3 and 4) show that in the case of the long-distance model, the change in potential accessibility will be most apparent in České Budějovice and Karlovy Vary, as a result of reaching the population-large Prague. The least change in potential accessibility will be seen in the case of Prague, as it benefits from its central location in all surveyed models. This comparison of the regional and long-distance model clearly shows the essential contribution of the fast transit to the interconnection of settlement centers with the Prague core.

### 3.2 Potential accessibility of municipalities in Czechia after the construction of HSR – regional model

The results from the regional models of potential accessibility after completion of the HSR in the eastern and southern RS1 variants are illustrated in Figures 5 and 6. The 100% value used in the visualization of relativized values is again the average potential of all municipalities from "null variant" because of the uniformity of maps' comparison.

In the case of the regional model, which in terms of population size most takes into account municipalities within 30 minutes of time accessibility, the municipalities northeast of Prague will gain the most in the case of the eastern variant of RS1, but also the relatively important area of the west of the Pardubice Region and the southern part of the Hradec Králové Region. The potential accessibility of Pilsen will change significantly, which in both variants will obtains a high quality and fast connection with Prague, whose existence will be reflected in the regional model.

If the regional model is applied to the railway network including the RS 1 in the southern variant, then, compared to the eastern variant, the Czech Siberia region (the boundary of the Central Bohemia and

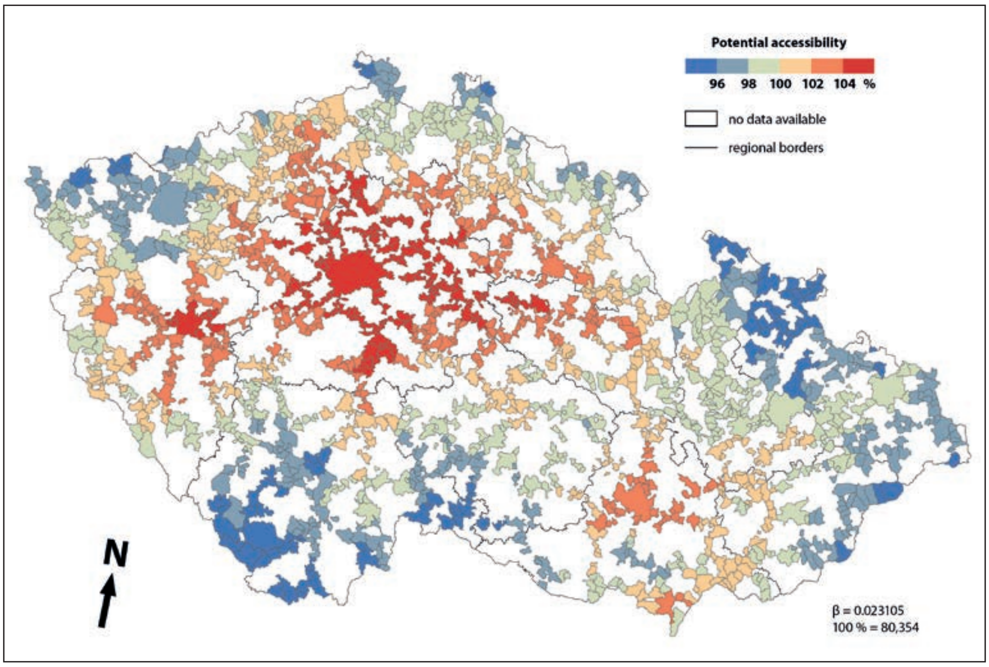


Fig. 5 Potential accessibility of municipalities in Czechia after the construction of HSR in the eastern variant (regional model).
Source: accessibility analysis, authors' calculation

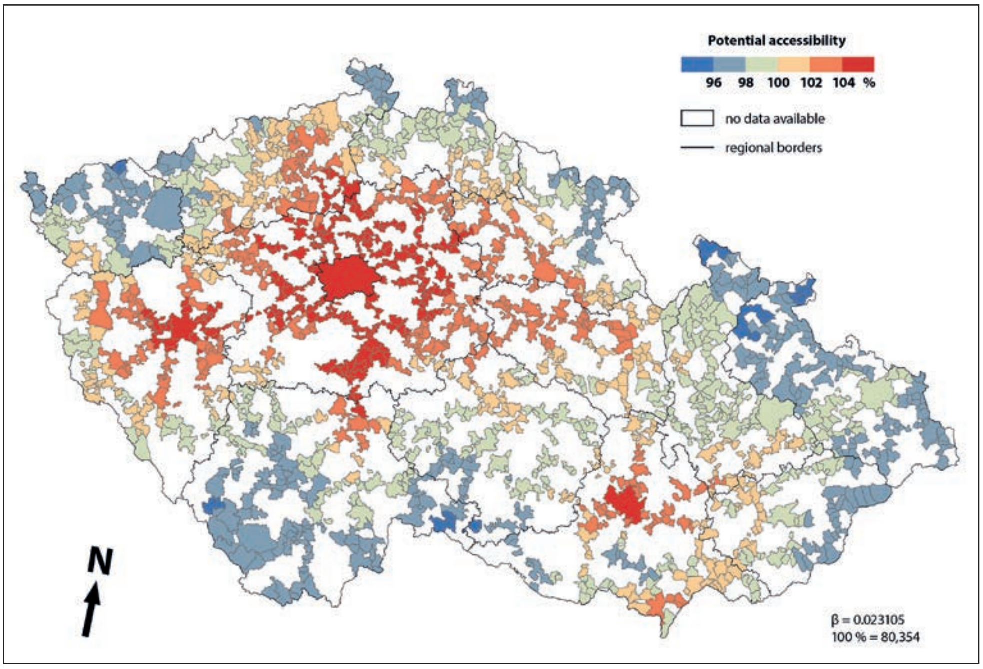


Fig. 6 Potential accessibility of municipalities in Czechia after the construction of HSR in the southern variant (regional model).
Source: accessibility analysis, authors' calculation

South Bohemia regions, the so-called inner periphery) has the greatest gains in the potential accessibility. The southern part of the South Bohemia region has little gains in the potential accessibility as well. In this variant, there will be no significant increase in the potential accessibility in municipalities in East Bohemia.

Table 3 below clearly shows changes in potential accessibility for all regional cities in Czechia. In the case of the eastern variant of RS 1, there is the greatest change in the potential accessibility in the cities of Pardubice and Hradec Králové and, of course, also in the cities currently less accessible – Zlín and Jihlava. In the case of the southern variant of RS 1, the change will be most apparent in České Budějovice, as well as in the eastern variant near Zlín and Jihlava. The regional model of the service is best recorded in the eastern variant of Karlovy Vary and in the southern variant by České Budějovice.

