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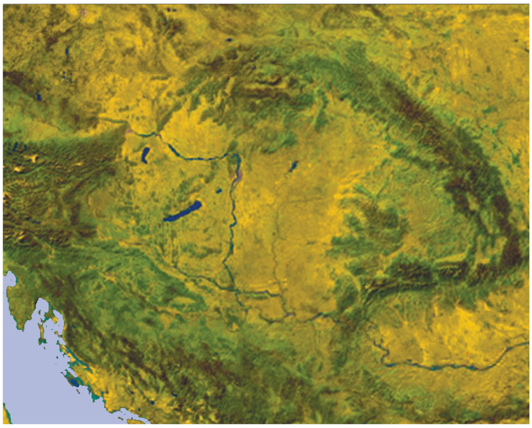

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Effects of renewable energy on landscape in Europe: Comparison of hydro, wind, solar, bio-, geothermal and infrastructure energy landscapes

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Abstract

Landscape quality has become a fundamental issue in the development of renewable energy (henceforth abbreviated RE) projects. Rapid technological advances in RE production and distribution, coupled with changing policy frameworks, bring specific challenges during planning in order to avoid degradation of landscape quality. The current work provides a comprehensive review on RE landscapes and the impacts of RE systems on landscape for most European countries. It is based on a review by an interdisciplinary international team of experts of empirical research findings on landscape impacts of RE from thirty-seven countries that have participated in the COST Action TU1401 Renewable Energy and Landscape Quality (RELY).

Keywords: landscape impacts, renewable energy, energy transition, landscape quality

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Introduction

Over the last two decades many European countries have adopted and implemented policies in order to initiate a transition to more sustainable energy systems (European Commission 2009). This energy transition is based on different kinds of renewable energy (abbr. RE) and associated systems. All these RE systems have transformed land use and, in many cases, reshaped the landscapes of Europe. RE has generally lower energy densities than other sources, requiring more surface area to produce an equivalent amount of power as non-RE systems (van Zalk, J. and Behrens, P. 2018) and their relative visual impact is often higher (Wolsink, M. 2007). Therefore, their impact on landscape quality has become a fundamental issue in the development of RE projects. Local opposition based on landscape issues has significantly limited the growth of the RE sector in Europe (Upreti, B.R. and van der Horst, D. 2004; Wolsink, M. and Breukers, S. 2010; Devine-Wright, P. and Batel, S. 2017). In addition, rapid technological advances in the production and distribution of RE, coupled with changing policy frameworks bring specific challenges for energy planning to avoid the degradation of landscape quality.

Each RE system transforms the landscape in a specific way, therefore it can affect landscape quality in different forms. In addition to the type of RE, the impact also varies depending on the context and scale of development and the methods used (Benediktsson, K. *et al.* 2018).

The main research questions were: (1) What are the geographical patterns of development of different forms of RE and landscapes associated with them in Europe? (2) What is the state of knowledge on landscape impacts of RE infrastructures in Europe and on different types RE landscapes? (3) How should be RE systems planned for converting a landscape with elements of energy chain into sustainable energy landscape? (4) What are the common features and differences between landscape impacts of hydro, wind, solar, bio and geothermal energies, and associated energy infrastructures?

Objectives of this paper are:

1. to explore the state of REs development in Europe that shows distribution of development of REs and thus extension of RE landscapes in Europe,
2. to provide a comprehensive review on landscape impacts of each RE system type,
3. to explore different characteristics of six RE landscape types that should be carefully planned in order to shape sustainable energy landscapes.

Theoretical background

A growing number of studies on different kinds of renewables (Pasqualetti, M.J. 2013; Bakken, T.H. *et al.* 2014; Frolova, M. *et al.* 2015a, b; Solomon, B.D. and Barnett, J.B. 2017; Pasqualetti, M. and Stremke, S. 2018; Roth, M. *et al.* 2018) has highlighted their impacts on landscapes and their quality. Energy landscape has become a recognized landscape type, defined as a multi-layer landscape characterized by one or more elements of the energy chain comprising combinations of technical and natural sources of energy within a landscape. Energy landscapes are best understood in terms of their multiple spatiality, including material and immaterial dimensions (Calvert, K. *et al.* 2019).

In this paper we study hydro, wind, solar, bio- and geothermal landscapes. Their spatial qualifications are based on the amount of space required for energy development and on spatial dominance (Pasqualetti, M. and Stremke, S. 2018). Renewable energy infrastructure creates a ‘component’ or ‘layer’ type, and ‘entity’ type of energy landscape. The ‘component’ or ‘layer’ type of landscape may require a large commitment of land. In ‘entity’ type landscapes, energy production presents the predominant land use. As the authors claim ‘entity’ energy landscapes require substantially different decision-making processes compared with ‘component’ energy landscapes. Finally, an ensemble of auxiliary elements referred to assimilation, conversion, storage, transport or transmission of energy produced is considered as 'infrastructure energy landscapes' (Uyterlinde, M. *et al.* 2017), spatially unique, largely empty entities within which other land uses are rarely possible (Pasqualetti, M. and Stremke, S. 2018).

RE landscapes are dynamic systems, shaped both by natural evolution of landscape and constantly changing societal needs. In this sense, it is important to take into consideration the evolving character of perceptions of RE landscapes. As any landscape, energy landscapes are also shaped by the perceptions of the people who use, share and value them (Olwig, K.R. 2007). Several studies have shown that whether the perception of these landscapes will be positive or negative depends not only on its characteristics, but also on the 'genius loci' shaped by relation between local people and their territory and resources, and reflects multiple layers, systems of values, aspirations and beliefs, associated to these landscapes (Frolova, M. 2017; Bevk, T. and Golobič, M. 2018).

The paper focuses on different aspects of RE effects on landscape with the aim of advancing the conceptual framework for RE landscape. We analyze the material sub-systems of the RE landscape which are related to the extraction and use of energy resources. Only if these sub-systems are carefully adapted to the other landscape sub-systems, landscape structure and functions, landscape quality is not affected and could be even improved. Therefore, a comparative analysis of RE effects on landscape is crucial for energy planning and for shaping sustainable energy landscapes. We explore both the substantive and spatial characteristics of RE landscapes in order to understand the scope of effects of RE infrastructures and the ways to avoid their negative impacts and to enhance their positive landscape effects.

Landscape impact is understood in this paper as the effect of RE systems on the physical landscape. Landscape impacts of RE systems can be negative or positive, permanent or temporary, primary or secondary; they can be accumulative and can arise at different scales (Bell, S. 2017). They also vary in nature and scale. These effects include both potential changes that arise to landscape character and available views in a landscape from a RE facility. Beyond the direct landscape impact of the RE facilities, there are potentially various negative environmental impacts with an influence on landscape character.

In this paper, we differentiate three groups of landscape-related impacts: 1. direct impacts on visual and aesthetical characteristics of landscape, 2. effects related with land use changes, 3. indirect landscape impacts related to environmental issues.

Materials and methods

This paper is based on literature review collected by a team of experts from the 37 COST countries. A map and a table were prepared that provide a European overview of production from hydro, wind, solar, bio- and geothermal sources, as well as the share of RE in energy consumption.

Secondly, a comparison was made of the state of knowledge on landscape impacts of different RE technologies, and some most commonly mentioned impacts and their mitigation strategies were described.

The data on RE utilization and electricity production capacities in the COST action-member countries were complemented with quantitative analysis on power density of land use efficiency for each RE source. Since there were no comparable data on their value for each type of RE in the European countries, we used estimations of van Zalk, J. and Behrens, P. (2019) and Trainor, A.M. *et al.* (2016). Van Zalk, J. and Behrens, P. (2019) calculated power densities for solar, wind, geothermal, hydro, and biomass, including consideration on the total footprint, efficiency and/or capacity factor. Trainor, A.M. *et al.* (2016) calculated the area of direct footprint for each RE type.

Finally, some essential characteristics, and those direct and indirect landscape impacts of RE of each landscape type that have been most discussed in the literature, were compared specifying sub-types of some RE landscapes.

Overview of renewable energy landscapes in Europe and their landscape impact

The literature on the impacts of RE systems is vast. Papers on hydropower have lost their earlier predominance, and studies of wind and solar energy now prevail. Studies of bioenergy impacts are growing in number. According to the reviewed papers, the most controversial RE system in terms of direct landscape effects is wind (Picchi, P. *et al.* 2019), followed by solar energy. In terms of environmental impacts and effects on land use, the most discussed RE system is bioenergy.

Figure 1 shows all forms of usable RE, including primary production in each country by type and total share in consumption. *Table 1* focuses only on electricity production capacities, specifying sub-types of some REs and provides data for tidal, wave and ocean energy in addition to the types mentioned above, based on 2016 data from the EU statistical office.

Certain clarifications and reservations need to be made regarding these data. For some RE sources, the production of energy can take several forms. This is especially the case regarding energy from biological sources, which is produced in various forms (solid, liquid or gas). The Eurostat database reports all these categories and they are included in the total figure, which is used as a basis for bioenergy on the map.

For solar energy, the Eurostat database reports two forms: photovoltaic (abbr. PV) and thermal. The latter, however, includes both electrical production and the direct production of hot water for domestic use. These two forms are shown together on the map. Likewise,

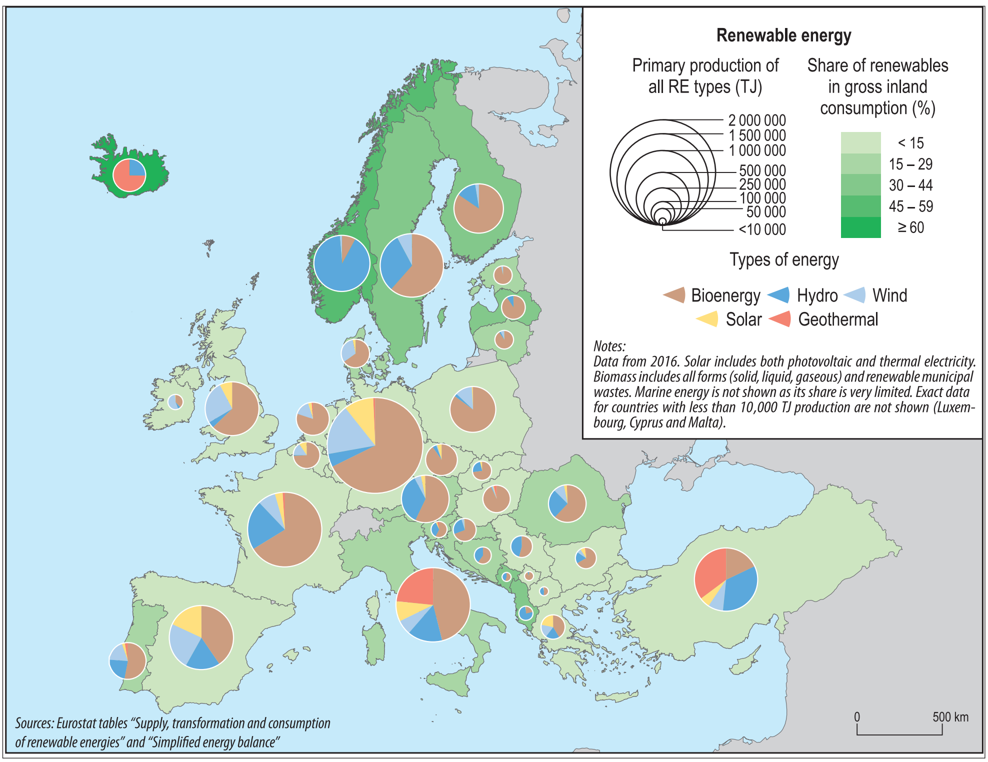

Fig. 1. Renewable energy utilization in Europe, 2016. Compiled by Benediktsson, K., Herrero-Luque, D., Kabai, R., Sismani, G. and Słupiński, M. *Data source*: Eurostat, BFE Switzerland.

Table 1. Electricity production capacities for renewables and wastes in 2017, MW

Country	Total	Hydro	Wind	Solar PV	Solar thermal	Geothermal	Solid biofuels	Liquid biofuels	Biogases	Municipal waste	Tide, wave, ocean
European Union member states											
Austria	19,687	14,150	2,887	1,269	–	0.9	837.8	1.2	180.1	541.4	–
Belgium	8,874	1,423	2,806	3,610	–	–	559.2	45.9	182.5	248.6	–
Bulgaria	5,158	3,372	698	1,036	–	–	23.0	–	29.0	–	–
Croatia	2,927	2,205	576	60	–	–	42.0	0.0	44.6	–	–
Cyprus	277	–	158	110	–	–	–	–	9.7	–	–
Czechia	5,471	2,265	308	2,070	–	–	402.0	–	372.0	55.0	–
Denmark	8,442	9	5,522	906	–	–	1,504.3	0.5	107.6	391.7	–
Estonia	705	7	312	–	–	–	165.0	–	11.0	210.0	–
Finland	7,356	3,272	2,044	74	–	–	1,966.0	–	–	–	–
France	50,138	25,706	13,512	8,610	–	15.9	808.0	4.1	385.9	876.6	218.9
Germany	119,216	11,120	55,718	42,337	2.0	32.0	1,600.0	230.0	6,169.0	2,008.0	–
Greece	8,686	3,392	2,624	2,606	–	–	2.6	–	61.5	–	–
Hungary	1,215	57	329	344	–	3.0	356.0	–	80.0	46.0	–
Ireland	4,002	529	3,318	16	–	–	5.5	–	56.1	78.0	–
Italy	56,471	22,426	9,737	19,682	–	767.2	684.1	986.7	1,371.5	816.3	–
Latvia	1,796	1,564	77	1	–	–	93.7	–	60.3	–	–
Lithuania	1,556	877	518	74	–	–	45.0	–	25.0	17.0	–
Luxembourg	1,623	1,331	120	128	–	–	14.8	–	12.3	17.3	–
Malta	117	–	0	112	–	–	–	–	4.6	–	–
Netherlands	8,264	37	4,202	2,903	–	–	252.0	–	221.0	649.0	–
Poland	9,434	2,390	5,759	287	–	–	708.8	–	229.2	59.2	–
Portugal	13,582	7,226	5,124	579	–	29.1	471.2	–	70.1	81.8	0.4
Romania	11,236	6,692	3,030	1,374	0.1	0.1	118.9	–	21.6	–	–
Slovakia	3,307	2,523	4	528	–	–	149.0	–	91.0	12.0	–
Slovenia	1,660	1,347	5	247	–	–	33.0	1.4	27.4	–	–
Spain	51,357	20,079	23,100	4,725	2,304.0	–	677.0	–	225.0	242.0	5.0
Sweden	28,746	16,502	6,611	244	–	–	3,706.0	547.0	2.0	1,134.0	–
United Kingdom	43,301	4,619	19,835	12,776	–	–	3,191.0	–	1,771.0	1,091.0	18.0
EFTA member countries											
Iceland	2,707	1,995	2	–	–	710.0	–	–	–	–	–
Liechtenstein	–	–	–	–	–	–	–	–	–	–	–
Norway	33,274	31,930	1,207	–	–	–	27.0	–	10.0	100.0	–
Switzerland	–	–	–	–	–	–	–	–	–	–	–

Table 1. (continued)

Country	Total	Hydro	Wind	Solar PV	Solar thermal	Geothermal	Solid biofuels	Liquid biofuels	Biogases	Municipal waste	Tide, wave, ocean
EU candidate and potential countries											
Albania	2,048	2,047	–	1	–	–	–	–	–	–	–
Bosnia and Herzegovina	2,228	2,211	–	16	–	–	–	–	1.0	–	–
Kosovo	121	80	34	7	–	–	–	–	–	–	–
Montenegro	724	652	72	–	–	–	–	–	–	–	–
North Macedonia	731	671	37	17	–	–	–	–	7.0	–	–
Serbia	3,086	3,038	25	10	–	–	–	–	13.0	–	–
Turkey	38,745	27,273	6,516	342	–	1,063.7	83.0	12.3	376.5	–	–
European Union – 28	474,784	155,118	168,934	106,707	2,306.1	848.2	18,415.7	1,816.9	11,820.9	8,574.8	242.3
Total	*558,449*	*225,015*	*176,827*	*110,178*	*2,306.1*	*2,621.8*	*18,525.7*	*1,829.2*	*12,228.4*	*8,674.8*	*242.3*

– Data not available. *Source*: Eurostat 2017.

geothermal energy (abbr. GE) is utilized in two distinct forms – directly as hot water and through conversion to electricity. The map shows them combined. Indeed, the Eurostat database does not distinguish between these forms. For the thermal part of GE, reliable and fully comparable statistics are hard to find. The map and the table give a good indication of the overall state of RE in Europe (in 2016 and 2017), and the considerable geographical diversity that exists in terms of RE development. It will serve as a reference point for the discussion of individual RE sources, their main characteristics and landscape impacts.

Generally, the geographical patterns of development of different types of RE systems match with the geography of studies on their landscape impacts.

Hydro energy landscape

Hydro energy landscapes are the best established among RE landscapes, probably due to the long history of development of hydro power. Hydro energy is the most mature technology that harnesses RE and the second most important source in Europe, representing 22 per cent of all RE. Norway leads in terms of absolute production, while its production is rather insignificant in Germany, Czech Republic, and the UK, and almost absent in countries where the topography is not conductive: Poland, Hungary and Denmark (see *Figure 1*).

The European Commission and the European Small Hydropower Association have set a threshold of 10 MW installed power for distinguishing between small and large hydropower plant (abbr. SHP and LHP) (European Commission 2015). In 2010 nearly 21,800 SHPs were in operation within Europe (Frolova, M. *et al.* 2015c). Nevertheless, in 2011 90 per cent of installed capacity in Europe was still made up of LHPs (European Commission 2013). Only Austria relies more heavily on SHPs by 16 per cent of total nationwide capacity of hydropower plants.

The hydropower landscape is based on collection of water and utilization of potential energy to generate electricity (Pasqualetti, M. and Stremke, S. 2018). Although it is often associated with dams as a key element, several types of hydropower plants exist: hydroelectric dams, pumped-storage plants, run-of-river plants and tidal plants. Additionally, hydropower plants are often classified according to their energy production capacity. Exact definitions and thresholds can be somewhat arbitrary (Frolova, M. 2017).

The impacts of hydropower developments depend on type, size and the landscape in which it is placed. Average power density of hydropower systems varies extensively from 0.01 W_e/m^2 to 0.11 W_e/m^2 in large facilities with reservoirs and up to 0.75 W_e/m^2, in case of large run-of-river plants (van Zalk, J. and Behrens, P. 2019). While the average direct footprint was estimated as 16.86 km^2/TWhr, it varies greatly from 6.45 to 86.95 km^2/TWhr (Trainor, A.M. *et al.* 2016). Due to the varied power density of hydropower plants, differences in the spatial extent of different types of facilities, and the visual dominance of hydroelectric energy infrastructures, hydropower landscapes offer a great variety of 'components' or 'layers', in case of SHP, and 'entity energy landscapes' in case of LHP.

Land use impacts are mentioned only in the context of flooded area and creation of artificial reservoirs.

It is commonly accepted that negative landscape effects of large facilities could derive from construction of power stations, damming rivers, and creating artificial reservoirs (Cohen, J.J. *et al.* 2014; Hastik, R. *et al.* 2015). In addition, in LHPs, dams, power stations and transmission lines are huge structures and their presence constitutes substantial change in landscape features (Hastik, R. *et al.* 2015). The river flow fluctuation caused by hydropower plants results in dramatic changes in downstream ecosystems and sometimes in the landscapes of entire river basins (Frolova, M. 2010).

Landscape impacts of SHPs are different, and considered relatively small. They often utilize natural differences in altitude, small flows or the decline in the pipes from water infrastructure to provision of power for small communities. SHPs also often utilize run-of-the-river designs, which may require a small, less obtrusive dam, diverts a portion of a river's water into a canal or pipe to spin turbines. Consequently, run-of-the-river designs have risen in popularity lately. Nevertheless, individual SHPs cover large areas and most of their infrastructure is usually visible from the surface while some of the infrastructures of LHPs are located underground. Therefore, the negative landscape impact of a large number of SHPs could exceed that of one LHPs with equivalent output (Abbasi, T. and Abbasi, S.A. 2011; Koutsoyiannis, D. 2011; Bakken, T.H. 2014).

Diversion for electricity generation can lead to drying up of large watercourses and the damming of rivers can lead to the erosion of the shoreline, therefore damaging soil and biota. Increased water discharge causes a bigger riverbank erosion downstream (Rosenberg, D.M. *et al.* 1995). Rapid flow variations due to hydro power plants can affect both physical and chemical qualities of water (Cushman, R.M. 1985; Evans, A. *et al.* 2009). These drastic changes in water-related ecosystems (Cushman, R.M. 1985; Čada, G.F. 2001; Evans, A. *et al.* 2009) threaten fish populations and various other species.

However, LHPs have also positive landscape impacts. Large dams and artificial lakes can generate positive visual impact and become regional attractions, boosting tourism and local income (Frolova, M. 2010; Hastik, R. *et al.* 2015).

Many adverse impacts of hydro power plants can be mitigated, e.g. fish ladders can help to mitigate the impact (Čada, G.F. 2001). Furthermore, utilizing existing infrastructure for the construction of SHPs may help to reduce their negative impact on the landscape (Stevović, S. *et al.* 2014). Landscape impacts of LHPs may be reduced by establishing reservoirs from natural lakes (Bakken, T.H. 1014).

Perception of visual impacts of both large and small hydro power systems may depend on the original state of the landscape and its cultural value. The social norms concerning these landscape aesthetics has been evolving over generations, and became an important type of landscape in many European countries (Frolova, M. 2017; Benediktsson, K. *et al.* 2018).

Wind energy landscape

Wind energy landscapes are also relatively common in Europe. It supplies about 11 per cent of RE as illustrated in *Figure 1.* In Denmark, the United Kingdom, and Spain, the share of wind in RE is highest. It is lower in Germany, which is, however, the largest single producing country, followed by Spain, the UK and France (see *Table 1*). Large-scale commercial offshore wind farms (abbr. WFs) have been developed in many European coastal countries, in particular in the UK, Germany, Denmark, Belgium, the Netherlands and Sweden.

Wind energy harnessing is based on using kinetic energy to pump water, process materials or to produce electricity (Pasqualetti, M. and Stremke, S. 2018). WFs consist of several individual wind turbines connected to the electric power transmission network. The most prominent elements of wind energy landscapes are the towers and turning blades of wind turbines. Usually WFs are classified as small or large based on the number of turbines and their capacity. Ruggiero, F. and Scaletta, G. (2014) classify onshore wind farms: large (1 + turbines, 1 < MW), medium size (single turbine, 0.5–1.0 MW), "miniwind" (1 + turbine, < 0.5 MW), and "micro-eolic" (single turbine, < 0.01 MW). The footprint increases essentially for capacity larger than 1 MW (van Zalk, J. and Behrens, P. 2019). Only about 3 per cent of land used for wind development is directly impacted by turbines and wind energy infrastructures, and the total area required includes the land in between the turbines (Trainor, A.M. *et al.* 2016), although this land can be used for agriculture, etc. Given the fragmenting effect on animal habitats, its ecological impact spreads on this total area required. Therefore, the indirect landscape impact affects a much larger area. While the average direct footprint of onshore wind farms is estimated as 16.86 km^2/TWhr (6.45–86.95 km^2/TWhr, depending on installed capacity), the indirect landscape impact has been estimated as 126.92 km^2/TWhr (*Idem.*).

Offshore winds generally flow at higher speeds due to reduced interference from topography, vegetation and the built environment, thus turbines can produce more electricity than onshore and at a lower height (Bilgili, M. *et al.* 2011). In addition, there is a considerable difference in average power densities for onshore ($\mu = 3.1 \pm 0.7\ W_e/m^2$) and offshore ($\mu = 4.2 \pm 1.7\ W_e/m^2$) wind farms; the latter requires less surface area to produce an equivalent amount of power (van Zalk, J. and Behrens, P. 2019).

Landscape issues have always been crucial in wind power development (Wolsink, M. 2007; Toke, D. *et al.* 2008; Strachan, P. *et al.* 2009; Pasqualetti, M.J. 2011). This landscape was one of the first RE landscape recognized as such by researchers (Möller, B. 2010; Schöbel, S. *et al.* 2012). Among the numerous studies on landscape impacts of onshore WFs, the main focus is their visual/aesthetic impact, although the impact on landscape functions and structure of large- or numerous small-scale WFs *(Photo 1)* are also important concerns (Hurtado, J.P. *et al.* 2004; Wolsink, M. 2007; Möller, B. 2010; Scottish Natural Heritage 2014). Indirect landscape impacts related to environment are also frequently discussed (Wolsink, M. 2007; MEDDE 2010), and land-use impacts are also considered as important issues for large-scale developments (Scottish Natural Heritage 2014).

Wind energy landscapes are characterized by visually disturbing height (~ 160 m) of wind turbines. A number of researchers emphasize that landscape impact of WFs is strongly influenced by the size, design and layout of wind parks, and also vary with the make and model of the turbine (Ruggiero, F. and Scaletta, G. 2014; Scottish Natural Heritage 2014). It also depends on the cumulative impact of multiple WFs, which requires not only environmental impact assessment (abbr. EIA), but also strategic spatial planning. Finally, landscape perception of WFs could also be affected by other dynamic

Photo 1. Wind farm "San Lorenzo", Castilla y Leon, Spain (Photo by Herrero, D.)

factors, such as night lights, shadow flicker and the stroboscopic effect (Kil, J. 2011).

The appearance of wind energy landscape depends on how the wind turbine is positioned in the landscape, the type of landscape, the wind turbine's size, and the proximity of the observer (Danish Energy Agency 2009).

Land use issues are also important because of requirement of a large commitment of land for WFs developments. However, they allow other concurrent uses of that land (Pasqualetti, M. and Stremke, S. 2018). Due to their compatibility with other land uses, their effect on spatial characteristics of landscape is not very high, therefore wind energy landscape was conceptualized as 'component' or 'layer' type (Pasqualetti, M. and Stremke, S. 2018). However, land use impacts for WFs are seen as essential (Scottish Natural Heritage 2014).

Although offshore WFs have significantly expanded in the last decades, their landscape impacts have only recently been investigated. Today most offshore WFs are installed near the shore where the water depth is relatively shallow. Landscape impact assessment becomes essential for local communities, considering that the deployment of offshore WFs could become conflicting with other activities (Sismani, G. *et al.* 2017). Visual impact is considered as the most perceptible direct landscape impact of offshore WFs (Ladenburg, J. 2009; Sullivan, R.G. *et al.* 2013).

As the distance between an offshore WF and the shore increases, the visual impact is reduced and for more than 8 km distance the impact is considered negligible (Henderson, A.R. *et al.* 2003). Visual perception of an offshore WF depends on the number and size of turbines, but is also affected by the time of the day (Sullivan, R.G. *et al.* 2013), the local environmental conditions and the movement of the blades (Bishop, I.D. and Miller, D.R. 2007).

As for the negative landscape onshore WFs impacts linked to environmental issues, they are related to the hazards that they pose to birds and bats, noise pollution, and destruction and loss or degradation of natural habitats (Wolsink, M. 2007; MEDDE 2010; Ruggiero, F. and Scaletta, G. 2014). The indirect negative effects of offshore WFs are noise, impact on the local ecosystem and coastal erosion (Tougaard, J. *et al.* 2008; Bergström, L. *et al.* 2014).

Many of the negative landscape impacts of onshore WFs could be reduced by their proper design, layout and location, avoiding their visibility from particularly sensitive viewpoints (Scottish Natural Heritage 2014), technical monitoring, environmental surveys and specific restoration operations (MEDDE 2010).

As for offshore wind developments, their negative impacts could be reduced through appropriate site selection (Lindeboom, H.J. *et al.* 2011) and the establishment of strategic planning processes (Bergström, L. *et al.* 2014).

Although landscape is often cited as an argument in the conflicts that arise around wind energy projects, its relationship with these developments is not always conflictive. From an aesthetic point of view, wind turbines can be perceived as sculptural elements in the landscape, evoke positive association by thematic relation to modern structures, and become associated with technological efficiency, progress, environmental cleanliness and utility (Department of the Environmental, Heritage and Local Government, Ireland 2006). The acceptance of both WF type is strongly affected by any prior experience of locals with wind developments (Ladenburg, J. 2009).

Onshore wind turbines may not be considered as a problem for local inhabitants, but instead they could constitute a positive aspect of the construction of a local landscape and sense of place and affirmation of an identity in a given landscape (Frolova, M. *et al.* 2015a). The development of a wind farm can act as the stimulus for restoration and/or improvement of land use around the site (Scottish Natural Heritage 2014). Agricultural and grazing exploitation in WFs often generate positive impact in perception of these landscapes. Frantál, B. *et al.* (2018) refer to cases of utilization of wind energy landscapes as educational centres and exhibition venues. Other smart practices which improve WFs perception are the following: using wind turbines as observation towers, utilizing their tourist potential and to improve the awareness and image of RE, integration with nature trails or for improving the image of environmentally stigmatized areas (Frantál, B. 2018).

Finally, offshore wind development may also lead to benefits in the ecosystem, as a consequence of reduced shipping, commercial trawling and dredging. The mitigation of impacts may facilitate the establishment of large areas of seabed, and consequently, the creation of a new habitat (Linnane, A. *et al.* 2000; Wilhelmsson, D. *et al.* 2006; Inger, R. *et al*. 2009; Wilson, J.C. and Elliott, M. 2009).

Solar energy landscape

In 2016 this type of energy provided about 6 per cent of all RE. The Mediterranean countries and southern Germany dominate the European solar energy map. Spain and Greece have the highest shares of their RE production from solar energy, and Spain, Germany and Italy have the highest production in absolute terms. The most common solar system for electricity production is PV. Within the EU, Germany and Italy are leading (see *Table 1*). In the Nordic and Baltic countries and Poland there is very little or no utilization (see *Figure 1*).

Concentrated solar thermoelectric power (abbr. CSP) is still an uncommon solution. However, Europe has a leading position, since Spain is the world leader in CSP with a total capacity of 2.7 GW out of 4.8 GW installed globally (EurObserv'ER 2017; Río, P. *et al*. 2018).

Finally, solar thermal systems represent a mature market. The installed capacity has almost doubled in the last decade and at the end of 2015 it reached 47.5 million m² of solar collectors (32.5 < GW_{th}) (ESTIF 2015). Regarding newly installed capacity, Germany represents almost 40 per cent of the European market, followed by Italy (10%) and Poland (9%). The market for combined production of hot water for sanitary uses and space heating is well established in Germany and Austria (Mauthner, F. *et. al*. 2016).

Solar PV landscapes include 2 subtypes: *on-ground PV* and *building added/integrated PV*. In the first case PV modules arrays are installed optimally oriented to maximize the solar radiation capture, covering significant areas. Its additional landscape impacts are effects from PV arrays, reflecting mirror arrays, and concentrating solar towers for large-scale facilities (Pasqualetti, M. and Smardon, R. 2017). As for the second solar PV topology, PV modules are added (BAPV) or integrated (BIPV) onto/into the building. If the modules are integrated, special PV components are used to perform additional functions than the merely electric generation.

As for CSP landscapes they include four types of systems: *parabolic troughs*, *solar power towers*, *linear Fresnel concentrators* and *Stirling parabolic dishes* having each of them different effects on landscape (Andrés-Ruiz, C. *et al.* 2015; Benediktsson, K. *et al.* 2018).

Finally, space heating and hot water production systems can be found in two topologies: *in/on building mounted* and *on-ground* solar thermal. In case of on-ground mounted systems, the number of units requires a larger solar field that cannot be accommodated on the roof of buildings.

In spite of the highest values of power density among solar energies, CSP systems with their $\mu = 9.7 \pm 0.4\ W_e/m^2$ (*Idem*.), their land use efficiency is lower and the area of direct footprint is higher (19.25 km^2/TWhr) than that of PV systems (15.01 km^2/TWhr) (Trainor, A.M. *et al.* 2016). The variations of area of direct footprint are from 12.30 to 16.97 km^2/TWhr for solar PV and from 12.97 to 27.98 km^2/TWhr for CSP systems Due to these characteristics and their spatial extent, solar energy landscapes can be seen both as 'component' or 'layer' type or as 'entity energy landscape'.

The landscape impacts of solar power facilities depend significantly on the size of the installations as well as on their concentration in a certain area. Numerous authors analysed landscape impacts of large scale on-ground PV: their land use effects (Fthenakis, V. and Kim, H.C. 2009; Dijkman, T.J. and Benders, R.M.J. 2010; Horner, R.M. and Clark, C.E. 2013; Lakhani, R. *et al.* 2014); visual and aesthetic impacts, including glare (Chiabrando, R. *et al.* 2009; Minelli, A. *et al.* 2014; Fernandez-Jimenez, L.A. *et al.* 2015); landscape and habitat fragmentation (Hernandez, R.R. *et al.* 2014); impacts on ecosystems (Hernandez, R.R. *et al.* 2014) and soil erosion (Turney, D. and Fthenakis, V. 2011). The negative effects of a massive expansion of large-scale solar systems on landscape can cause an important change in landscape functions and structures (Scognamiglio, A. 2016).

For solar on-ground PV and CSP the concerns about visual impact and land use are more pronounced than for BAPV/BIPV and solar thermal systems, due to the large areas covered (Hastik, R. 2015), making the selection of appropriate location crucial (Hernandez, R.R. *et al.* 2014). As for CSP, the glare effect from the mirrors and metal structures, the visual impact of the tall vertical cooling towers and the columns of steam released into the atmosphere have been acknowledged as the main direct landscape impacts. Impacts related to water issues are also essential, since CSP installations consume large amounts of water and are normally situated in semi-arid areas (Andrés-Ruiz, C. *et al.* 2015). Finally, the negative impacts on biodiversity of large on-ground PV and CSP is considered an important issue (Hernandez, R.R. *et al*. 2014; Andrés-Ruiz, C. *et al.* 2015).

Negative effects of solar on-ground and CSP installations on land use can be reduced through a dual use of land for PV and agriculture (Ravi, S. *et al.* 2016) or grazing (with possible increase of crop production thanks to the shade provided by modules; and possible grass maintenance cost decrease), or for PV and other types of energy production. Artificial water surfaces can be also used to save land (Nordmann, T. *et al.* 2010; Hernandez, R.R. *et al*. 2014). Actually, most National RE Action Plans of EU's member states do not encourage the installation of solar farms in high quality cropland (Hernandez, R.R. *et al*. 2014).