**Tab. 3** The value of the potential accessibility of regional cities and its change (regional model).

| City | Potential accessibility – regional model (null variant) | Potential accessibility – regional model (RS1 eastern variant) | Change of potential eastern/null | Potential accessibility – regional model (RS1 southern option) | Change of potential southern/null |
|---|---|---|---|---|---|
| Prague | 82,124.23 | 82,741.12 | +0.75% | 82,738.11 | +0.74% |
| Pilsen | 81,312.67 | 82,411.54 | +1.35% | 82,359.90 | +1.28% |
| Karlovy Vary | 78,540.41 | 79,926.00 | +1.76% | 79,123.55 | +0.74% |
| České Budějovice | 78,550.65 | 79,441.17 | +1.13% | 80,562.72 | +2,56% |
| Ústí nad Labem | 80,501.89 | 81,110.88 | +0.75% | 81,024.12 | +0,64% |
| Liberec | 79,492.65 | 80,377.82 | +1.11% | 80,564.45 | +1.11% |
| Hradec Králové | 80,591.91 | 82,618.24 | +2.51% | 81,788.13 | +1.48% |
| Pardubice | 81,051.36 | 82,599.24 | +1.90% | 82,034.11 | +1.21% |
| Jihlava | 79,396.74 | 81,704.26 | +2.90% | 81,653.87 | +2.84% |
| Brno | 80,878.07 | 82,235.98 | +1.67% | 82,171.99 | +1.59% |
| Zlín | 79,363.48 | 81,485.12 | +2.67% | 81,451.92 | +2.63% |
| Olomouc | 79,629.44 | 81,338.15 | +2.14% | 81,293.51 | +2,09% |
| Ostrava | 79,188.89 | 80,362.62 | +1.48% | 80,259.18 | +1.35% |

Source: accessibility analysis, authors' calculation

The total change in the potential for all assessed municipalities in the case of the eastern variant is from 132,855,112.81 to 134,967,575.21, which means an increase of potential by 1.59%. In the case of the southern variant, the change from 132,855,112.81 to 134,249,520.78 means a potential increase of 1.05%. From point of view of total change, the potential accessibility, the eastern routing of RS 1 appears to be a more advantageous option when applying the regional model, which increases accessibility within the traditional settlement core in the northern "half" of Bohemia. But a fast connection should be the main goal of building HSR, although it will serve for combine service with regional trains. And a regional improvement of accessibility should be the substantial criterion, not an overall one. This view provides the long-distance model in the following chapter.

## 3.3 Potential accessibility of municipalities in Czechia after the construction of the HSR – long-distance model

The results from the models of potential accessibility after completion of the HSR in the eastern and southern RS1 variants, which are considered by the so-called long-distance transport model, are illustrated in Figures 7 and 8.

In the case of the long-distance model, which in terms of population size takes more into account the municipalities within 60 minutes of time accessibility, in the case of the eastern variant of RS1, municipalities northeast of Prague will gain the most, but also a relatively important area of the west of the Pardubice Region and the southern part of the Hradec Králové Region. The potential accessibility of Pilsen will change significantly, due to a high quality and fast connection with Prague again. There will also be a significant increase in the potential accessibility of Brno and municipalities in its hinterland, while the potential of municipalities in the South Bohemian Region will decrease significantly.

If the long-distance model is applied to the railway network including the RS 1 in the southern variant, then, against the eastern variant, the greatest gains in the potential accessibility have the Central Bohemian-South-Bohemian border region and the southern parts of the South Bohemian Region. The potential accessibility of Pilsen will also increase, and the potential accessibility in Brno's hinterland will increase. In this variant, there will be no significant increase in the potential accessibility in municipalities in East Bohemia.

Table 4 below allows see the changes in potential accessibility more precisely. In the case of the eastern variant of RS1 as well as in the regional model, the greatest change in the potential accessibility in the towns of Pardubice and Hradec Králové and of course also in the regional cities currently less accessible – Zlín and Jihlava. In the case of the southern variant of RS 1, the change will be most apparent in České Budějovice, as well as in the eastern variant near Zlín and Jihlava. The long-distance model records most in the eastern variant of Hradec Králové, which will thus become more easily accessible from the regions of South Moravia, in the southern variant of České Budějovice, as their accessibility from the whole Czech Republic will improve.

The total change in the potential for all assessed municipalities in the case of the eastern variant is from 135,515,582.28 to 138,054,138.04, which

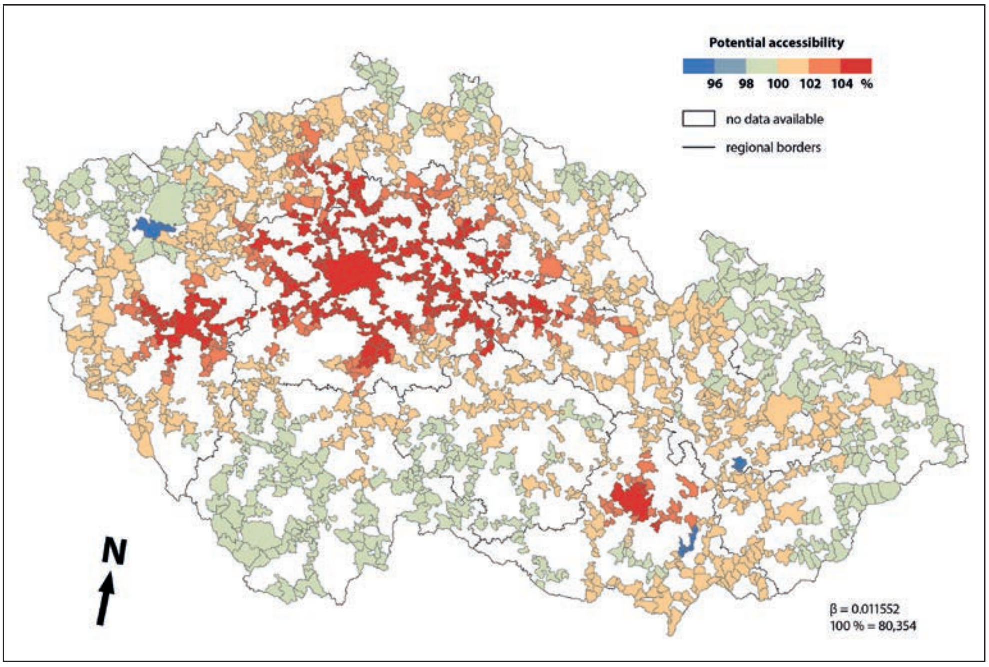


Fig. 7 Potential accessibility of municipalities in Czechia after the construction of HSR in the eastern variant (long-distance model).
Source: accessibility analysis, authors' calculation