Some authors suggest that an appropriate mitigating strategy for reducing the solar PV systems visual impact is to integrate them in a landscape and to choose sites with a reduced visibility of PV installations or integrate them in buildings (Chiabrando, R. *et al.* 2009; Kapetanakis, I.A. *et al.* 2014; Scognamiglio, A. 2016). Nowadays, the implementation of BIPV uses technical solutions and innovative ideas that minimize negative aesthetic impact. Design strategies at the architectural scale have also been suggested for limiting the glare impacts of PV, such as the application of mitigation measures at both reflectors (diffusive reflection coatings) and receptors (plant shadings) (Chiabrando, R. *et al.* 2009).

Other strategies for generating positive landscape impacts of solar PV systems are the following: (1) The supporting structures of PV can be used as land stabilization elements; (2) The pattern of the PV fields can be designed so as to improve the spatial definition of a certain area (e.g. public parks, bike lanes, walking paths); (3) PV modules can provide shade in spaces where this is needed; (4) PV can be designed so as to meet certain given ecological and landscape objectives (Scognamiglio, A. 2016); (5) Solar PV farms can be also used for conversion of brownfield (underused, abandoned, and often contaminated land) in productive landscape; (6) Large-scale solar parks can be used as educational centres. Finally, solar power is used for the creation of energy roads and roofs (Röhner, S. and Roth, M. 2018). This versatile character of solar energy landscapes contributes to their positive perception in many European countries (Prados, M.J. 2010; Kontogianni, A. *et al.* 2013; Tsantopoulos, G. *et al.* 2014).

Geothermal energy landscapes

In Europe in 2016, geothermal sources provided almost exactly the same amount of energy as solar sources did. This is the category that has the most uneven distribution of all those described here, due to differences in geological conditions. It is potentially widely available, but its harnessing is easiest in regions where the geothermal gradient is higher than average. This applies to several regions of Europe, especially Iceland and parts of Italy, Greece and Turkey (Hurter, S. and Haenel, R. 2003). Most countries either have quite limited production, and then almost entirely through direct use or none at all.

Geothermal resources are used either to provide thermal energy directly or to produce electricity. In Europe, the former type of usage is most important in Turkey and Iceland. In Turkey, almost a third of geothermal direct use relates to balneology-therapy and spas, with district heating and greenhouses coming next (Parlaktuna, M. *et al.* 2013). In Iceland, almost three-fourths of direct use is for district heating, ~ 90 per cent of such heating in the country is now geothermal (National Energy Authority 2019).

Within Europe, most geothermal electricity by far is produced in Iceland and Italy, followed by Turkey. In 2016 Turkey and Italy had the largest installed capacity (see *Table 1*). In Iceland, some 30 per cent of all electricity is now coming from geothermal plants (National Energy Authority 2019). Installed capacity in Island in 2016 was 665 MW_e (see *Table 1*). Two stations are found in the west of Turkey with a total of 397 MW_e capacity (Bertani, R. 2015). In Germany, Portugal, France and Austria electricity production from geothermal resources is still minuscule.

Geothermal landscape is based on the use of geothermal energy (abbr. GE) for heat/power generation. Geothermal resources are classified as either low or high enthalpy, with a temperature of 150 °C, at surface pressure frequently used as the limit (Martín-Gamboa, M. *et al.* 2015). Water from low-enthalpy geothermal fields is often suitable for direct use. Geothermal fluids from high-enthalpy fields are much more suitable for electricity production.

Whether GE is in fact ‘renewable’ can be debated (Barbier, E. 2002). In low-enthalpy systems that only use naturally flowing hot water, the renewability is unquestionable.

However, if the extraction of fluids from a particular reservoir is higher than the capacity of that reservoir to regenerate, the operation is more akin to mining a non-renewable resource (Arnórsson, S. 2011).

Geothermal infrastructure can have a considerable impact on landscapes (Kristmannsdóttir, H. and Ármannsson, H. 2003). According to van Zalk, J. and Behrens, P. (2018) the power density of GE systems varies from 0.08 to 14.94 W_e/m^2, with substantial difference between high-temperature plants (μ = 4,9 ± 2.9 W_e/m^2), and low-temperature systems (μ = 1.6 ± 1.0 W_e/m^2). The direct footprint also varies from 2.14 to 10.96 km^2/TWhr (Trainor, A.M. *et al.* 2016).

Negative visual landscape and environmental impacts of geothermal energy facilities are the most controversial, while land use impacts are less discussed in the reviewed literature.

In case of direct-use installations, the impact is mostly limited to wellheads and pipelines, but sometimes natural geothermal surface features may be affected. At high-enthalpy fields (used for electricity production), the landscape impact is more conspicuous and wide-ranging. Some of it occurs already at the research stage, as wells/boreholes need to be drilled. Each well pad is from 2,000 to 5,000 m^2 large, and needs an access road. Some of the research wells become production wells, whereas others turn out to be unsuitable for production, yet leave the landscape altered. Following initial research, more production wells are added, as well as reinjection wells related to the other end of the production process. The linear form of gathering pipelines can be very conspicuous in the landscape, and zigzagged or U-shaped thermal expansion loops further accentuate the contrast with natural forms. Finally, the power station itself is a complex amalgam of steam separators, turbines and generators, cooling towers and other necessary facilities (Di Pippo, R. 2015). All this considered, geothermal electricity generation usually creates a very 'industrial' landscape *(Photo 2).*

GE is often presented to the public as almost without any substantial environmental impacts, apart from direct modifications of the physical landscape with construction. However, its landscape impacts related to environmental issues are considerable too (Kristmannsdóttir, H. and Ármannsson, H. 2003). Especially the use of high-enthalpy fields entails a range of negative consequences, some of which can affect landscape quality in a less direct way. Stability of hillsides can be weakened by thermal changes in the soil and landslides have oc-

Photo 2. Hellisheiði Geothermal Power Station, Iceland (Photo by Centeri, Cs.)

casionally followed the building of geothermal plants. Land subsidence can also occur with the extraction of fluids. Surface manifestations of geothermal activity, such as springs and fumaroles, can be altered or may disappear.

Landscape-wise, chemical pollution may alter vegetation in the vicinity of the power plant unless measures are taken to get rid of the pollutants, with e.g. reinjection of fluids. Noise from blowing boreholes and geothermal plants, and the distinctive smell of hydrogen sulfide can negatively affect the perception of landscape quality.

Geothermal fields are often located in rare or visually interesting landscapes due to peculiar surface formations (hot springs, fumaroles or craters). Due caution is therefore necessary when planning for GE infrastructure in the landscape. Careful attention to design and engineering can mitigate some of the unavoidable long-term negative impact.

Given the characteristics outlined above, it is hard to envisage positive landscape changes with GE development. The technology is rather new and has not become valued as 'industrial heritage'. In some cases, however, unforeseen landscape impacts have turned out to be positive. The best example perhaps is the 'Blue Lagoon' in Iceland, which has become a major tourist attraction and spa.

Bioenergy landscapes

Bioenergy is by far the most important category of RE in Europe, with more than 50 per cent of the total RE. Compared to other RE sources it is rather equally distributed between different countries, although it comes in many forms (solid, liquid and gaseous biofuels, sometimes with in-situ conversion to electricity). The share of bioenergy of all REs is highest in the Baltic States, the Czech Republic and Hungary. In absolute terms, Germany is by far the largest producer, followed by France, Italy and Sweden. Norwegian production is very limited, and at the other end of the spectrum are Iceland, Switzerland and Bosnia and Herzegovina, where bioenergy is almost absent (Eurostat 2016).

The growth of production and use of bioenergy was spectacular in the last decade. The leading producers since 1970s have been Brazil and the United States, but recently several European countries have become important producers like Germany, Italy, France, the Benelux countries, Spain, etc. (Solomon, B.D. and Barnett, J.B. 2017). There are two main types of bioenergy: biofuel and biomass.

Biofuel technologies are classified into first-generation, where the raw material is grains or sugar beet derivatives, and advanced or second-generation technologies, where use is made of non-fossil, non-food materials. Production of the first generation technologies is limited in Europe due to lack of available land, while the biodiesel markets and feedstock production are larger (Solomon, B.D. and Barnett, J.B. 2017). The leaders of the bioethanol production in EU are France, Germany and Belgium, while the top three producers of biodiesel/hydrogenated vegetable oils (abbr. HVO) are Germany, France and the Netherlands (Flach, B. *et al.* 2016). As for advanced or second-generation biofuels its production has taken off in the EU only since the past six years, due to favourable policies for its development related to their lower greenhouse gas emissions. Several HVO thermochemical and biochemical plants have been built in Finland, the Netherlands, Spain and Italy.

The term biomass refers to various types of biological material which can be converted into energy, a solid or liquid biofuel or other products (Calvert, K. *et al.* 2017, 2019). There are basically three types of biomass materials. According to their origin they are classified as: (1) energy crops grown primarily for the production of energy; (2) agricultural/forest residues that are generated when grains are harvested, trees pruned/cut; (3) by-products and organic waste that is generated in the processing of biomass for the development of food products, from which energy can be recovered. Heat and power are generated either through direct combustion of biomass or through use of biomass for the biogas production. Forestry products are the main feedstock for direct combustion, while a wide range of inputs is used for the production of biogas. Main three pellet producers among the COST action countries are Germany, Sweden and Latvia (Flach, B. *et al.* 2016). As for biogas, Germany with its 8,928 biogas plants of total capacity of 4,177 MW is the leader in biogas production, accounting for 65 per cent of total EU production. It is followed by Italy (2,100 plants/900 MW) (Flach, B. *et al.* 2016).

The advantages of using bioenergy are accompanied, in general, by inherently problematic properties (stationarity, low-energy density, scattering, direct and indirect land-use change, etc.) (García-Frapolli, E. *et al.* 2010).

Land-use and environmental impacts are the main concerns of the literature on bioenergy, while visual impacts are less discussed in the reviewed literature. Bioenergy induces direct and indirect land-use changes, the latter when pre-existing agricultural activity is converted into new, often more intensified forms of agriculture (Palmer, J.R. 2014). Bioenergy transforms pre-existing agricultural landscapes and their related social practices, thereby imposing new value system on landscape (Calvert, K. *et al.* 2017). Biomass systems have very low median power density of 0.08 W_e/m^2 ($\mu = 0.13 \pm 0.02$ W_e/m^2), and low maximum power density (0.60 W_e/m^2) (van Zalk, J. and Behrens, P. 2019). Therefore, large amounts of biomass must be grown that leads to re-surfacing of infrastructure and activity associated with biomass distribution and conversion.

Bioenergy surface area requirements are the highest among the RE technologies, with the average area of direct footprint estimated as 809.74 km^2/TWhr (557.93 to 1,254.03 km^2/TWhr) (Trainor, A.M. *et al.* 2016). In addition, biogas tends to be produced on a large industrial scale, which in some cases leads to important impacts on landscape character and its decoupling from the local community (Bluemling, B. *et al.* 2013).

Due to diversity of subtypes and scales of bioenergy landscapes they may belong both to 'component' type and 'entity energy landscape'. The biomass processing facilities could vary in size (Calvert, K. *et al.* 2017), so their landscape impact is scale-dependent.

Bioenergy indirect landscape impacts related to environmental issues are multiple: effect on soil, gaseous emissions, unfamiliar smell and possibility of water pollution (Hastik, R. *et al.* 2015; Sokka, L. *et al.* 2016). The continued withdrawal of organic matter from the forest may have very negative impacts on landscape due to decrease of soil quality and medium-term impacts on the landscape (Holland, R.A. *et al.* 2015). There may be long time-lags before the populations reach new equilibriums after the extraction of bioenergy is initiated (Johansson, V. *et al.* 2016).

In order to minimize some negative consequences of bioenergy production on landscape the production of energy crops is often encouraged or restricted onto land considered marginal or abandoned for agricultural purposes (Calvert, K. *et al.* 2017). Another more general strategy in bioenergy policy is to favour development of advanced or second generation of biofuels that use a wider range of feedstock including lingo-cellulosic material, waste and residues or stimulate production of algae origin biodiesel and do not compete with food production. For landscape management and protection, the policies regulating the development of bioenergy should be integrated into agricultural, forest and environmental protection policies.

The production of second-generation biofuels from the valorisation of domestic and forest waste is a route with very positive impacts in terms of landscape and environmental value. The recovery of waste allows them to be valued, reducing the negative impacts of dumps and landfills. The use of forest residues makes it possible to prevent forest fires, which are particularly significant in the countries of southern Europe and which have drastic consequences in terms of landscape and environment.

Finally, positive experiences of eco-remediation of degraded land by growing energy crops (Frantál, B. 2018) and visualization of bioenergy landscapes through using them as a part of nature trail or incorporating bioenergy facilities into historical farm buildings (Frantál, B. 2018) make us suggest that bioenergy landscapes may offer good examples of sustainable energy landscapes.

Infrastructure energy landscapes

RE installations entail an ensemble of auxiliary elements referred to assimilation, conversion, storage, transport or transmission of energy produced. Although they may differ greatly across the different energy sources, in general terms infrastructure energy landscapes include ancillary buildings, substations and transmission lines, roads, tracks, canals and access tracks. They can have as much impact on the landscape quality, or more, than the very devices which produce power from renewable sources (Swanwick, C. 2002; Uyterlinde, M. *et al.* 2017). Associated hazards and needed accessibility, both directly and indirectly, discourage other land uses along these infrastructures, sometimes creating and dividing function between land uses on either side of their pathway (Pasqualetti, M. and Stremke, S. 2018).

In addition, the auxiliary elements may have impacts on the materiality of historical and natural heritage, mainly when they interfere with archaeological sites or historical areas or require deforestation of buffer zone (Harvey, A. and Moloney, K. 2013). These elements may also cause perceptual alterations or modification of the visual relations of scale and hierarchy between the different elements that compose a scene (Landscape Institute and Institute of Environment Management and Assessment 2013).

Finally, new roads and access tracks for the maintenance of facilities produce an increased accessibility in areas that often were previously difficult to access or inaccessible, in detriment of their wilderness (Scottish Natural Heritage 2003).

Discussion and conclusions

Today, renewable energy landscapes are part of European landscapes. Due to differences in components, spatial extent and visual dominance of different RE facilities, there is a considerable variety of sub-types of RE landscapes.

The overview of the state of RE developments shows a great diversity and an uneven distribution of RE landscapes in Europe. Italy and Turkey are the countries with the most varied RE landscapes with a significant presence of most RE types, while Bosnia and Herzegovina have the most uniform RE landscape with an absolute predominance of hydropower.

Most RE landscapes can be classified both as 'component' and 'layer' types or as 'entity energy landscape' *(Table 2)*. According to the consulted literature, visual landscape impact is the most important concern for wind, BAPV/BIPV and BA/BI hot water and space heating, CSP and small-scale geothermal energy landscape. Land use impacts is the most cited impacts group for on-ground solar PV, bio- and infrastructure energy landscapes; and landscape impacts related to environmental issues, in particular to biodiversity and water issues, for large-scale hydro and high temperature geothermal energies.

In spite of these differences, all the consulted authors consider visual/aesthetic landscape impacts of REs as an important issue. The impact also depends on the landscape type concerned, and may be relatively higher in rural areas with open or exposed views. Associated infrastructures may also have a significant impact and often form a different 'infrastructure energy landscape'. Due to unique visual properties of the most part of RE facilities combined with large size, ordered angular geometry, and highly reflective surfaces of wind and solar power plants, they add strongly contrasting artificial elements to the landscape. Landscape impacts of all the RE developments depend on their sub-type, size and the landscape in which they are placed. However, generally the question of the RE project's scale is crucial. Although the small-scale projects generally have a smaller landscape impact, the cumulative impact of multiple small-scale projects could exceed that of one large-scale project (Bakken, T.H. 2014; Scottish Natural Heritage, 2014).

Table 2. Overview of spatial characteristics of RE landscape types and their landscape impacts

Energy landscape		Scale	Spatial characteristics/ spatial extent	Average energy density[1)], W_e/m^2	Average land use efficiency[2)], $km^2/TWhr$		Most cited group of negative impacts in the consulted literature	Most cited positive aspects linked to landscapes
Type	Sub-type				Area of direct footprint	Area of total footprint		
Hydro energy	–	small	Component/layer EL	0.01	16.86		Landscape impacts related to environmental issues impact	Visual/aesthetic impacts, tourism attraction
		large	Entity EL	0.11–0.71				
Wind energy	Onshore	small	Component/layer EL	3.1	1.31	126.92	Visual/aesthetic impacts	Aesthetic impacts*
		large	Entity EL					
	Offshore	large	Entity EL	4.2				Landscape impacts related to environmental issues
Solar energy	On-ground PV	large	Component/layer EL	5.8	15.01		Land use	Aesthetic impacts**
		small	Entity EL					
	BAPV/BIPV	all scales	Component EL	3.7			Visual/aesthetic impacts	Minimization of visual impact of solar systems
	BA/BI hot water and heating			6.7	No data	–		
	CSP	large	Entity EL	9.7	19.25			No positive aspects cited
Geothermal energy	Low temperature	all scales	Layer/entity EL	4.9	5.14		Visual/aesthetic impacts	Possibility of co-use for tourism (geothermal waters)
	High temperature			1.6			Landscape impacts related to environmental issues	–
Bioenergy	Biomass		Component/layer EL	0.08	809.74		Land use	Reduction of negative impacts***
Infrastructure	–			No data	–			No positive aspects cited

[1)] Based on van Zalk, J. and Behrens, P. 2018. [2)] Based on Trainor, A.M. *et al.* 2016. *Possibility of land co-use for agriculture, grazing, industry, tourism etc., improving of image of stigmatized landscapes. **Possibility of land co-use for agriculture, grazing, industry, tourism etc., conversion of brownfields in productive landscapes. ***Impacts of gamps and landfills, forest cleaning, restauration of degraded lands. Abbreviations: BAPV = building added (BA) photovoltaics, BIPV = building integrated (BI) photovoltaics, CSP = concentrated solar thermoelectric power, EL = energy landscape.