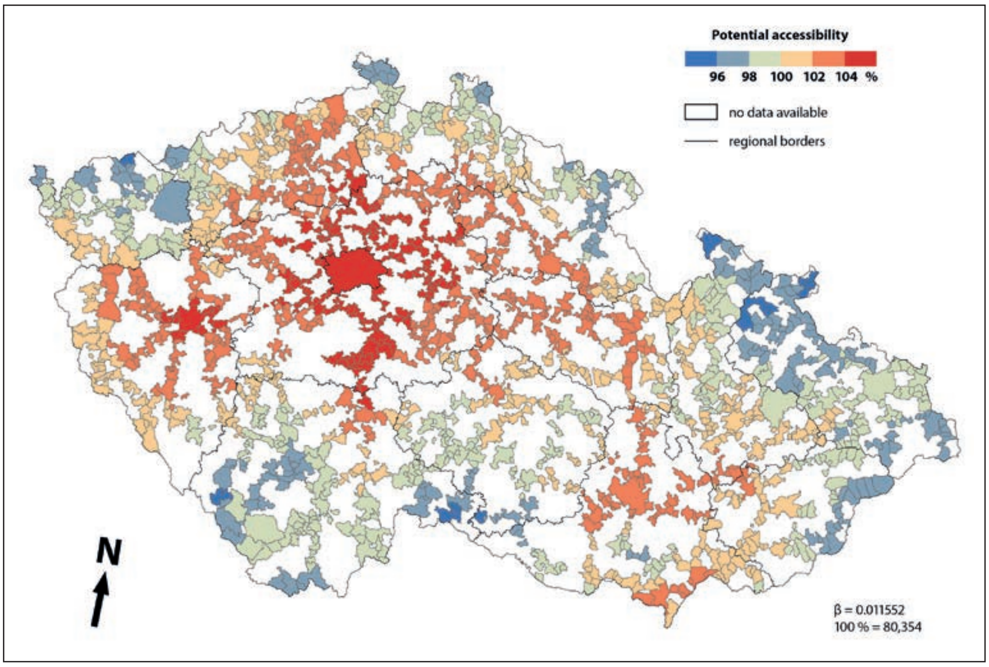


Fig. 8 Potential accessibility of municipalities in Czechia after the construction of HSR in the southern variant (long-distance model).
Source: accessibility analysis, authors' calculation

means an increase of potential by 1.87%. For the southern variant, the change from 135,515,582.28 to 137,658,182.57 represents a 1.58% increase in potential. In terms of changing the total potential accessibility, the eastern RS1 route appears to be the more advantageous option again. But, as can be seen from Figures 5 and 6, from the regional benefits point of view, the southern variant of the long-distance model shows a significant increase in the number of municipalities with above-average potential accessibility than the eastern variant (65% of municipalities with an above-average potential value in the eastern variant, 73% of the municipalities in the southern variant). From this point of view, on the contrary, the southern variant of the RS1 routing seems to be more advantageous, which, moreover, promotes the accessibility of the relatively remote South Bohemia with its long-term undersized transport infrastructure.

Tab. 4 Value of potential accessibility of regional cities and its change (long-distance model).

| City | Potential accessibility – long-distance model (null variant) | Potential accessibility – long-distance model (RS 1 eastern variant) | Change of potential eastern/null | Potential accessibility – long-distance model (RS 1 south variant) | Change of potential southern/null |
|---|---|---|---|---|---|
| Prague | 82,849.16 | 83,531.72 | +0.82% | 83,448.19 | +0.72% |
| Pilsen | 82,384.74 | 83,499.54 | +1.35% | 83,458.79 | +1.30% |
| Karlovy Vary | 80,992.00 | 81,826.30 | +1.03% | 81,823.25 | +1.02% |
| České Budějovice | 81,141.20 | 82,200.67 | +1.30% | 83,202.32 | +2.54% |
| Ústí nad Labem | 82,030.83 | 82,965.85 | +1.13% | 82,824.82 | +0.97% |
| Liberec | 81,357.02 | 82,390.52 | +1.27% | 82,241.51 | +1.09% |
| Hradec Králové | 82,011.54 | 83,781.26 | +2.15% | 82,848.37 | +1.02% |
| Pardubice | 82,269.64 | 83,891.28 | +1.97% | 83,139.10 | +1.06% |
| Jihlava | 81,404.25 | 83,144.76 | +2.14% | 83,231.78 | +2.24% |
| Brno | 82,298.58 | 83,635.18 | +1.62% | 83,471.39 | +1.43% |
| Zlín | 81,475.80 | 83,281.12 | +2.21% | 83,151.27 | +2.06% |
| Olomouc | 81,438.17 | 83,289.95 | +2.27% | 83,213.01 | +2.18% |
| Ostrava | 80,312.55 | 81,442.02 | +1.41% | 81,339.98 | +1.28% |

Source: accessibility analysis, authors' calculation

## 4. Discussion and conclusion

The aim of this article was to present the use of potential accessibility models in decision-making on tracing the high-speed rail infrastructure. On the example of so-called Rapid connections planned in Czechia, the possibilities of different calibration of the given analysis were introduced. The analyses of potential accessibility were always carried out for all municipalities in Czechia that are serviced by rail transport. At the same time, different routing of HSR from Prague to Brno in the Central Bohemian Region (RS1 eastern and southern variant) was assessed. Both levels of analysis compared both variants of routing in terms of the potential accessibility of all municipalities in the railway network. At the same time, the so-called regional and long-distance model were considered for both variants, which take into account the manner of servicing the entire territory.

Globally, accessibility profit was maximized at all major settlement centers in all 4 calculation variants in the future. Comparing the results from the individual service models, it became clear that in any case, profit was maximized in all district towns and lower-order centers. However, there was a greater gain for the eastern variant of RS1, as it will serve the relatively highly populated area of eastern Bohemia, and the cities of Pardubice and Hradec Králové are better located in the transport network than the eccentrically situated České Budějovice. However, in the calculations of the long-distance model (which is more significant from the HSR point of view, as it will enable the connection of regional cities to the backbone system of territorial service) the southern variant seems to be more advantageous (73% of municipalities with above-average potential over the "null variant" without HSR). Furthermore, a significant geographical aspect is evident where the peripheral areas of Czechia (such as Karlovy Vary Region, Zlín Region, etc.) get the most out of the whole system of Rapid Connections. It is also important to mention that when assessing high-speed rail, the main criterion should be the results from the long-distance model, as high-speed rails are built mainly because of connecting remote areas to major centers and also because of the connection of Czechia to the neighboring countries (although in our country mixed operation also for conventional trains that would serve micro-regional service is assumed).