The extensive nature of land occupation of RE systems that affects landscape quality is a widely discussed topic too. These facilities do not merely represent new elements in the landscape, but often change the patterns of the landscapes concerned. Adverse, permanent effects of RE systems on landscape, arising at a larger scale, are of greater concern in the literature on RE impacts.

Direct land occupation of RE facilities raises the issue of the spatial extent of low-density renewable technologies with a large land use footprint, termed 'energy sprawl' (Trainor, A.M. *et al.* 2016). Renewable power density means varies greatly from 0.08 for biomass to 6.6 W_e/m^2 for solar (van Zalk, J. and Behrens, P. 2019). There is a considerable difference between power densities of different sub-types of renewables, depending on their characteristics and scale (see *Table 2*).

As for land use efficiency, it does not always directly depend on power density. It varies substantially too, from 1.31 km^2/TWhr for wind energy to 809 km^2/TWhr for biomass. However, when indirect landscape impact is considered, wind is estimated as one of the least land-use efficient sources of electricity, due to the total area occupied by wind farms and their infrastructures (Trainor, A.M. *et al.* 2016; van Zalk, J. and Behrens, P. 2019) (see *Table 2*). Interestingly, according to the estimations of Trainor, A.M. *et al.* (2016), despite CSP having the highest value of power density among RE systems, its average land use efficiency estimation is lower and the area of direct footprint is higher than the average values for geothermal, solar PV and hydro energy systems (see *Table 2*).

The comparison of land occupation and the share of different RE types in total RE production in Europe (see *Figure 1*), can help to identify some critical landscape issues that need further study. Bioenergy landscape is the most important category of RE landscape in Europe, not only due to the bioenergy share in the total RE mix and its presence in many European countries, but also owing to its great land use footprint. The next in importance is the wind energy landscape. In spite of its share in the RE mix being much lower than that of hydro energy, the second most important source in Europe, its total footprint is over 7.5 times more extensive. Geothermal energy and CSP landscapes are the less extended in Europe.

In addition, RE systems often involve greenfield development, limiting the opportunities for food production in agriculture (Azar, C. 2005; Rathmann, R. *et al.* 2010) or for tourism (Sæþórsdóttir, A.D. and Ólafsson, R. 2010).

Landscapes that have been dominated by extensive technical installations help to assimilate RE developments due to thematic association with industrial structures (Danish Energy Agency 2009). Appropriate design can further reduce visual misfit of RE facilities. Generally small-scale deployments are considered a way to reduce landscape impacts of most RE infrastructures, however, having limited and insufficient outputs to achieve long-term national targets for emission reduction (Frantál, B. 2018) and creating cumulative impact of multiple RE plants.

Strategic planning and landscape character studies are important tools to mitigate potential adverse landscape and accumulative effects with proper siting. Landscape Character Assessments provide a good basis for both location and design of RE developments.

The review has revealed several gaps related to the studies of impact of RE facilities that should be brought into the focus of scientific research. Most publications center on the facilities necessary for energy production, while other structures associated with RE systems get less attention. However, they should also be located and designed with respect to the character of surrounding landscapes. Increased research activity in these fields would result in a better understanding and management of this complex issue.

Bioenergy landscapes should receive much more attention in the future European research, due to their spatial extent and the important role of bioenergy in the RE mix of many countries. On the other hand, despite constantly growing energy density of wind energy facilities, their landscape effects should continue to be considered an important concern, due to their considerable presence in Europe and extensive area of indirect footprint. The considerable spatial extent of hydro energy facilities, both due to their significant role in the energy mix of many European countries and large direct footprint, should be taken into consideration in the future studies of their landscape impacts.

Finally, the review shows that perception of different RE landscapes depends not only on technical and visual characteristics of RE facilities, but also on the landscape in which they are placed. In addition, aesthetical assimilation of RE systems depends on historical and socio-cultural background of its development, on relation between local people and their resources and possibilities to use RE landscape for other territorial practices.

As numerous studies argue, landscapes may benefit both from the socio-economic impacts of RE developments and from ′smart practices′ developed within RE landscapes. Therefore, we can suggest that if RE projects are properly located and designed and are beneficial for local people and tourists, society will gradually learn to love these landscapes and to adapt to their aesthetic properties.

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Granulometric properties of particles in Upper Miocene sandstones from thin sections, Szolnok Formation, Hungary

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Abstract

Particle size and shape are among the most important properties of sedimentary deposits. Objective and robust determination of granulometric features of sediments is a challenging problem, and has been standingin the focal point of sedimentary studies for many decades. In this study, we provide an overview of a new analytical approach to characterize particles from thin sections of sandstones by using 2D automated optical static image analysis. The analysed samples are originated from the turbiditic Lower Pannonian (Upper Miocene) sediments of Szolnok Formation. Sandstone samples were analysed from 1,500 to 2,250 m depth range. According to the previous studies: the detrital components are quartz, muscovite, dolomite, K-feldspar and plagioclase. Diagenetic minerals are mostly carbonates (calcite, Fe-dolomite, ankerite, siderite), clay minerals (illite, kaolinite), ankerite, siderite and kaolinite. As the discussed Szolnok Formation is considered as a potential CO_2 storage system (to reduce atmospheric CO_2 concentration), special attention has to be paid on grain size and shape alteration evaluation, since pore water-rock interactions affected by CO_2 injection may cause changes in particle properties. The primarily aim of the present study was to develop a method for effective characterization of the particle size and shape of sandstones from thin sections. We have applied a Malvern Morphologi G3SE-ID automated optical static image analyser device, what is completed with a Raman spectrometer. Via the combined analysis of granulometry and chemical characterization, it was obvious that there were specific relationships among various grain shape parameters (e.g., circularity values correlate to width and length ratios, as well as to convexity) and the results indicated that based simply on particle shapes, muscovites can be effectively separated from other minerals. Quartz and feldspar grains showed the highest variability in shapes as these are detrital ones, and sometimes arrived as lithic fragments from which other parts were dissolved The size and shape of carbonate minerals depends highly on the original pore size and shape because these minerals are mainly diagenetic. The shape of detrital dolomites depends on diagenetic ankerite, as it replaces the rim of dolomites.

Keywords: grain size; grain shape; sandstone; image analysis; pore water-rock interaction

Introduction

Particle size and shape analysis of sediments is a basic and widely applied analytical method. Granulometric properties are among the most important features of clastic deposits, containing general information on source areas, transport processes, depositional environment and post-depositional alterations. The different grain size fractions, their abundance and relative proportion provide the basis for the classification of sediments (e.g., sand, aleurite/silt, clay). The physical properties of sediments largely depend on the mass or volumetric proportion of different grain size fractions (Wentwort, C.K. 1922; Folk, L.R. 1954). Several analytical techniques (e.g., pipette-sieve methods, laser diffraction, static and dynamic image analysis) have been used and applied successfully for particle sizing of unconsolidated,

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loose sedimentary units (e.g., Quaternary loess, paleosols, windblown or fluvial sands).

Objective and quantitative particle size and shape characterization of consolidated sediments (e.g., sandstones) is a complex issue, generally, several compromises have to be taken during particle size and shape analyses as mineral particles and/or lithic fragments of the deposits has to be analysed mostly in thin sections or on disaggregated sediments (Kellerhals, R. *et al.* 1975; Burger, H. and Skala, W. 1976; Barrett, P.J. 1980; Schäfer, A. and Teyssen, T. 1987; Mingireanov Filho, I. *et al.* 2013; Asmussen, P. *et al.* 2015; Jiang, F. *et al.* 2018). Particles in thin sections cannot be regarded as intact grains, cross-sections of sliced non-spherical particles are often not representative for the whole sample, hence, a large number of particles has to be characterized. Disaggregation of the sediments can cause changes in general grain morphology. The morphology of sedimentary particles depends largely on the mineralogy and transport processes, furthermore, the diagenetic processes may also influence the particle shapes as minerals dissolve and re-precipitate, or form during the diagenetic processes (Pettitjohn, F.J. 1952). These processes depend on the detrital material, the water chemistry and physical properties (such as porosity, permeability, pressure and temperature) (Larsen, G. and Chilingar, G.V. 1979)

In this study, samples from Lower Pannonian (Upper Miocene) Szolnok Formation were investigated from Zagyvarékas. The units comprise fine and very fine sandstones, siltstones, clay marls and marls, with the dominance of sandstones, and are generally regarded as turbidite clastic deposits. The mineral composition of the sedimentary rocks is known, and easy to analyse by X-ray powder diffraction (XRD) or optical microscopy. The main minerals in the sandstone samples from the Lower Pannonian formations are quartz, feldspars, carbonates, clay minerals (Mátyás, J. and Matter, A. 1997; Juhász, A. *et al.* 2002). These minerals are Raman active, hence mineral compositions can also be determined by Raman spectrometry (Nasdala, L. *et al.* 2004). After the final deposition of sand grains, burial and associated diagenesis processes have altered the sedimentary deposits. Under these conditions, the deposited detrital grains of sand have gradually been experienced higher pressure and temperature, while the pore water is not in equilibrium with the detrital minerals, hence, some minerals dissolve (e.g., feldspar) whereas others, mainly carbonates and clay minerals, precipitate. The interaction between pore water and grains may cause changes in granulometric parameters of mineral particles and lithic fragments. Furthermore, this is the most potential formation for the CO_2 geological storage (Szamosfalvi, Á. *et al.* 2011). Storage of CO_2 in geological formations is a possible method to reduce the atmospheric content of this greenhouse gas, and beside tillage management and appropriate usage of soils (Bilandžija, D. *et al.* 2017; Zacháry, D. *et al.* 2018; Zacháry, D. 2019), geological sequestration provides a unique possibility to mitigate the carbon emission. Effects of CO_2 on the reservoir pore water-rock system must be well understood before industrial storage projects (Bachu, S. *et al.* 2007; Arts, R. *et al.* 2008; Király, Cs. *et al.* 2016) are initiated.

The main objective of the study is to present a method, which can help to determine the shape parameter of constituent grains of consolidated sandstones of Szolnok Formation from thin sections. The applied device in this study is a Malvern Morphologi G3SE-ID, a 2D automated optical static image analyser equipped with Raman spectrometer, which enables the determination of morphological properties of grains as well as their mineralogy. Additionally, the whole analytical procedure was carried out in thin sections without the necessity of disintegration of samples and loose textural information.

Geological background and analysed samples

Zagyvarékas is located in the centre of the Pannonian Basin. Intensive sedimentation characterized this area around 6–7 Ma (Magyar, I. *et al.* 2013). Series of the sediments started with an abyssal deposit (Endrőd Formation). The overlying sedimentary facies is a turbiditic sandstone (Szolnok Formation), above the clayey-aleurolite Algyő Formation deposited. These are the Lower Pannonian sediments. The Upper Pannonian sediments consist of a sandy unit (Újfalu Formation) and a strongly varying sequence with alternating sand and clay (Zagyva Formation) (Juhász, Gy. 1992; Juhász, Gy and Thamó-Bozsó, E. 2006). Turbidity deposits characterizing the Szolnok Formation were deposited in a pro-delta subenvironment *(Figure 1).*

Two sandstone samples (Za1-10/2R and Za1-11/2R) from the vicinity of Zagyvarékas were studied in this paper. The samples originated from the Szolnok Formation, which in some cases deposited in remarkable >1,000 m thickness in this area (Juhász, Gy. 1992). The samples were studied in the perspective of CO_2 geological storage (Sendula, E. 2015). Grain size distribution, modal composition and petrography were studied in detail also by Sendula, E. (2015). The two analysed samples are light grey, fine-grained sandstones from

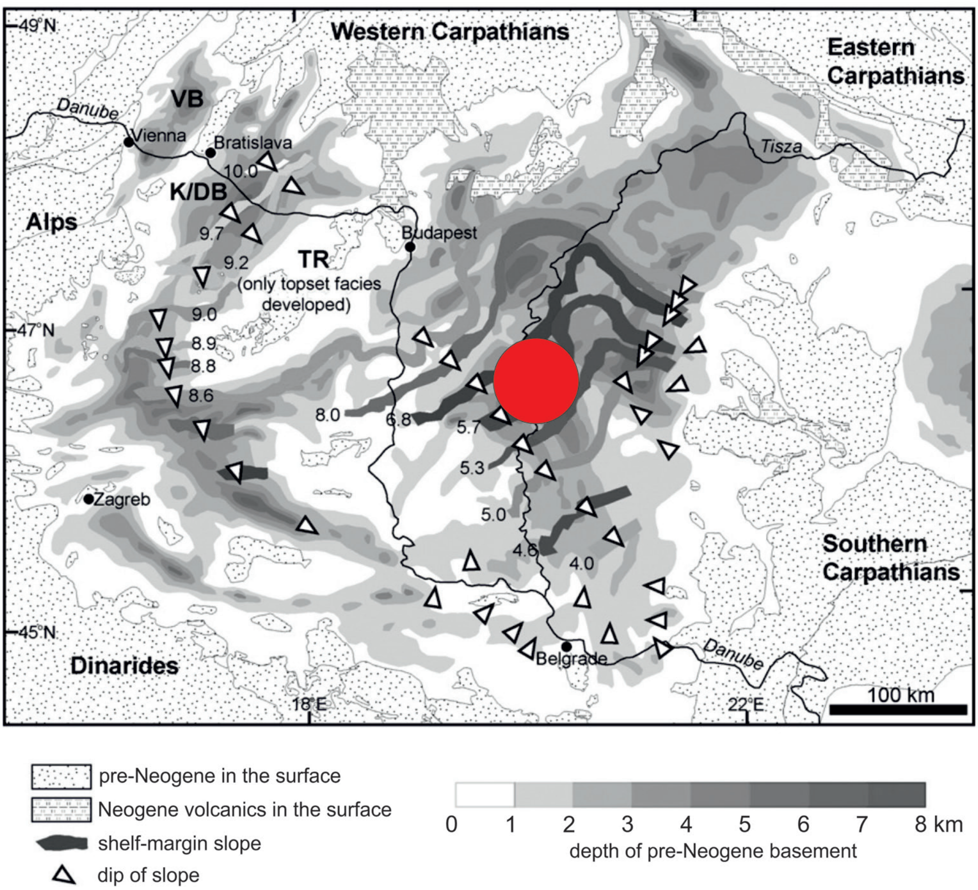

Fig. 1. Progradation of shelf-margin slopes across the Pannonian Basin during Late Miocene and Early Pliocene times. Ribbons = width of the slope; numbers = approximate age in million years; arrows = dip directions as appeared on 2D profiles; VB = Vienna Basin; K/DB = Kisalföld/Danube sub-basin; TR = Transdanubian Range; red circle = study area. *Source*: Horváth, F. and Royden, L. 1981; Magyar, I. *et al.* 2013.

1,867–1,868.5 m and 2,056–2,061 m depth. The sandstones are clast-supported, mid-sorted, carbonate cemented materials. According to published laser diffraction analyses, the following grain size fractions are present in the samples: sand [62.5< μm] (59–60 v/v%), silt [2.0–62.5 μm] (40–41 v/v%) and clay [<2 μm] (0.1–0.6 v/v%). The grain size distribution curves show two modal peaks (13.2 μm and 152.5 μm) (Sendula, E. 2015).

The main minerals are quartz, dolomite + ankerite + siderite, illite + muscovite, calcite, plagioclase, kaolinite *(Table 1).* The petrographic analysis determined that detrital minerals are quartz (as metamorphic rock fragments, mono- and polycrystalline quartz), muscovite, plagioclase, dolomite as well as in a small proportion of calcite and illite is also detrital in origin. Microscopic observations showed that the detrital quartz grains are sub-rounded. According to the 300 points QFL classification, the samples are lithic arenites (Sendula, E. 2015).

Muscovite flakes are oriented parallel to the layering, and as an effect of compaction, some of them were bent and broken *(Figure 2).* Furthermore, in the sample originating from a greater depth, the ratio of the line contact between grains is increased, indicating stronger compaction (Ali, S.A. *et al.* 2010; Sendula, E. 2015).

Diagenetic minerals are carbonate minerals, clay minerals, quartz overgrowth and plagioclase (just in Za1-11/2R). The cement material is a mixture of ankerite, calcite, siderite and kaolinite. The main part of ankerite occurs as mineral replacement of dolomite, followed by ankerite overgrowth. The siderite is a fine-grained pore-filling material, which may be formed from biotite. Kaolinite is also present between muscovite layers (Sendula, E. 2015).

The petrography of the sandstones indicates that during the diagenetic processes albite formed from plagioclase. Subsequently, one part of albite dissolved and kaolinite replaced the albite. In the Za1-11/2R sample, authigenic plagioclase is also present. The porosity of the samples is 8–10 per cent (Sendula, E. 2015).

The methodology of 2D image analysis

Recently, morphological characterization of grains is also a dynamically developing method when studying various sediments (Moss, A.J. 1996; Rogers, C.D.F and Smalley, I.J. 1993; Varga, Gy. *et al.* 2018; Varga, Gy. and Roettig, C.-B. 2018). Originally the morphological characterization of particles was not a mathematically grounded method, however, recently the 2D automated optical static image analysis enabled the solution of this problem. Furthermore, earlier the number of analysed grains was not sufficient for robust statistical analysis, this problem has also been successfully overcome with automatized systems (Cox, M.R. and Budhu, M. 2008). Using well established mathematical toolset and considering more shape properties it seems clear that the widely used Krumbein-classification does not work (Sochan, A. *et al.* 2015). Earlier studies based on this methodology have to be revised.

Thin sections of the two sandstone samples in blue-coloured epoxy resin were measured by Malvern Morphologi G3 SE-ID instrument in the Laboratory for Sediment

Table 1. Modal composition, porosity and grain fractions of the studied samples

Samples	Quartz	Dolomite + ankerite + siderite	Illite + muscovite	Calcite	Plagioclase	Kaolinite	Porosity	Sand	Silt	Clay
								fractions		
	m/m%							v/v%		
Za1-10/2R	49	21	11	9	4	6	10.33	58.84	40.50	0.62
Za1-11/2R	50	14	15	10	7	4	8.33	60.03	39.80	0.15

Source: Sendula, E. 2015.

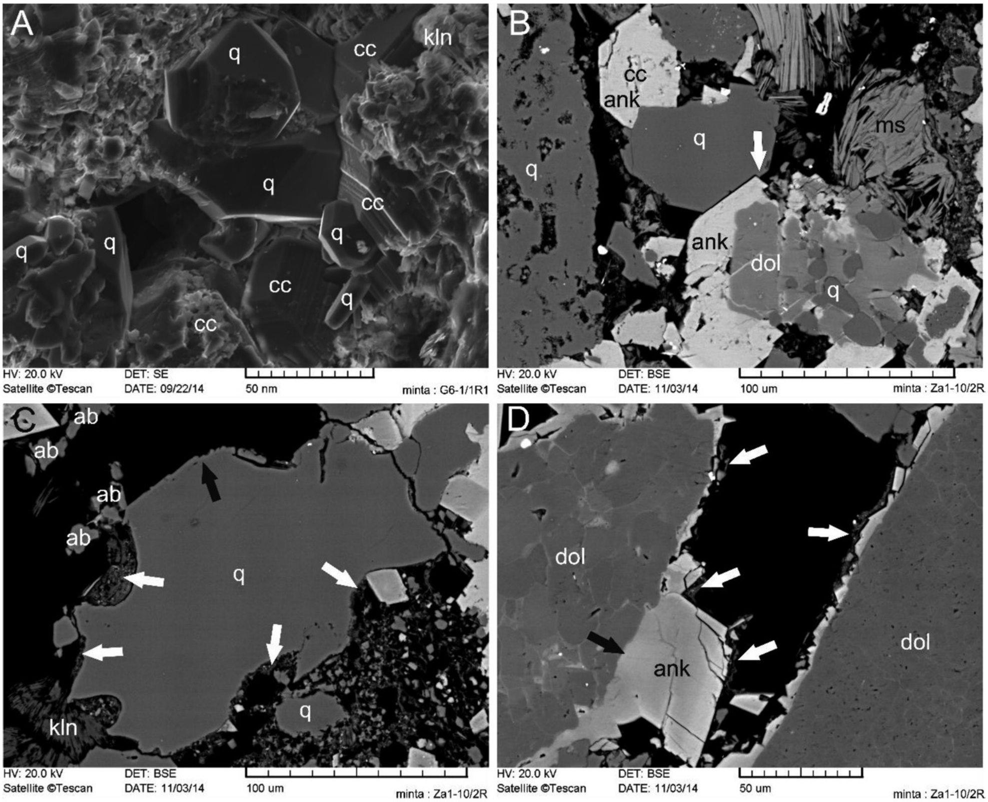

Fig. 2. Scanning electron images from Za1-10/2R and Za1-11/2R samples. A = a secondary electron image, where quartz overgrowth can be observed with diagenetic calcite. B = a backscattered electron image where ankerite cement precipitated around dolomite, the morphology of ankerite depends on the quartz (arrow). The muscovite crystals are broken in this sample. C = a backscattered electron image showing that albite dissolved from albite-quartz rock fragment, furthermore kaolinite precipitated from albite. D = also a backscattered electron image, where different morphological properties of dolomite-ankerite assemblage can be observed, which show dependence on a thin clay layer around the carbonates (Sendula, E. 2015).

and Soil Analysis (Geographical Institute, Research Centre for Astronomy and Earth Sciences). Contrary to widely used laser diffraction measurements, image analysis provides direct observational data of particle size, and due to the automatic measurement technique, a large number of particles are characterized allowing us a more robust and objective granulometric description of particles compared to manual microscopic approaches (Varga, Gy. *et al.* 2018).

55 mm^2 areas of the thin sections were scanned by using the 2.5× and 5× objective lenses of the built-in Nikon eclipse microscope and CCD camera, providing 1.2 and 0.3 μm^2/pixel resolution, respectively *(Figure 3).* The focus was manually determined, and we did not use Z stacking (no additional vertical focal planes were used). The applied greyscale intensity threshold was 0–45 in case of 2.5× objective, and 0–57 in case of 5× objective. All of the scanned grains are stored as separate greyscale images and several size and shape parameters are determined automatically *(Table 2).* After the measurement, the program saves a high-res-

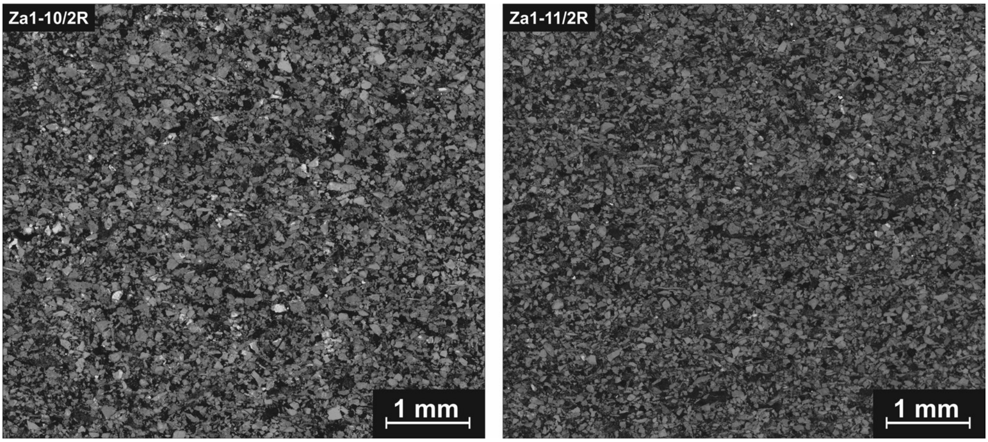

Fig. 3. Scanned thin section images

Table 2. Mathematical background of the different morphological parameters

Parameter	Equation	Description
Area (pixel)		Particle area in pixels (pixel size is dependent on resolution)
Area (μm²) [A]		Particle area in μm²
Aspect ratio [AR]	W/L	Particle width and length ratio
Circle equivalent diameter [CED]	D = A	Diameter of a circle with the same area as the particle
Centre X position (μm)		Particle location coordinate
Centre Y position (μm)		Particle location coordinate
Circularity [C]	$(2\times \pi^{0.5} - A^{0.5})/P = (CED \times \pi)/P$	Proportional relationship between the circumference of a circle equal to the object's projected area and perimeter
Convexity [K]	P_{conv}/P, where P_{conv} is the perimeter of convex hull	Ratio of perimeter of the convex hull to the particle perimeter
Spherical equivalent volume (μm³)	$(\pi \times CED)^3/6$	Volume of a sphere with CED of the particle
Width (μm) [W]		Particle width
Elongation [E]	1 – W/L = 1 – AR	1 minus AR
High sensitivity circularity [HS C]	$C^2 = ((2 \times \pi^{0.5} - A^{0.5})/P)^2 = ((CED \times \pi)/P)^2$	Ratio of the object's projected area to the square of the perimeter of the object
Intensity mean [Ia]	$(\sum_{1=1}^{i=N} I_i)/N$	Mean value of particle intensities
Intensity standard deviation	$((Ia^2 - (Ia^2/N)/N)^{0.5}$	Standard deviation of particle intensities
Length (μm) [L]		Particle length
Major axis (°)		Angle of the Major Axis from a horizontal line
Max distance (μm)		Furthest distance between any two points of the particle
Perimeter (μm) [P]		Particle perimeter
Solidity	A/P_{conv}	Ratio of the particle and convex hull areas

olution image from the scan area, which can be used for further analyses of the sample.

Circle-equivalent (CE) diameter is regarded as the most important size parameter of image analytical sizing techniques of the non-spherical, irregular-shaped particles. It is calculated as the diameter of a circle with the same area as the projected two-dimensional particle image. To transform number-based distributions into volume-based distributions sphere-equivalent (SE) diameter is used as a weighting factor. The volume of a given size bin is specified by weighting with the total SE volume of particles classed into this size range.

Length and width are estimated from major and minor axes of the particles (Malvern Instruments Ltd. 2015). All perimeter points of the object are projected onto the major axis (minor axis), and the longest distance between the points is the length (width) of the particle as shown in *Figure 4*. Other simple grain size parameters as particle area or perimeter can easily be determined using the acquired images.

Aspect ratio is the ratio of width and length, while elongation is calculated as 1-aspect ratio. The circularity parameter of a particle describes the proportional relationship between the circumference of a circle equal to the object's projected area and perimeter, while High Sensitivity (HS) circularity is the ratio of the object's projected area to the square of the perimeter of the object. Convexity and solidity are determined using the convex hull (theoretical rubber band wrapped around the particle – indicated as grey area on *Figure 4*) of the two-dimensional images. Convexity is the ratio of the perimeter of the convex hull to the particle perimeter, while solidity is the ratio of the particle and convex hull areas; these are parameters of the particle edge roughness. Relation between the particle shape parameter were described with correlation analyses and f-test in Microsoft Excel.

Simultaneously, the mean greyscale intensity and standard deviation of particles were also measured from the images. White light intensity of each pixel of particles is recorded on an 8-bit (2^8) scale from 0 to 255, where the intensity value of zero is white, 255 is black.

Phase analysis was performed using the built-in Raman spectrometer of the Malvern Morphologi G3 SE-ID. The laser of Raman spectroscope was operating with the following parameters: wavelength: 785 nm, energy: <500 mW, measurement time: 5 sec. Spectra were acquired from several hundreds of targeted individual particles. These spectra were compared with library spectra (BioRad-KnowItAll Informatics System 2017, Raman ID Expert) and correlation calculations were performed to determine the mineralogy of the targeted sedimentary grains.

Image analysis-based measurements were organized into a number-based database. All of the particles have their own identity number (ID) being the primary key in the data matrix. Each row represents one particle, while the columns are various size and shape parameters, completed with light transmissivity data and Raman correlation scores. Large numbers of measured particles ensure a statistically robust and objective insight into the granulometric characteristics of the investigated samples.

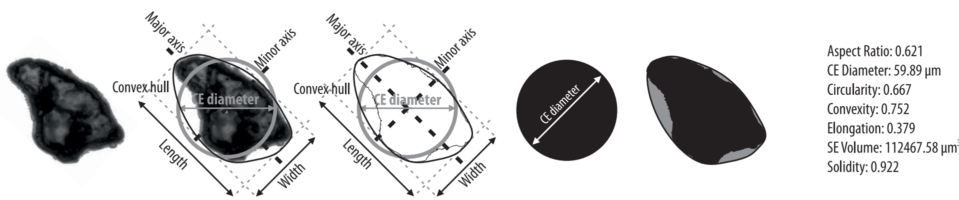

Fig. 4. Schematic illustration of major grain size and shape parameters of irregular mineral particles (grey areas represent the convex hull – modified after Varga, Gy. *et al.* 2018)

Results and discussion

Grain size results of image analysis based on $n_{Za1-10/2R}$ = 26,501 and $n_{Za1-11/2R}$ = 34,362 individual particles indicates the high volumetric proportion of fine sand-sized fractions in the samples. Mean (D[4,3]) diameters of the samples are 75.8 μm and 76.2 μm, respectively. The unimodal volumetric grain size distribution curves have their maxima in the fine sand fraction, while the modal values of number-based distributions are located around 3 μm (*Figure 5*). Volumetric size fractional proportions are the followings: Za-1-10/2R: clay: 0.04 per cent; silt: 61.36 per cent; sand: 38.6 per cent; Za-1-11-10/2R: clay: 0.019 per cent; silt: 54.43 per cent; sand: 45.56 per cent.

Intensity curves indicate a more homogeneous grayscale patter of Za1-11/2R sample and the presence of some scarce but rather large outlying dark particles in Za1-10/2R sample (also visible in *Figure 3*). The shape parameters show similarly the higher volumetric proportion of more irregularly shaped particles (lower nominal values of volumetric curves) in Za-1-10/2R sample. It is worth noting, that in all cases, the number-based shape distribution curves incline into the direction of more spherical general shape-character as a result of a high number of very fine particles with quite low-resolution (resulting blurred edges) at the applied magnifications.

Analyses of Raman spectra of selected n = 70 particles from the coarse silt-fine sand

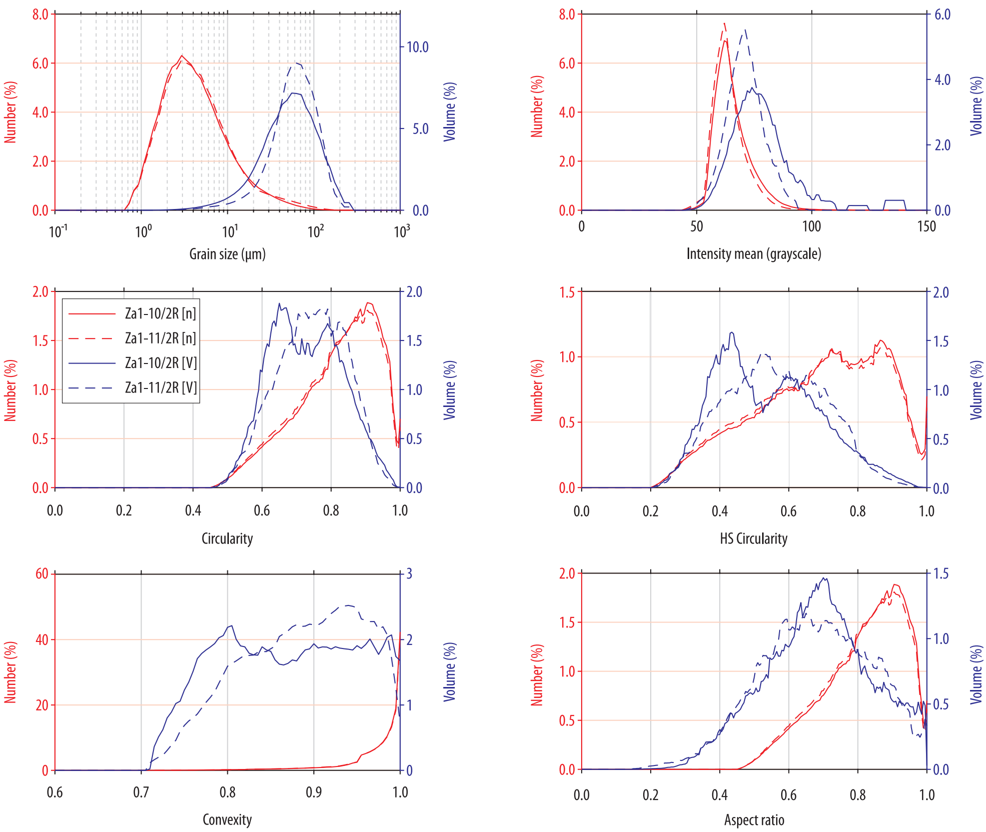

Fig. 5. Number- (n [red]) and volume- (V [blue]) based distribution curves of selected granulometric and optical parameters of bulk samples

fractions Za1-11/2R show that the main minerals in the studied fractions are quartz (75%), feldspar (11%), carbonates (9%) and mica (3%). The studied fractions show differences in Za1-10/2R (n = 90), where the carbonate (21%), feldspar (18%) and mica (6%) is higher and amount of quartz is significantly lower (56%).