With regard to the fact that these analyses involve modeling in the GIS environment and the results are partially distorted (they do not include the waiting time of the train at the station, the time for transfer, etc.), it is important to also consider the reality of railway transport in Czechia. South Bohemia is today poorly connected in terms of capacity transport and modernization of the so-called 3rd transit corridor counts on connection to HSR near Benešov. South Bohemia is also currently missing a motorway connection (D3 across the Central Region is difficult to negotiate). This fact, together with the results of all models of accessibility then speaks for the routing of the RS1 southern variant around towns of Benešov and Vlašim.

According to the literature discussed and the results of this research, the change in regional accessibility is the most significant territorial impact of high-speed rail. It manifests itself in various spheres of human activity – from spatial changes of population distribution, support and, development of regional/local economy to changes in tourism attractiveness. When assessing the appropriate routing of traffic structures not only in Czechia, it is therefore important to address this topic in detail. However, when assessing multiple options, accessibility models (whether time or potential) are not the only scientific tools and the economic and environmental impacts of each solution must always be assessed as well.

Potential accessibility has proved to be a suitable tool for assessing changes induced by the construction of new high-speed infrastructure, since it not only takes into account the change in time but also the importance of settlements and their mutual location. The effects of regional and long-distance transport can be appropriately simulated by calibrating the beta time coefficient. Potential accessibility is therefore a challenge predominantly in transport planning and should be given more attention in the preparation of strategic documents and in the preparation of CBA analyzes, as these mostly work with simple time accessibility, respectively with time savings. The potential accessibility can better describe the changes that the construction of new infrastructure will bring.

## Acknowledgements

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# Watershed prioritization for the identification of spatial hotspots of flood risk using the combined TOPSIS-GIS based approach: a case study of the Jarahi-Zohre catchment in Southwest Iran

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**ABSTRACT**

Flash flooding caused by excessive rainfall in a short period of time is one of the worst environmental hazards, especially in arid and semi-arid regions. Watershed prioritisation identifies and ranks the different watersheds in a catchment based on multiple parameters, which play a role in the land and water degradation. This article deals with the prioritization of 24 sub-catchments in the Jarahi-Zohre catchment in southwest Iran by applying the mixed multivariate linear model of TOPSIS. Morphometric parameters, such as the constant of channel maintenance, drainage density, ruggedness number, infiltration index, stream power index, stream frequency, slope, drainage texture rate, relief rate, form factor, bifurcation ratio, as well as the topographic wetness index, were used as TOPSIS input data, along with precipitation information. The results obtained from the weighting analysis show that ruggedness number, slope and rainfall information have the largest impact on flood events. The sub-catchments Seidyon, Emamzadeh Jafar, and Takht Deraza have a high flood risk and should be given the highest priority for soil and water conservation measures. To validate the results, the prioritization scheme was compared to the flood events in recent years.

**KEYWORDS**

morphometry; flood risk; TOPSIS; GIS

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## 1. Introduction

Flood hazard is a type of natural disaster that affects the lives of many human being (Guzzetti et al. 2005; Penning-Rowsell et al. 2005; Salvati et al. 2010). It is one of the natural disasters that recently affect many areas especially with arid and semi climate around the world. People's lives are lost during these disasters, and infrastructures may be destroyed. Floods are regarded as the most terrible climatic disaster in the world in terms of loss of life and property damages. Floods are basically extreme hydrological events due to heavy precipitation. Floods occur at different intervals and with varying durations. Recently, considerable progress in the subject of fluvial geomorphology has been achieved by quantitative studies of streams, drainage basins and underlain substrates. New insights emerged because of quantitative studies using hydro-geometry and/or hydro-morphometry leading to quantitative measures of the land forms. Obviously, human activities have increased flood risk because of increasing population growth and rapid urban and rural development. Flood events are often more severe in developing countries and they are the most severe limitation for sustainable development.

In many countries particularly in developing countries, the management of sediment-related environmental problems is deprived by a lack of information on the rate of erosion and sediment in river catchments (Zakerinejad, Maerker 2014, 2015). Therefore, flood events may cause strong damages and erode the fertile top soils. Moreover, it is one of the most effective phenomena that leads to decreasing soil productivity and pollution of water resources.

Particularly, arid and semi-arid areas are affected since they have scarce vegetation cover after long dry periods and intensive rainfall events in these regions.

Therefore, there is an urgent need for management of water resource and for controlling flood events in the susceptible areas. Morphometric analysis of catchments provides a quantitative description of the drainage system (Rao et al. 2010). Morphometric analysis and land use parameters can be used to conduct a proper prioritization of watersheds even without the availability of soil maps. Hence, watershed prioritization is an essential need for management of prone areas that allows the identification of spatial hotspots of flood risk.

Many recent studies on morphometric analysis use remote sensing and GIS techniques to assess the flash flood susceptibility of catchments (Ames et al. 2010; Bajabaa et al. 2014; Youssef et al. 2016). Some effective and finite parameters were applied by different authors to evaluate flood risk. These parameters include land use, lithology, soil type, drainage density, distance from river, topographic wetness index (TWI), altitude, slope aspect, slope angle and plan curvature (Biswas et al. 1999; Kia et al. 2012; Bajabaa et al. 2014).

There are only few studies that focus exclusively on the morphometric parameters to prioritizes sub-catchments. Many investigations recently conducted in Iran show that terrain parameters (slope, aspect, SPI, TWI, catchment area, …) are the most important factors to predict flood events (Khanbabaei et al. 2013; Cao et al. 2016). Various methods have been used for flood susceptibility mapping. In some recent studies methods were applied like multi-criteria evaluation (Balogun et al. 2015), decision tree (DT) analysis (Tehrany et al. 2013), weights-of-evidence (WoE) (Tehrany et al. 2014), artificial neural network (ANN) (Campolo et al. 2003; Kia et al. 2012; Tiwari et al. 2010), or frequency ratio (FR) (Rahmati et al. 2016).

Hence, he main aim of this research is to prioritize 24 sub-catchments of the Jarahi-Zohre in southwest of Iran using morphometric parameters in order to identify the respective flood risk. In this study we apply GIS tools and the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) model.

## 2. Study Area

The study area is the Jarahi-Zohre catchment, draining into the Persian Gulf (Fig. 1). The study area is located in the southwest of Iran, between 48°16′ to 52°16′ N and 29°46′ to 31°40′ E, and covers an area of ca. 41,014 km$^2$. The area is located on the interface between the over-thrust and the folded Zagros, which structurally follows the over-thrust Zagros.

The altitude of the area approximately varies from 0 to 3639 m a.s.l. The Jarahi-Zohre catchment has


Fig. 1-1 Location of the Jarahi-Zohre catchment in Iran.

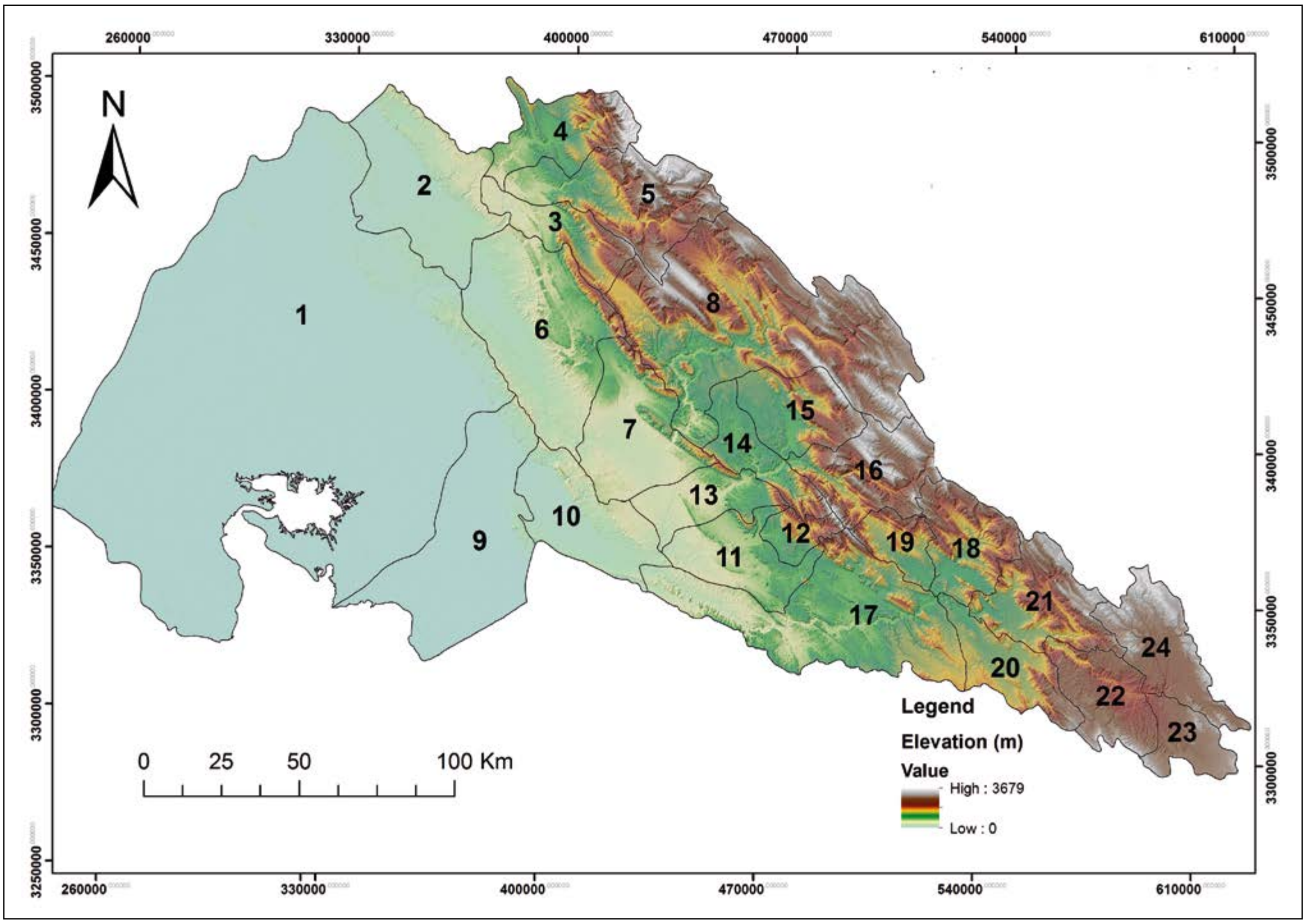


Fig. 1-2 Location of the Jarahi-Zohre catchment in Iran.
The number indicated the name of each sub-catchment (1. Shadegan, 2. Ramhormoz, 3. Daloon, 4. Baghmalek, 5. Sydoon, 6. Jayzan, 7. Bebahan, 8. Takhtedaraz, 9. Handijan, 10. Zydon, 11. Lishtar, 12. Dogonbadan, 13. Khirabad, 14. Sarpari, 15. Dehdasht, 16. Shahbahram, 17. Emamzadeh Jafar, 18. Dashte Rostam, 19. Basht, 20. Norabad, 21. Fahlyn, 22. Saranjilak, 23. Kodyan-Sarga, 23. Ardan-Cheshmeh).

24 sub-catchments, that mostly are located in Khuzestan province in southwest of Iran but some parts of the study area are located in Fars-, Kohgiluyeh-, and the Boyer-Ahmad provinces. The Mediterranean air masses entering from the northwest result in considerable precipitation in the area, which in winter times turns to snow on the higher elevations. The average annual precipitation of the area is 976 mm, the mean temperature is 10.4 °C (Iranian Water Resources Management Company). The Zohreh River enters the Zeydun plain after the confluence with the Kheir Abad. In the South of Aghajari the Zohreh River it is redirected to the South and passes through the Hendijan (Azarang et al. 2019). The river finally arrives at the Persian Gulf at a location called Chatla. The most parts in east and southeast have mountain areas while the area in west they are mostly flat with low angle slopes.

## 3. Methodology

Digital Terrain Models (DTM) are a gridded digital representation of a terrain, with each pixel value corresponding to a terrain elevation above a specific datum. DTMs are useful to extract morphometric parameters that characterize the terrain morphology and related processes (Wilson, Gallant 2000; Montgomery, Dietrich 1994). In this study we used the ASTER GDEM with 30 m resolution to extract the morphometric parameters for the whole study area. The Arc Hydro extension in Arc GIS10.4 and SAGA 7.8.0 (System for Automated Geo-Scientific Analyses, Conrad 2006) were used to prepare the ASTER GDEM and to derive the morphometric parameters for our study area. We can differentiate between morphometric parameter describing:

i) the morphology of the surface,
ii) hydrological parameters to describe runoff generation and potential flow pattern,
iii) transport and deposition of sediments,
iv) climatic parameters (Hengl et al. 2003).