The results of the shape analysis show that the quartz and feldspar particles have the most diverse appearance. Mica morphological parameters show minor variation, while shape parameters of carbonates are more diverse, but not as much as the quartz or feldspars *(Table 3).*

Volumetric grain size distributions were calculated from the number-based size distributions by weighting with SE diameter (raw number-based size distribution show rather different curves, but this cannot be compared to results of previous volumetric laser diffraction results by Sendula, E. 2015). The volumetric grain size results of image analysis, however, showed a completely different picture from the laser diffraction. This is logical consequence of the different approaches. The indirect estimations of laser devices are always dependent on several unknown factors (e.g., representative complex refractive index of the polymineral sample) beside the composition of the real particles (Varga, Gy. *et al.* 2019). Another, explanation of this discrepancy could be that the selected objectives are ideal for detailed characterization of particles larger than 6.5 μm in diameter, on the other hand, significant size polydispersity of the samples (particle sizes ranging from clay to sand fractions) is a known issue of image analysis-based sizing. Very few amount of large particles have a remarkable effect on size distribution curve if the number of scanned particles is not sufficient (depending on the polydispersity, sufficient number could be several tens or hundreds of thousands of particles), indicating the unavoidable necessity of usage of automated approaches. Consequently, the whole range of sample grain size distribution in a relatively small (1×1) thin section cannot be determined without compromises, for instance, large grains (>200 μm) are visible with objective 2.5×, the other grains can be analysed by objective 5×, and clay patches may be studied by using the 20× magnification lens providing a resolution of 0.019 μm^2/pixel.

The correlation analysis of various shape parameters shows that there is a strong correlation between HS circularity and convexity (r = 0.75, p <0.001) and between HS circularity and aspect ratio (r = 0.60, p <0.001) *(Figure 6)*. However, we have to note, that the shape parameters of muscovite depend on the kaolinite between the muscovite layers (Sendula, E. 2015), which led to misinterpretations. Consequently, if muscovite is excluded from the analysis, the correlation becomes stronger.

Determination of roundness (described in detail by Krumbein, W.C. 1941; Krumbein, W.C. and Sloss, L.L. 1951) was carried out on quartz particles. This quite widely used parameter is not defined mathematically and

Table 3. Results of shape analyses of selected particles

Sample	Mineral	Number	HS circularity	Aspect ratio	Convexity
			min-max		
Za1-10/2R	quartz	38	0.19–0.85	0.15–0.97	0.81–0.99
	feldspar	12	0.31–0.73	0.32–0.81	0.91–0.98
	carbonates	14	0.40–0.75	0.34–0.80	0.81–0.98
	mica	4	0.15–0.24	0.15–0.36	0.81–0.91
Za1-11/2R	quartz	86	0.19–0.82	0.21–0.99	0.76–0.99
	feldspar	12	0.40–0.91	0.43–0.91	0.79–1.00
	carbonates	10	0.45–0.72	0.46–0.81	0.84–0.94
	mica	6	0.10–0.40	0.15–0.32	0.82–0.93

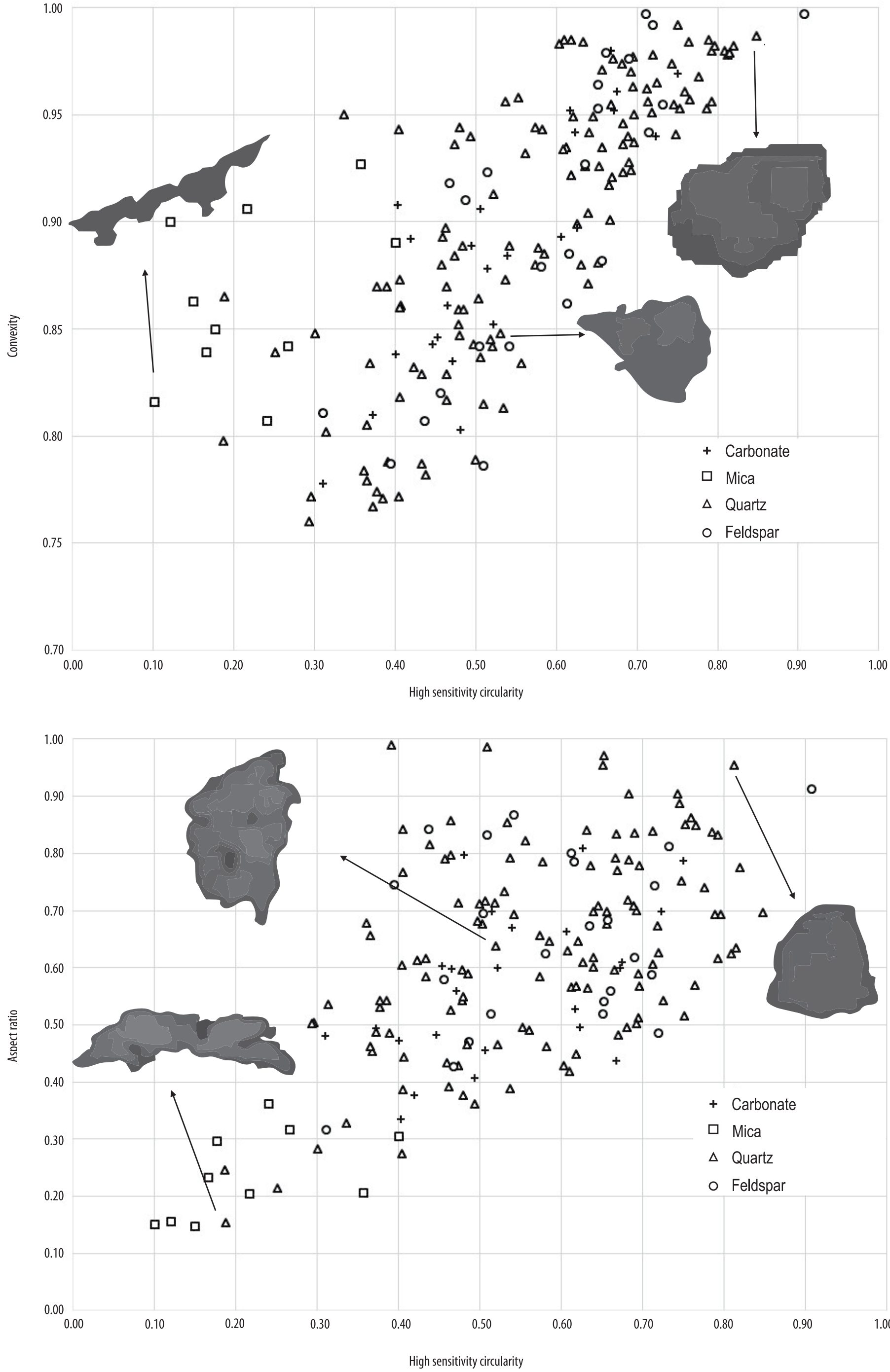

Fig. 6. Particle shape properties are in correlation (HS circularity-convexity, HS circularity-aspect ratio) in case of the two studied samples (Za1-10/2R, Za1-11/1R)

is regarded as a semi-quantitative approach (Kim, Y. *et al.* 2019), it depends on the convexity and HS circularity (Xia, W. 2017). According to Sendula, E. (2015) these samples are sub-rounded, however, the morphological parameters of quartz show that HS circularity (0.19–0.85) and convexity (0.76–0.99) are very diverse. The convexity in natural grains is generally >0.7, for this reason, the clumped or aggregated grains were filtered by using proper thresholds of convexity (0.75, which was checked according to the deleted grains). For this reason, the classification of roundness cannot be determined based on the results of 2D image analyses. This is in harmony with Sochan, A. *et al.* (2015), who demonstrated that Krumbein-Sloss classification is not working in case of 2D image analysis.

The effect of fluid-rock interaction is expected to influence the morphological properties of certain grains. Consequently, complex interpretation of shape analysis is necessary to understand what reactions could have taken place in the system. Quartz is mainly a detrital mineral which deposited as rock fragments, polycrystalline and monocrystalline quartz. In the rock fragments, different minerals are present (feldspar, mica, carbonate), which may have dissolved during the diagenesis. Furthermore, during the diagenetic processes quartz overgrowth occurred, which also affected the particle shapes. These phenomena contribute to the varying appearance of quartz. The feldspar is also mainly a detrital mineral, which is partly dissolved during the diagenetic processes. The dissolution of feldspar can cause lower convexity and HS circularity values. The carbonates are present both as detrital and diagenetic minerals. According to the petrography, ankerite precipitated around dolomite, which may change the morphological properties of these complex carbonate grains. Part of calcite is detrital, which may easily deform during the compaction. This effect also influenced the shape parameters. Therefore, morphological parameters of carbonates depend largely on the free pore space, and from clay coatings (see also in *Figure 2*). As a result of sheet-like shape, muscovite is deposited with its flat surface parallel to sedimentary layering. Subsequently, the muscovite is slightly deformed as a result of compaction and kaolinite precipitated between its layers. These effects caused the low convexity and HS circularity values in mica crystals.

The automated identification of minerals of the investigated thin section, the modal composition of samples can be determined precisely in a faster and more exact way compared to the widely used 300-poins analysis. However, due to the inaccurate determination of the proportion of lithic fragments, the Q-F-L classification cannot be done without manual control.

Conclusions

It was demonstrated that Malvern Morphologi G3 SE-ID system is capable to determine various size and shape parameters and mineral composition of a large number of particles from thin sections of sandstone samples. The results show that the particle shapes of minerals were amended during the diagenetic processes. The most useful parameters to characterize the particle shapes in sandstones are HS circularity, convexity and aspect ratio, which may describe the roundness of the particles. The advantages of the method are the following: (1) high resolution/high-quality image from the scanned area; (2) mineral composition of grain size fractions can be clearly and easily defined; (3) particle shape analysis of particles from thin sections; (4) particle size and shape distributions in selected size-fraction; and (5) the thin section and its high resolution scanned image is available for further analysis.

With further studies, the clarification of how diagenetic processes affect the morphology of particles and pores can be achieved. However, we notice disadvantages of the methods: (1) the important grain size fractions have to be chosen; (2) clay fraction cannot be examined; and (3) QFL diagram can only be done with manual control.

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Analysing the sensitivity of Hungarian landscapes based on climate change induced shallow groundwater fluctuation

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Abstract

One of the undoubtedly recognizable consequences of the ongoing climate change in Hungary is the permanent change of groundwater depth, and consequently the sustainably reachable local water resources. These processes trigger remarkable changes in soil and vegetation. Thus, in research of sensitivity of any specific landscape to the varying climatic factors, monitoring and continuous evaluation of the water resources is inevitable. The presented spatiotemporal geostatistical cosimulation framework is capable to identify rearrangements of the subsurface water resources through water resource observations. Application of the Markov 2-type coregionalization model is based on the assumption, that presumably only slight changes have to be handled between two consecutive time instants, hence current parameter set can be estimated based on the spatial structures of prior and current dataset and previously identified parameters. Moreover, the algorithm is capable to take into consideration the significance of the geomorphologic settings on the subsurface water flow. Trends in water resource changes are appropriate indicators of certain areas climate sensitivity. The method is also suitable in determination of the main cause of the extraordinary groundwater discharges, like the one, observed from the beginning of the 1980's in the Danube–Tisza Interfluve in Hungary.

Keywords: climate change, shallow groundwater, spatiotemporal sequential Gaussian cosimulation, Markov 2-type coregionalization

Introduction

Last century environmental researches revealed, that the alterations of various landscape factors (e.g., hydrologic conditions, soil, vegetation) are closely related to the changing climate (Ladányi, Z. *et al.* 2009; IPCC 2014; NORDEN 2015; EEA 2017; Rakonczai, J. 2018). Thus, to clarify how severely our landscapes with different environmental settings are affected to the climatic changes is crucial (Faragó, T. *et al.* 2010; USAID 2017; Patron, C. 2018).

Spatial, temporal, thereby joint spatiotemporal scale-related problems in geology as well as *"dynamic up- and downscaling"* in GIS are widely distinguished problems (Wilbanks, T.J. 2002). In contrast to the well interpretable environmental dynamics at the scale of geological history, where temporary outlying inferences are averaged over time, the explanation of tendencies of the significantly noisier observations of the near past is tricky. The questioning of the existence of global warming is actually rooted to the interpretation of trends of these noisy datasets (Sterl, A. *et al.* 2009). From practical aspect, the separation of the noise from the trend is a regularly returning question, which is ultimately based on the decision of the individual modeller (Thiébaux, H.J. 1997).

Hungarian hydrological science pays special attention to the shallow groundwater, thus, provide more sophisticated analyses, than it can be found in common practice (Kovács, J. *et al.* 2010; Kohán, B. and Szalai, J. 2014). Although flow and transport modelling ori-

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ented papers mostly use the "unconfined groundwater" expression for the top subsurface water layer, these articles usually written by researchers who are more focusing on realistic simulations of underground processes. While for studies, whose perspective from above, the "shallow groundwater" expression sounds much more expressive (Dillon, P. and Simmers, I. 1998; Alkhaier, F. *et al.* 2012; Wang, X. *et al.* 2015; Gowing, J. *et al.* 2016). In addition, unlike the international literature, the historical Hungarian research distinguish different definitions to the confined and unconfined groundwater (Marton, L. 2009).

The past two decades of the Hungarian climate research inferred that alteration of the shallow groundwater can be a substantial indicator of climate change (Rakonczai, J. 2011). The temporal pattern of the groundwater smoothly follows the changes of cumulated precipitation (Réthátі, L. 1977). Furthermore, the significant alterations of the groundwater depth at certain areas has triggered further transformation in the vegetation (Ladányi, Z. *et al.* 2009; Mezősi, G. *et al.* 2013; Gulácsi, A. and Kovács, F. 2018).

Based on interactions between different environmental factors (*Figure 1*), presumably changes of climatic conditions (particularly alteration of amount and temporal distribution of precipitation) triggers the changes and fluctuations of groundwater level. While less precipitation results less amount of infiltration, during heavy rainfalls large amount of water runs off on the surface, instead of infiltrating into the soil (Margóczi, K. *et al.* 2007; Pongrácz, R. *et al.* 2016; Gulácsi, A. and Kovács, F. 2018). Climate forecasts show that in the Carpathian Basin, the global warming leads to less precipitation averages in the warm half of the year, triggering more extreme rainfalls, along with decreased precipitation volume in the cold season (Van der Linden, P. and Mitchell, J.F.B. 2009; Stábitz, J. *et al.* 2014). The generally less

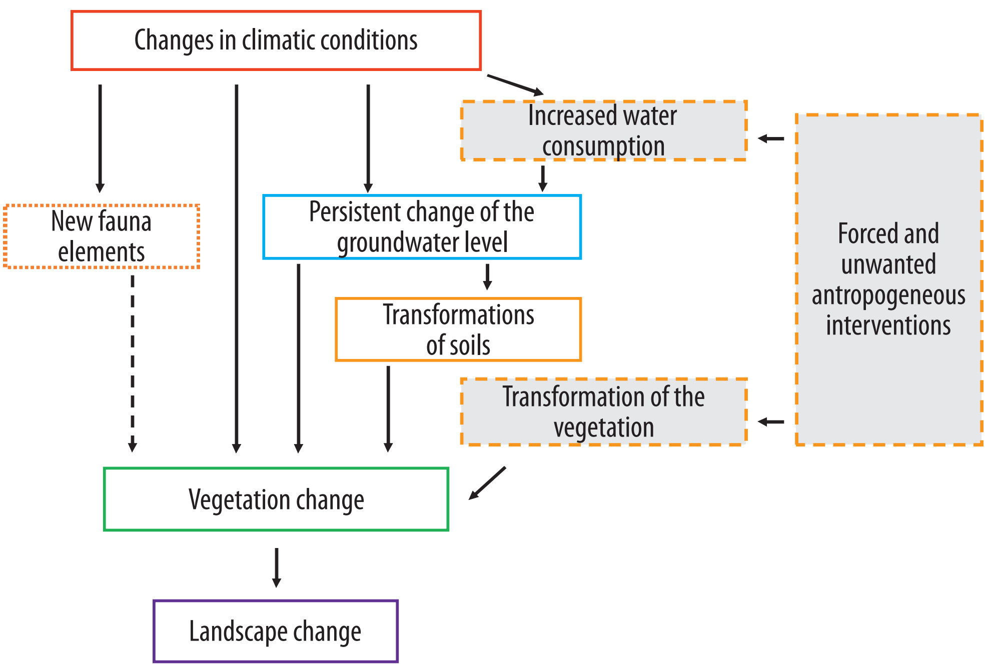

Fig. 1. Schematic relationship between climate change and landscape alterations in Hungary. Based on Farkas, J.Zs. *et al.* 2017.

precipitation would most likely reach the shallow groundwater reservoirs, too.

In areas where surface water is not available for agricultural usage, and during drought periods, farmers are forced to irrigate from subsurface reservoirs, thereby water extraction further amplifies groundwater discharge. As a consequence of steady groundwater decrease it might happen to reach a critical depth when certain plants cannot obtain sufficient moisture. Decade-long alteration of the groundwater table might even trigger the change of soils and ultimately vegetation changes can be observed (Rakonczai, J. *et al.* 2012; Ladányi, Z. *et al.* 2016). The alteration of the vegetation as a response to the climatic effects can be often experienced even without the change of the groundwater level or the soil settings (Gulácsi, A. and Kovács, F. 2018). Climate change might have further impact as well as on fauna. As a consequence of the milder climate, appearance of new pests in Central Europe is a typical example of that (Laštůvka, Z. 2009; Farkas, J.Zs. *et al*. 2017). These briefly described processes may jointly trigger significant landscape changes, in which the depth of water table is a key factor.

Objectives in the light of unanswered questions

From the 1980s a regional scale groundwater discharge has been experienced in Hungary. Due to its severity, the majority of domestic research focused on the Danube–Tisza Interfluve. The region itself provides an interesting framework for various disciplines due to its topographical and geological settings, hydrological characteristics (lack of major rivers) and the complex human interventions supplemented by the consequences of changing climate. The area itself is formed by sedimentary deposits from river Danube, which is later covered by windblown sand. The elevation of the area is between 83–172 metres a.s.l.

First and foremost, experts of the Kiskunság National Park had challenged with the adverse effects of shallow groundwater discharge, when drastic transformations of the wetlands were perceived (Pálfai, I. 1992, 1994). Nearly 1,000 mm lack of precipitation piled up between 1971 and 1985 (Major, P. 1994), which would infer almost 8.3 km^3 water shortage on the surface (Rakonczai, J. and Fehér, Z. 2015). The rate of mean areal decrease of shallow groundwater exceeded two meters (it would equal to 2 km^3 water deficit), while much higher rates occurred at the most elevated regions. Since then, drier conditions of the highest areas have not been able to recover even after longer wet periods (Margóczi, K. *et al.* 2007; Ladányi, Z. *et al.* 2009; Faragó, T. *et al.* 2010; Rakonczai, J. *et al.* 2012; Rakonczai, J. and Fehér, Z. 2015).

Various opinions on the background of groundwater depletion

After recognition of the problem by the early 1990s, scientists of various disciplines prepared their analyses of the possible reasons (Pálfai, I. 1994; Szilágyi, J. and Vörösmarty, C.J. 1993, 1997; Völgyesi, I. 2006). These studies clearly pointed out that their authors built in their arguments logically on their own specialized, thus, restricted professional fundaments. However, the final conclusions are diverse, sometimes even contradictory in several aspects.

It is agreed that one of the main reasons is the decade-long arid period, although afforestation, extraction of underground water, regulation of surface water bodies, (mainly the drainage of periodically occurring excess water) are also enlisted among the attributed reasons. Changes in land use and consequences of hydrocarbon production may also act as additional factors (Rakonczai, J. and Fehér, Z. 2015).

Surprisingly, even the role of rainfall shortage is very differently judged by certain researchers. The model study of Szilágyi, J. and Vörösmarty, C.J. (1993, 1997) recognized only 15 per cent of importance, another researcher team led by Pálfai, I. (1994) attached an importance of 50 per cent to shortage of precipitation, while the analysis of

Völgyesi, I. (2006) considers 80 per cent for the role of weather as a determinate factor for the higher parts of the sand ridge.

We experience nearly similar differences in reference to the assessment of underground water extraction. It is considered to be the main cause (70%) of groundwater discharge according to Szilágyi, J. and Vörösmarty, C.J. (1993, 1997). In the meantime, Pálfai, I. (1994) calculated a 25 per cent role of that, to which the extraction of groundwater contributes a further 6 per cent. However, Völgyesi, I. (2006) considered an almost insignificant 2 per cent for the role of underground water extraction for the analysed 10 years.

The arid period coincided with new constructions of water supply (thus with increased extraction of underground waters), and the intensified hydrocarbon exploration in the area. On most part of the Danube–Tisza Interfluve, positive hydrodynamic gradient can be experienced, therefore the infiltration from above prevails on the landscape even until 300–400 m depth (Erdélyi, M. 1978). Hydrological research considers annually 20–40 mm infiltration, thus on 6,000 km^2 area. This means that from the shallow groundwater to the confined water zones approximately 440–660 thousand m^3/day infiltration can be estimated. However, the amount of confined water extraction in the 1970s–1980s was only a third of this volume (Liebe, P. 1994). Thereby the full amount of extracted confined water would trigger maximum 40–50 cm groundwater discharge (Rakonczai, J. and Fehér, Z. 2015).

The role of confined water extraction on the landscape between 1960 and 2000, at most 2 km^3 in total (*0.20–0.45–0.70 and ~0.60* km^3 by decades correspondingly) (Rakonczai, J. and Fehér, Z. 2015). However, as it is going to be presented in current paper, the climatic effects are able to cause such volume of change even within a year (in a positive and a negative way alike).

One of the priority objectives of the current paper was to find some "truth" among the very different opinions above. After the quantitative analysis of changes in groundwater resources, we aimed to evaluate the role of climate change on selected areas with various natural conditions of the Great Hungarian Plain.

Study areas and datasets in the light of the natural background and processing issues

Current research was carried out for the area of the Great Hungarian Plain, whereto an adequate number of shallow groundwater time series is available. The area consists of several mesoregions with significantly different geographic conditions. Some significant details related to the groundwater dynamics are collected into *Table 1.*

Previous research has revealed that the official shallow groundwater database of the National Water Directorate of Hungary struggled with numerous errors (Mezősi, G. *et al.* 2017; Fehér, Z. 2019). The missing, mistyped or incorrect geographic elevation and reference zero points of observation gauges, as well as data conversion, database integrity and query errors resulted sudden jumps on the hydrographs. Sometimes these sections cannot be corrected, causing ignorance of decade-long valuable observations.

Sufficient length of the hydrographs (in this case 10 years was chosen as a criteria) is important to discover the temporal pattern and relation to nearby gauges. The research attempted to minimize effects of obvious, short range anthropogenic and environmental inferences, like irrigations or floods.

Reliably accurate results could be inferred on four regions of the Great Plain (areas of 4,700–8,300 km^2), on nearly 25,000 km^2 *(Figure 2).* Only the areas above the maximum measured flood levels of the major rivers (Danube, Tisza and Körös) were considered in the analysis, thereby their interference could be filtered out.

Since water table trends slowly follow the cumulated precipitation, consideration of the monthly aggregated groundwater level is sufficient, and spares significant computation capacity. For current research monthly median was considered, which is capable

Table 1. Environmental characteristics of the study sites

Study area	Typical rocks and soils	Geomorphological characteristics	Watercourses, the water resources and their anthropogenic influences
Danube–Tisza Interfluve	– Blown sand – Sandy soils with low fertility – Soils with low water retention capacity	– Aeolian sand forms, which are stabilized by forests (mainly pines with small water demand) – North–South oriented ridge area, steeper western slopes	– Lack of permanent watercourses – Canals with temporal water flow – Unconfined aquifers – Local water withdrawal from aquifers for irrigation
Nyírség	– Blown sand – Sandy soils with low fertility, soils with low water retention capacity	– Stabilized aeolian sand forms	– Lack of permanent watercourses – Unconfined aquifers
Southern Tiszántúl	– Occurrence of versatile fluvial sediments	– Alluvial plain with abandoned river-beds	– Lack of permanent watercourses – Alternated appearance of confined and unconfined aquifers
Foothills of the North Hungarian Mountains	– Deluvium, blown sand – Loessy sediments	– Increasingly sloping plain to the South direction, with some small alluvial plains	– Several small watercourses with insignificant runoff – Large amount of subsurface water extraction in order to support open-cast mining in two areas
Central Tisza Region	– Poorly permeable clayey surface – Frequent occurrence of saline soils	– Plain with low relief, whose significant part was regularly flooded before the river regulations in the 19th century	– Occurrence of rare natural water courses – Separated by irrigation channels – Groundwater-table under strong anthropogenic impacts

to filter outliers and insensitive to the number of observations in any given month. Thereafter the temporal outliers were filtered out using a 2-year moving box-plot. Finally, 848 of the 1,131 available time series were considered in the current study.

Weaknesses of conventional groundwater change maps

For a long time, changes in groundwater resources were presented on such maps where the depths of groundwater were related to the average of a particular reference period. While in the late 1960s anthropogenic interventions strived to mitigate with significant water surplus (like inland excess water), the precipitation increasingly reduced from the mid-1970s. These changed circumstances caused significant question of the proper designation of the widely used *"30-year reference-period"* in the discipline.

Figure 3. displays the water level changes after three consecutive, extreme dry years in 2003 compared to the mean water depth between 1956–1960. Three regions with different characteristics can be designated: A significant reduction in water level can be seen in the sand ridge area of the Danube–Tisza Interfluve (*Figure 3*, site A). This is an area with higher altitude than its surroundings, thus other surface water recharge cannot be gained, except from precipitation.

Contrarily to this, an increase of water level can be discernible on the Central Tisza Region, which is one of the most arid areas of Hungary (*Figure 3*, site E). After the reference period, a considerable number of irrigation canal structures has been established on this site. Besides conventional irrigation, the flooded rice production means further influence on ground-

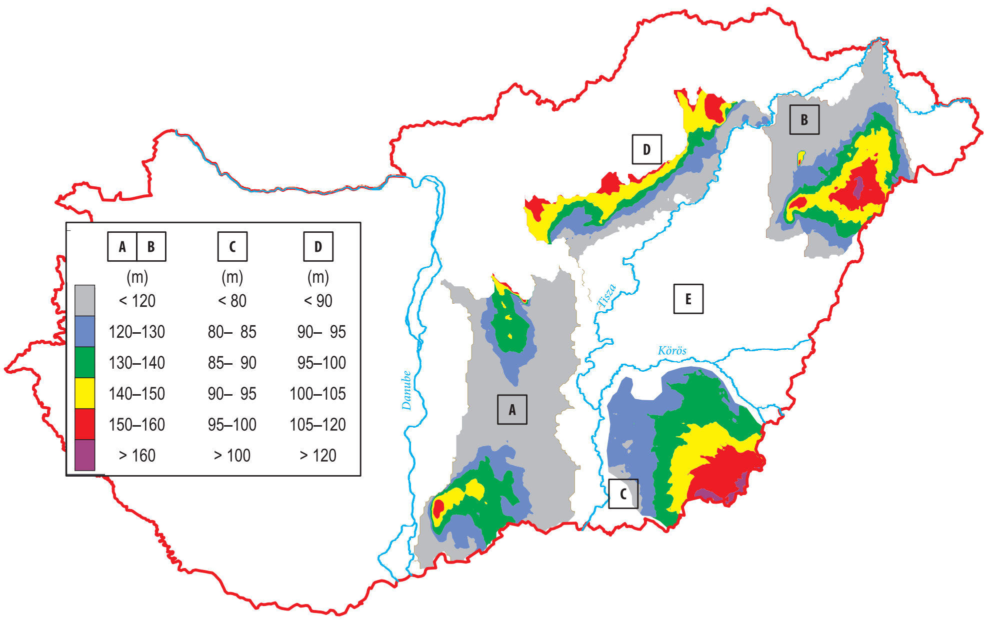

Fig. 2. Elevation map of areas involved in evaluation of fluctuation of groundwater table. Study areas: A = Danube–Tisza Interfluve; B = Nyírség; C = Southern Tiszántúl; D = Foothills of the North Hungarian Mountains; E = Central Tisza Region

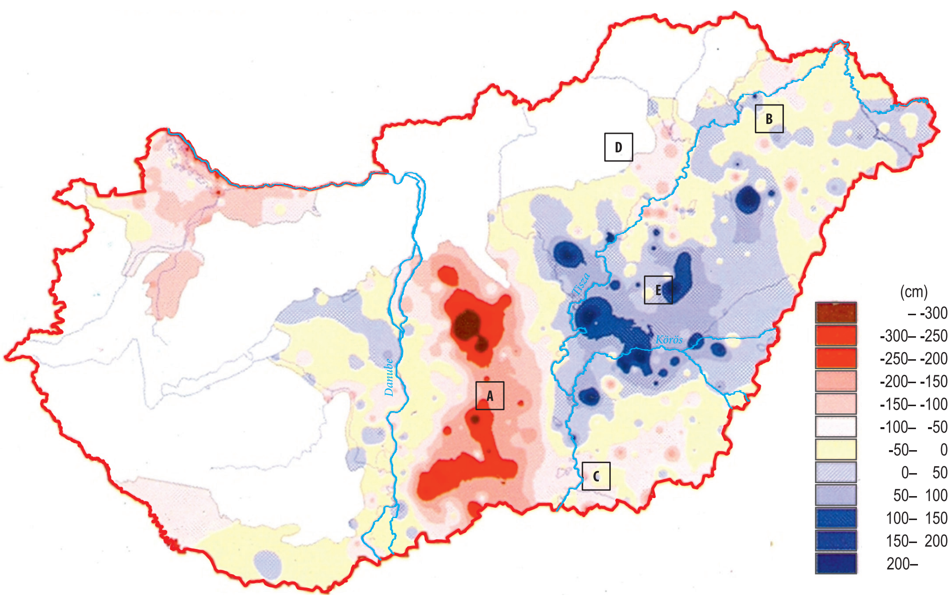

Fig. 3. Deviations of the annual average in the extreme dry year 2003 from the average shallow groundwater level 1956–1960. For study areas A–E: see *Fig. 2*. *Sources*: KSH=VÁTI 2005; original source: VITUKI.

water. Thus, supposedly the increase of the groundwater is a consequence of some specific purposive anthropogenic interventions.

Although, the national construction of drinking water networks had been carried out during this period too, which accompanied with intensive extraction of the confined water. In addition, due to the absence of wastewater network, the amount of wastewater leakage increased the groundwater table as well. After all, the Central Tisza Region was excluded from the current study, due to the spatially and temporally irregular intensity of significant anthropogenic impacts on the groundwater table. The presented methodology is not capable to handle such a complex problem.

The biggest issue is to decipher possible reasons for significant differences between Nyírség (*Figure 3*, site B) and Danube–Tisza Interfluve, in spite of the fact that Nyírség bears similar natural characteristics. Despite the less amount of precipitation in Nyírség, the question is, that whether Nyírség does not face any shortage in groundwater or the discharge is barely not seen for some reason.

Such maps were created by some traditional, isotropic spatial interpolations, whereas the gravitational flow mechanisms and geological settings were entirely ignored. The unsystematic river floods in some areas may interfere the assessment of the groundwater resources. Moreover, maps which has traditionally been prepared to indicate fluctuation of groundwater, are often not proven to be suitable to detect the most important changes. However, the most important factor was the lack of such an index that allows the comparison of various effects. Yet another problem is that these kind of maps do not allow the realignments of subsurface water resources. However, they are capable to highlight the areas face with long-term water shortage.

Methodology

Since correlations between the groundwater table and terrain is significant, a Digital Elevation Model (DEM) can improve the water resource estimations (Fehér, Z. and Rakonczai, J. 2012). However, estimation by means of simple linear regression equation will not give proper results, since the higher (more affected) altitudes significantly diverges from the regression line. Only single and bivariate kriging techniques (Goovaerts, P. 2000; Fehér, Z. 2007), capable to handle the geographical anisotropy properly. In most cases the spatial anisotropy is modelled by the so called variogramm models (Pannatier, Y. 1996).

Our experiences confirm that the order of magnitude of groundwater volume changes are fairly similar, if the estimations are performed based on similar spatial data structures (with the same spatial structure of the conditional dataset, identical interpolator and slightly different spatial parameterization) (Fehér, Z. and Rakonczai, J. 2012; Fehér, Z. 2015a). In case of same estimation method, however, the comparison of estimates between two time instants results miscalculations close to the gauges of non-complete series (Fehér, Z. 2015a). The different conditioning datasets constitutes differently structured equation systems of the spatial estimation functions. Since more or less missing sections can be observed on every single hydrograph, thus these missing values have to be handled. Ultimately, the comparison of point- and volumetric estimations become questionable in the presence of missing data (Fehér, Z. 2015b). Straightforward solutions to minimize the effect of the non-complete dataset can be either to ignore them (Kohán, B. 2014), or to apply mathematical estimation of the missing data based on some time series characteristics (Réth※áti, L. 1977). While the former solution results lower level of information content, application of the latter way becomes problematic if unmeasured periods exceed the temporal autocorrelation.

The benchmarks of bivariate kriging interpolators revealed the efficiency and flexibility in parameterization of the versatile cokriging solutions (Fehér, Z. and Rakonczai, J. 2012; Kohán, B. 2014; Rakonczai, J. and Fehér, Z. 2015). Geiger, J. (2015) published that the Markov 1 type (De Almeida, A. and Journel, A.G. 1994) variogram construction is mostly effective in the case of groundwater depth estimation in temporal sequence, since the variogram estimation is based on the distance of the groundwater from the surface. These variogram parameters are very variable, and related to the hydrometeorological conditions, thus need to be modelled for each instant separately. While Fehér, Z. and Rakonczai, J. (2012) revealed that variogram construction in case of water table elevation is more effective by exploiting the spatial continuity function of the DEM. Since observed geographical superposition of the groundwater table has a high impact on the subsurface water flow, and the temporal variability of each time series is lesser scale, thus the spatial structure in two extreme states is fairly identical (Fehér, Z. 2015a, 2019). This revealing led to the application of the Markov 2-type variogram construction. This approach minimizes the manual parameterization demand and calculates the necessary spatial continuity parameters automatically for each time instant (Shmaryan, L.E. and Journel, A.G. 1999).