For this study we derived a set of topographic indices (Table 1) that included: Bifurcation ratio (Rb), Drainage density (Dd), Constant of channel maintenance (C), Stream frequency (Fs), Form factor (Ff), Drainage texture (T), Ruggedness number (Rn), Relief ratio (Rh), Average slope (Sm), Topographic Wetness

**Tab. 1** Formulae for computation of morphometric parameters.

| | Morphometric parameters | Formula | Reference |
|---|---|---|---|
| **1** | Bifurcation ratio (Rb) | Rb = Nu / Nu + 1,<br>where Nu = total number of stream segments of order ‘u’,<br>Nu + 1 = number of segments of the next higher order | Sharma et al. 2008 |
| **2** | Drainage density (Dd) | Dd = Lu /A,<br>where Dd = drainage density,<br>Lu = total stream length of all orders,<br>A = area of the basin(km²) | Sharma et al. 2008 |
| **3** | Constant of channel maintenance (C) | $C = A/\sum_{i=0}^{i=n} Li$,<br>where A = area of the basin, km²,<br>Li = total number of stream segments of order | Horton 1945 |
| **4** | Stream frequency (Fs) | Fs = Nu/A,<br>where Fs = stream frequency,<br>Nu = total number of streams of streams of all order,<br>A = area of the basin, km² | Horton 1945 |
| **5** | Form factor (Ff) | Ff = A/Lb²,<br>where Ff = form factor,<br>A = area of the basin, km²,<br>Lb = basin length | Sharma et al. 2008 |
| **6** | Drainage texture (T) | T = Nu/P,<br>where Nu = total number of streams of all orders,<br>P = basin perimeter, km | Horton 1945 |
| **7** | Relief ratio (Rh) | Rh = ΔH/Lb,<br>where ΔH is the height difference of the catchment,<br>Lb = total stream length of all orders | Moore et al. 1991 |
| **8** | Ruggeness number (Rn) | Rn = ΔH × Dd,<br>where ΔH is the height difference of the catchment,<br>Dd = Drainage density | Moore et al. 1991 |
| **9** | Average of slope (Sm) | Sm = ΔH/A,<br>where ΔH = the height difference of the catchment,<br>A = area of the basin, km² | Sharma et al. 2008 |
| **10** | Topographic Wetness Index (TWI) | TWI = ln(a/tagβ)<br>where a = the upslope contributing area,<br>β = the topographic gradient (slope) | Olaya, Conrad 2008 |
| **11** | Stream Power Index (SPI) | SPI = As × tagβ,<br>where As = specific catchment area,<br>b = slope in degree | Moore, Wilson 1992 |
| **12** | Infiltration factor (Ig) | Ig = Dd × Fs,<br>where Dd = drainge density,<br>Fs = stream frequency | Zavoiance 1985 |
| **13** | The mean perceptions of the catchment (Rm) | Rm = Rd/A | – |

Index (TWI), Stream Power Index (SPI), as well as Infiltration (Ig) and mean perception (1985–2012). The listed indices were used in the prioritization procedure as as input information for the TOPSIS model.

Table 2 shows these indices and the respective methods applied for their delineation from the ASTER GDEM. The ASTER GDEM was preprocessed with low pass filtering to extract artefacts and errors like local noise and terraces (Maerker, Heydari Guran 2009; Zakerinejad, Maerker 2013; Vorpahl et al. 2012). Subsequently, the ASTER GDEM was hydrologically corrected eliminating sinks using the algorithm proposed by Planchon and Darboux (2001).

After calculating and mapping the topographic parameter, in order to prioritize 24 sub-catchment areas, the multivariate linear mixed-TOPSIS model was applied for the study area. In the next step the model was validated using information on recent flood events existing for each sub-catchment.

## 3.1 TOPPIS Model

In this research, the TOPSIS model (Technique for Order of Preference by Similarity to Ideal Solution) (Hwang, Yoon, 1981) was used as screening tool to derive a prioritization of the watersheds.

This model is a multi-criteria decision analysis method and it is based on the concept that the chosen alternative should have the shortest distance to the positive ideal solution (PIS) and the longest distance to the negative ideal solution (NIS). The TOPSIS model is flexible in terms of input data and hence, a valuable tool for land use planner and for monitoring purposes in changing landscapes. The TOPSIS approach has been successfully applied in different environments (e.g. Badar et al. 2013; Biswas et al. 1999; Chu, Lin 2009), although it is not as widely applied as other multi attribute methods. This model is an effective method in handling Multicriteria Decision-Making (MCDM). The positive ideal solution attempts to seek the maximization of benefit criteria and the minimum of the cost criteria, whereas the negative ideal solution is just the opposite.

### 3.2 The structures of TOPSIS model

Suppose that there is an MCDM problem with m alternatives and n criteria, and the decision matrix is $[x_{ij}]_{m\times n}$. The procedure of TOPSIS consists of the following steps:

1. Calculate the normalized decision matrix, this step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. Normalize scores or data as follows:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1,\ldots,m, j = 1,\ldots,n \quad (1)$$

2. Calculate the weighted normalized decision matrix, assume we have a set of weights for each criteria $w_j$ for j = 1, ..., n. Multiply each column of the normalized decision matrix by its associated weight

$$v_{ij} = w_j n_{ij}, i = 1,\ldots,n \quad (2),$$

where $w_j$ is the weight of the j-th criterion, and $\sum_{j=1}^{n} w_j = 1$.

3. Determine the positive ideal ($A^+$) and negative ideal ($A^-$) solution.

$$A = \{v_{1,\ldots,}^+ v_n^+\} = \{\max v_{ij}, j = 1,\ldots,n\} \quad (3)$$

$$A = \{v_{1,\ldots,}^- v_n^-\} = \{\min v_{ij}, j = 1,\ldots,n\} \quad (4)$$

4. Calculate the separation measures, using the dimensional Euclidean distance. The separation of each alternative from PIS is given by

$$d_i^+ = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2\right\}^{\frac{1}{2}}, i = 1, \ldots, m \quad (5)$$

Similarly, the separation from NIS is given by

$$d_i^- = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2\right\}^{\frac{1}{2}}, i = 1, \ldots, m \quad (6)$$

5. Calculate the relative closeness to the ideal solution.

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1, \ldots, m \quad (7)$$

6. Rank the preference according to $C_i$.

For the validation of the TOPSIS approach, the prioritization of each sub-catchment to flood risk was compared to the recent flood events using the Frequency Index (FI).

## 4. Result and discussion

Terrain analysis or morphometry is yielding valuable quantitative information on the earth's surface and on processes forming the earth surface forms and features. Hence, these techniques provide useful information for the evaluation of watersheds and their management.

In this study, Morphometric parameters (bifurcation ratio, drainage density, constant of channel maintenance, stream frequency, form factor, drainage texture, ruggedness number, relief ratio, average slope, topographic wetness index, stream power index, infiltration factor, and rainfall factors) were used as input parameters for the TOPSIS approach in order to derive a proper prioritization of the watershed to identify the spatial hotspots of flood risk of each sub-catchments in our case study in the southwest of Iran.

In this study, we used the multivariate regression for weighting the criteria since flood data were available for the whole study area.

After the calculation of the flood event frequency, each sub-catchment was ranked attributing with the score between 0 and 10. Afterwards we processed each scores for 534,231 homogenous units and 13 morphometric parameters using SPSS software. Between different multivariate regression, the ENTER regression with 93% confidence level was selected.

Figure 2 shows the overlaid flood events points and homogenous units map and also Equation 8 shows the results from stochastic analysis with, R = 0.96 for the study area.

$$Y = 0.07 - 0.0018 X_C - 0.0032 X_{Dd} + 0.68 X_{Rn} + 0.00056 X_S + 0.00089 X_{SPI} - 0.0031 X_{Fs} + 0.24 X_{Slope} - 0.0057 X_{Rt} + 0.0023 X_{Rh} + 0.0041 X_{Ff} + 0.016 X_{Rain} - 0.018 X_{Rb} + 0.0019 X_{TWI} \quad (8)$$

The results for the weighting criteria applying the linear regression shows that the ruggedness number, slope and rainfall with 0.068, 0.024 and 0.16 rated as the highest impact on flood events in the study area (Table 2).

In some other studies, these parameters have been the most important factor for the flood events (Khayri Zadeh et al. 2012; Saghafian et al. 2008).

While drainage texture, drainage density and stream frequency respectively, with values of −0.0057, −0.0032 and −0.0032 respectively have the lowest impact on flood events in the study area. The other parameters fall between these maximum and minimum ranking values highest and lowest ranking.

**Tab. 2** The results of multivariate regression analysis.

| Morph metric parameters | Mark equations | Weight | The significance level |
|---|---|---|---|
| Constant of channel maintenance | $X_C$ | −0.00180 | 0.0010 |
| Drainage density | $X_{Dd}$ | −0.03200 | 0.0010 |
| Ruggedness number | $X_{Rn}$ | 0.06800 | 0.0010 |
| Infiltration factor | $X_S$ | 0.00056 | 0.0000 |
| Stream Power Index | $X_{SPI}$ | 0.00089 | 0.0010 |
| Stream frequency | $X_{Fs}$ | −.003100 | 0.0001 |
| Slope | $X_{Slope}$ | .024000 | 0.0000 |
| Drainage texture | $X_{Rt}$ | −.005700 | 0.0010 |
| Relief ratio | $X_{Rh}$ | .002300 | 0.0010 |
| Form fact | $X_{Ff}$ | .004100 | 0.0000 |
| Rainfall | $X_{Rain}$ | .016000 | 0.0000 |
| Bifurcation ratio | $X_{Rb}$ | −.018000 | 0.0000 |
| Topographic Wetness Index | $X_{TWI}$ | .019000 | 0.0000 |

Sub-catchment according to the equations applied in step 3 of the TOPSIS algorithm, the positive ideal solution ($A^+$) and negative ideal solution ($A^-$) are calculated for all criteria, and then a layer is created for each v + j and v − j. The separation of each alternative from the positive ideal solution layer and the separation of each alternative from the negative ideal solution layer are calculated based on Equations 3–6, respectively (Table 3).

According to table 3 the result of the ranking procedure of each sub-catchment indicates that the Sydon, Emamzadeh Jafar and Takhte Daraz sub-catchments have the shortest distance to the positive ideal (0.0097, 0.0098, 0.0095) and highest distance to the negative ideal (0.7745, 0.769, 0.7625), therefore they are ranked in the first three rating classes for flood risk. Therefore, these susceptible sub-catchments should get more attentions and should be prioritized by land use planner and for a sustainable landuse management.

On the other hand, the Jayzan, Saranjilak and Shadegan subcatchments show the highest distance to the positive ideal (0.0065, 0.0063, 0.0059) and shortest distance to the negative ideal (0.0080, 0.0081, 0.008) and are characterized by the lowest scoring of 0.5532, 0.5633 and 0.5766 respectively. Thus, they show the lowest flood risk.

The Sydon sub-catchment shows high flooding risk expressed by high values of the applied morphometric parameters. In turn, these parameters have a direct relationship with flood events. Therefore, these sub-catchments has the highest flood risk. The Sydoon

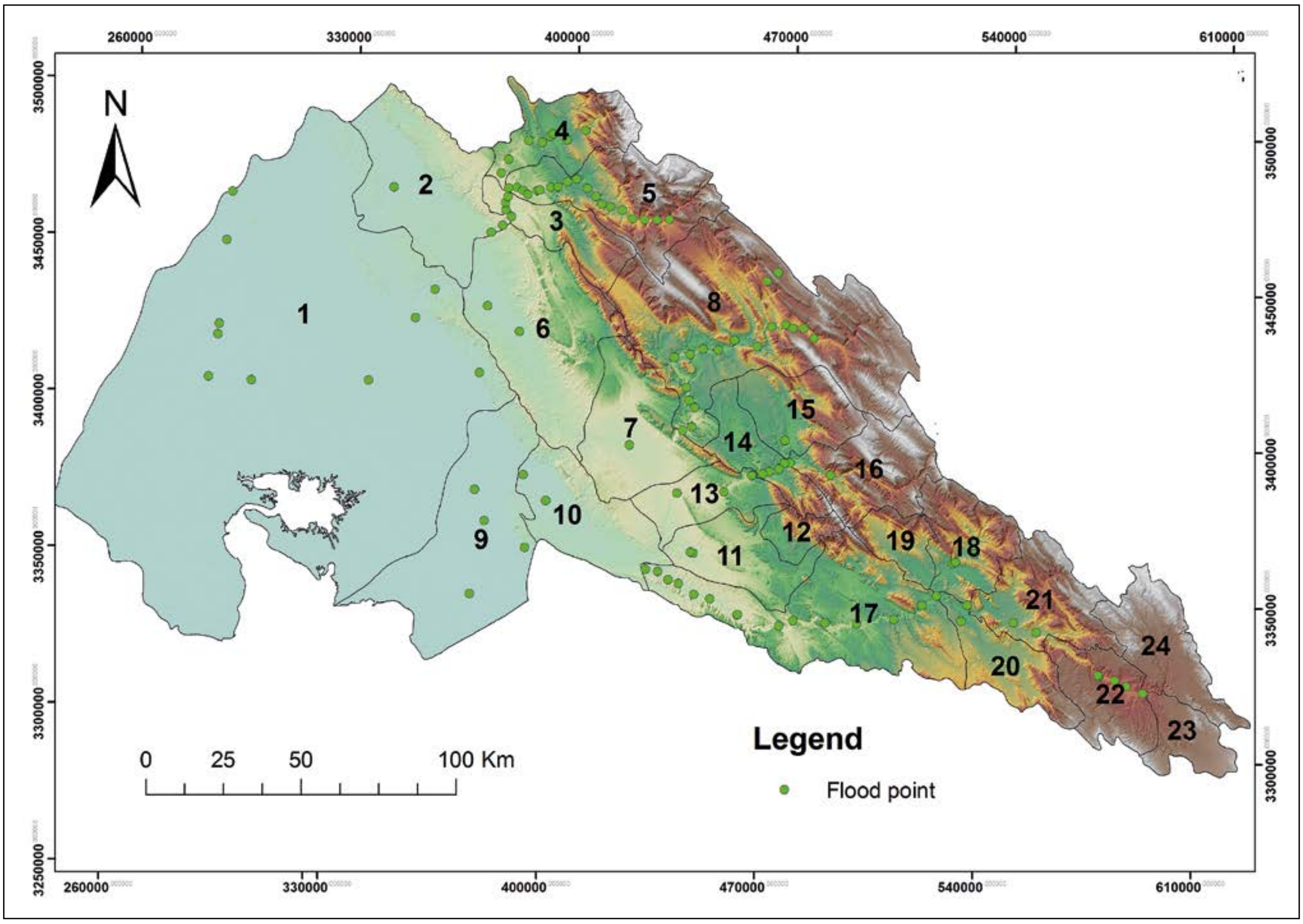


**Fig. 2** The distribution of flood events in the study area.

Tab. 3 The normal matrix of the all sub-catchments in the study area.

| Sub-catchment | $D_i^+$ | $D_i^-$ | $Cl_{i+}$ | Ranking | Flood frequency |
|---|---|---|---|---|---|
| Shadegan | 0.0059 | 0.0080 | 0.5766 | 22 | 2 |
| Ramhormoz | 0.0054 | 0.0081 | 0.5996 | 19 | 1 |
| Dalon | 0.0031 | 0.0093 | 0.7497 | 6 | 3 |
| Bagh Malek | 0.0032 | 0.0096 | 0.7470 | 7 | 4 |
| Sydon | 0.0028 | 0.0097 | 0.7745 | 1 | 14 |
| Jayzan | 0.0065 | 0.0080 | 0.5532 | 24 | 1 |
| Bebahan | 0.0035 | 0.009 | 0.7180 | 13 | 1 |
| Takhte Daraz | 0.0029 | 0.0095 | 0.7625 | 3 | 12 |
| Hendijan | 0.0057 | 0.0080 | 0.5848 | 20 | 2 |
| Zidon | 0.0057 | 0.0079 | 0.5801 | 21 | 1 |
| Lishtar | 0.0038 | 0.0089 | 0.6964 | 16 | 1 |
| Dogonbadan | 0.0030 | 0.0094 | 0.7559 | 4 | 2 |
| Khirabad | 0.0035 | 0.0089 | 0.7145 | 15 | 2 |
| Sarperi | 0.0030 | 0.0094 | 0.7541 | 5 | 5 |
| Dehdasht | 0.0031 | 0.0092 | 0.7457 | 8 | 1 |
| Shahbaram | 0.0034 | 0.0091 | 0.7281 | 11 | 2 |
| Emamzdadeh Jafar | 0.0029 | 0.0098 | 0.7690 | 2 | 12 |
| Dashte Rostam | 0.0035 | 0.0089 | 0.7166 | 14 | 2 |
| Basht | 0.0033 | 0.0090 | 0.7295 | 10 | 0 |
| Norabad Mamsani | 0.0039 | 0.0086 | 0.6865 | 17 | 1 |
| Fahlian | 0.0035 | 0.0089 | 0.7188 | 12 | 2 |
| Saranjilak | 0.0063 | 0.0081 | 0.5633 | 23 | 1 |
| Kodian | 0.0044 | 0.0084 | 0.6554 | 18 | 0 |
| Ardakan | 0.0033 | 0.0091 | 0.7343 | 9 | 1 |

sub-catchment shows especially steep slopes (39.4%) indicating high runoff velocities and quick drainage. Thus, as stated by Tucker and Bras (1998) the hill slope processes control the watershed hydrology.

The high value of drainage density indicates the poor vegetation and low infiltration rate while the low drainage densities are related to highly permeable soils and coarse textures (Horton 1945; Sharma et al. 2008). Stream frequency in these high rated flood risk sub-catchments implies increasing stream numbers with respect to increasing drainage density (Bhattacharjee 2016).

The ruggedness number reflects the topography and hydrological characteristics of the catchments and is directly related to flooding events (Aher et al. 2014). The relief ratio has a direct relationship with the river slope, basin hydrological processes and soil erosion processes (Srivastava et al. 2003). The form factor describes the direct impact of flows in the watershed in terms of water dischrage and sediment yield. The form factor is identical to unity when the basin shape is a square, and decreases with increasing elongation (Zavoianu 1985). The higher bifurcation ratio of the Sydon sub-catchment is also responsible for early hydrograph peaking during the storm events compared to the others sub-catchments.

## 5. Conclusions

Flood events can dramatically erode and destroy fertile top soil layers and are the main cause of desertification in many parts of arid and semi-arid areas in the world.

Watershed prioritization for the identification of spatial hotspots of flood risk using a combined GIS-TOPSIS based approach is a cost effective procedure requiring a limited amount of input data and hence, is a is very useful tool for land use planner and basin managers. We applied the method to assess the influence of watershed characteristics on the flood risk in the Zohreh and Jarahi catchment in southwest of Iran.

The parameters used in this study are include, bifurcation ratio, drainage density, constant of channel maintenance, stream frequency, form factor, drainage texture, ruggedness number, relief ratio, infiltration factor, rainfall, topographic wetness index, stream power index and average slope parameters. Since there is a close relationship between the morphometric parameters and the mean annual floods (Cao et al. 2016), we know that sub-catchments with high values of morphometric parameters are more prone to flood risk.

The results of the prioritization parameters using multivariable linear regression showed that especially the ruggedness, slope and rainfall indices have the highest impact on the occurrence of flood events in our study area.

The Sydon, Emamzadeh Jafar and Takhte Daraz sub-catchments show a high risk of flood hazard compared to the other sub-catchments. Therefore, land use planners and basin managers should give more attention to LULC management particularly, in these high flood risk areas. In order to validate the results of the TOPSIS model, the prioritization of sub-catchments of flood risk were compared to recent flood event data.

The overlay of the spatial distribution of flood events with the sub-catchments show that the three-sub-catchments Sydon, Emamyadeh Jafar and Takhte Daraz have a higher number of flood events than the other sub-catchments. Consequently, there is a good correspondence of the model results and the validation information. We conclude that the TOPSIS results can be used for future studies and the model be applied in other watershed areas.

In fact, using morphometric parameters we can prioritize the watershed in order to develop protection plans for each sub-catchments with low cost and time effort (Aher et al. 2014; Javed et al. 2009).

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