In the past 15 years, two complex, GIS-based approaches have been developed for the evaluation of the shallow groundwater, as a spatiotemporal phenomenon. The approach of spatially correlated time series undermines the detailed temporal characteristics of the hydrographs, thus capable to estimate groundwater depth changes of any hydrographs over the temporal range and capable to simulate artificial time series at any locations inside spatial range very accurately (Kyriakidis, P.C. and Journel, A.G. 1999). However, this approach is less sensitive to the geographic elevation of the area (Fehér, Z. 2015a). In contrast, the currently applied recursive stochastic method is a straightforward process, which is very robust in the presence of a non-complete dataset for the concerning time instant, while honours the geographic elevation in the same time. The latter process performs well in processing near real time estimations for the groundwater level, undermining the short-memory dependencies with the previously estimated state of groundwater level (Kyriakidis, P.C. and Journel, A.G. 1999; Fehér, Z. 2011, 2019).

In contrast to the widely known kriging interpolators, modern geostatistical approaches, like stochastic simulations, account with small-scale spatial variability (Deutsch, C.V. and Journel, A.G. 1998; Szatmári, G. *et al.* 2015). The currently applied sequential Gaussian simulation (sGs) enables to mimic the process of the information gathering, by making large number of assumptions to the groundwater level at non-gauged spatial coordinates (Mucsi, L. *et al.* 2013). The algorithm designates the order of estimation nodes randomly, and considers the already estimated values as observations (in contrast to any kind of interpolations), until the last unknown spatial coordinate is estimated. Repeating this random path estimation multiple times, a large number of estimated groundwater grids (realizations, ensembles or stochastic images) are created. However, none of these images can be considered as the "*best one*", but in contrast to the single optimal estimate of any interpolations, it results multiple, *equally probable* spatial patterns of the groundwater state (Fehér, Z. 2008). In case of proper parameterization, each of these stochastic images entirely reproduce the statistical distribution of the input dataset, as well as fully honour the variogram model applied (Mucsi, L. *et al.* 2013). The sequential Gaussian simulation (sGs) enables to use any kind of kriging interpolator, including the currently applied cokriging with Markov-type variogram constructors (Fehér, Z. 2015a). By aggregating the estimated grids, different consequences, like the most probable level of groundwater table, can be expressed at each coordinate (Fehér, Z. 2008; Mucsi, L. *et al.* 2013).

The main goal of the recursive scheme was that the statistical distribution of differences between simulated grids reproduce the statistical distribution of the calculated water change per gauge for any two chosen time instants properly. This comparison was elaborated by visual cross-validation of percentiles. This is a straightforward process, if the parameters and the spatial structure doesn't differ significantly (*Figure 4*, left col).

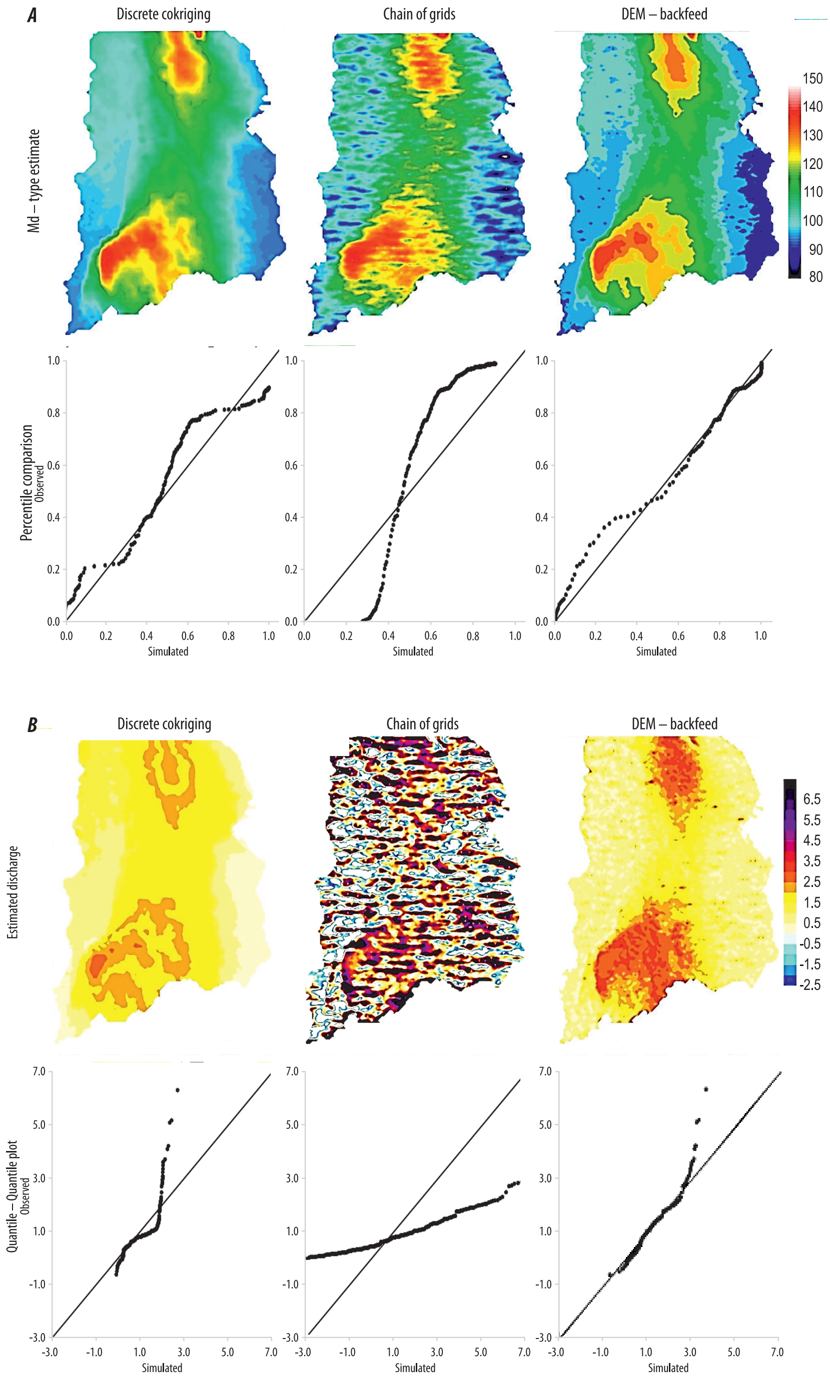

Fig. 4. Estimation and cross-validation of the groundwater table (A) and change of groundwater level (B) applying three different spatiotemporal schemes.

In spatiotemporal case however, the previous state is undermined to estimate both the actual spatial pattern and its parameters, while it has to consider the missing data and the DEM as auxiliary data too. The previously available recursive algorithms for this task (Kyriakidis, P.C. and Journel, A.G. 1999; Geiger, J. 2015) are not adaptable properly, since the relation between groundwater and DEM is significantly distorted, as well as the cross validation shows weak results as it is well noticeable already after the 28th consecutive recursive step in our benchmark example (*Figure 4*, middle col).

However, the disturbance mentioned above can be eliminated by the following steps:

1. estimation of the past spatial pattern of groundwater level, based on a complete dataset, by performing sGs and considering DEM as an auxiliary data;
2. estimation of the current spatial pattern of groundwater level, based on a non-complete dataset, using sGs and considering previous groundwater estimate as auxiliary data;
3. filling out the missing observations of the current dataset with the estimations from step 2;
4. estimation of the current spatial pattern, based on the already completed dataset, using sGs and the DEM as auxiliary data.

The algorithm keeps the spatiotemporal integrity of both the groundwater levels *(Fig. 4,* A, right col*)* and correctly reproduces the statistical distribution of the groundwater resource changes expected by mathematical calculations from gauge measurements *(Fig 4,* B, right col).

Results

The groundwater table estimation

The quantitative analysis of the temporally varying water resources has been carried out for each month between 1950 and 2017 applying the above introduced recursive sGs, with the Markov 2 type coregionalization model. A 1,000 m resolution auxiliary dataset has been generated from a 5 m resolution DEM. The resolution switch was carried out by the means of median-based downscaling, which enables to consider the most typical elevation value from the measured 200 × 200 values over every 1 km^2. In addition, this calculation enables the robustness against outlier values in the elevation database.

For each month, 125 alternative, equiprobable realization of groundwater table elevations were generated, and the most probable (median type estimation) simulated value were chosen for each spatial location and each time instant (median of simulated values, Md-type estimation). The difference of the Md-type values between two time instants resulted the relative volumetric change. Since no proper geological map is available, which would honour spatial heterogeneity from geostatistical aspect, the effective porosity was considered as an aggregated 30 per cent, according to Marton, L. (2009). The results allow the quantitative comparison of the water resources as a *"common denominator"*.

Analysis of quantitative changes in groundwater resources for natural regions

Based on the monthly water table estimations for each of the four designated sites between 1960 and 2017 *(Figure 5)*, the average of the estimations of the whole examined period was chosen as a reference *"0 value"*.

Generally, the estimated water resources for the four regions closely follow the precipitation patterns (the depicted precipitation is estimated by the following steps: ordinary kriging of monthly precipitation sums for each time instant is divided by the area under study, then half of the sum of the estimated precipitation volumes of the previous 24 months formulates the considered precipitation volume.). However, it can be seen, that on two of the sites, where the groundwater can be recharged from nearby external (higher areas), only some minor anomalies can be sensed on the estimated resources. The volume of these irregularities does not exceed 1.5 km^3, and reflects the precipitation well.

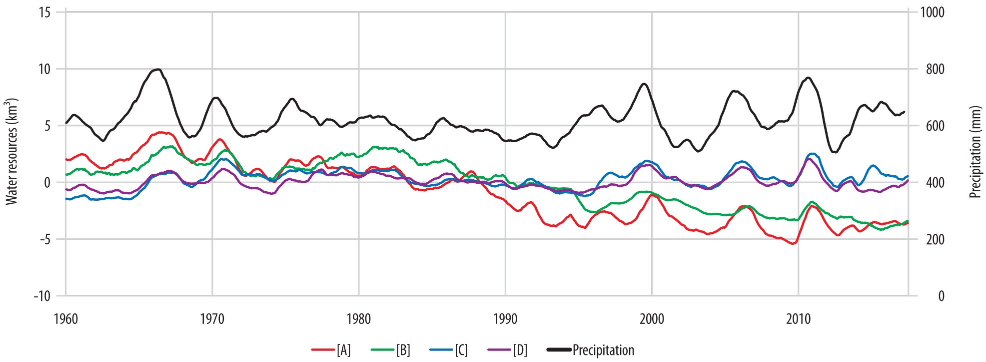

Fig. 5. Deviation of the estimated shallow groundwater compared to the long-term average, on the four study areas (1960–2017). Study areas: A = Danube–Tisza Interfluve; B = Nyírség; C = Southern Tiszántúl; D = Foothills of the North Hungarian Mountains. In addition, the annual sum of biannual moving average of the precipitation.

In contrast the two sandy areas (Danube–Tisza Interfluve and Nyírség), where the recharge of the groundwater is restricted to the local precipitation, a significant groundwater discharge can be observed over nearly 60 years. The estimated volume of this discharge is 6–8 km^3, compared to the second half of the 1960's.

However, the impact of rainy and dry periods is pronounced much faster on the Danube–Tisza Interfluve, because even a single dry or wet year can trigger 2–3 km^3 alteration in the groundwater resources. In contrast, the water resources of the Nyírség are rather characterized by slow, trend-like changes. The different dynamics of the two landscapes will be interpreted later in this study.

Thereby significant resource discharge can be measured on the Nyírség region definitely. However, it needs to be explained, why this discharge is hidden on the maps above analysed. It can be detected by detailed areal analyses, that during the 1970–2000 period, which in recent years was considered as reference data, there is a short period (between 1979–1983), when significant rainfall difference was evolved between the Nyírség and the Danube–Tisza Interfluve.

During this 5 years, 400–600 mm more rain fell on the Nyírség. Because of the significant precipitation surplus, until the middle of the 1980s, the groundwater level raised slightly higher than average, thus the dry period began later and lasted shorter. In addition, the recharge of the groundwater can be faster, since the water table is closer to the surface.

Connection between relief and changes in groundwater resources

The next step was the calculation of specific groundwater resource, namely the groundwater changes by unit area (km^2). These calculations were performed for each study site and evaluated according to the relief *(Figures 6–9)*. The analysis allows to find relationships between certain reliefs and volume of changes. In addition, we can compare fluctuations for the different areas mentioned above. Besides, it allows to infer variations of groundwater resources within certain regions.

Changes have been well identified from the mid-1970s (started from a position well above the average), fully playing its role by the mid-1990s, in accordance with the shifting in precipitation patterns. Indeed, stagnation has been observed until the early 1980s: groundwater tables were practically unchanged–except for the moderate effects of the years 1966, 1967 and 1970, hit by inland excess waters.

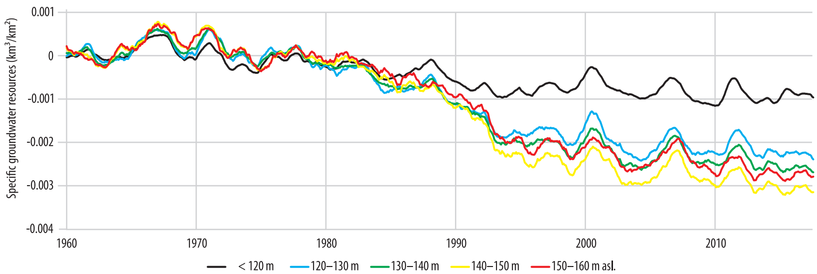

Fig. 6. Estimated specific groundwater resources according to relief, referred to Danube–Tisza Interfluve (reference period: 1961–1965).

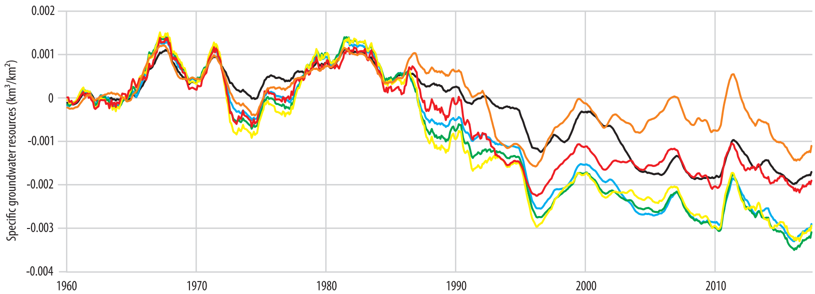

Fig. 7. Estimated specific groundwater resources according to relief, referred to Nyírség (reference period: 1961–1965).

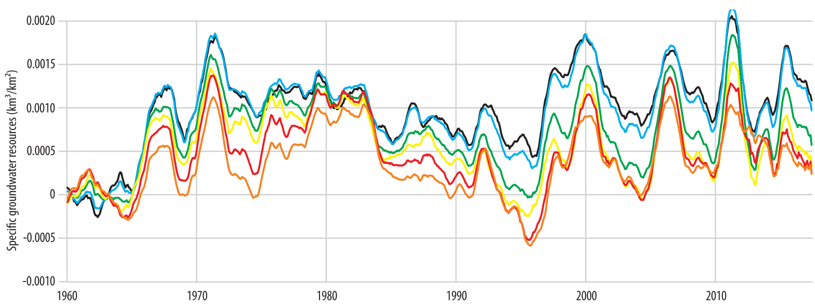

Fig. 8. Estimated specific groundwater resources according to relief, referred to Southern Tiszántúl (reference period: 1961–1965).

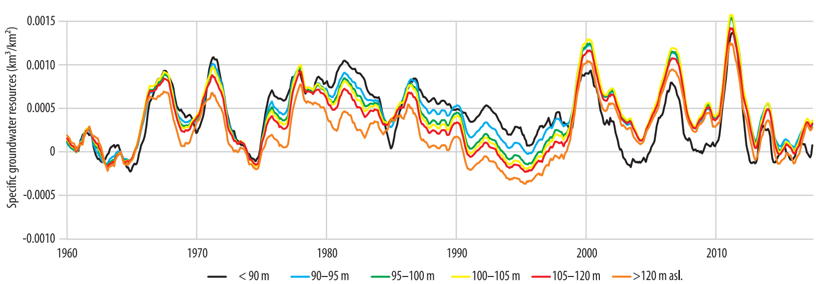

Fig. 9. Estimated specific groundwater resources according to relief, referred to the Foothills of the North Hungarian Mountains (reference period: 1961–1965).

Movements of groundwater under the surface is particularly visible in those sand-covered areas which can gain water supply solely from rainfall. Areas with low relief face less shortage of water even on the course of rather drought years, because of down streaming from higher areas. The highest decrease depends on the relief, namely the inclination of groundwater (see Darcy's law). The most moderate decrease of specific groundwater resources can be observed at the areas with the lowest reliefs; however, the steepest decline did not occur at those areas with the highest relief.

Evaluations revealed that the main reasons are either the deeper levels of groundwater (related to the surface) as deeper groundwater responds less sensitive to external influences, and that, on the other hand, limited inclination of the groundwater table. The steepest decline of specific groundwater does not occur within the two, particular sand-covered areas (as their surface inclination is not the steepest in their highest parts), but its surroundings with higher relief.

The facts depicted above are confirmed by the figures, displaying sensitivity of groundwater levels to environmental impacts *(Figures 10–12)*. These maps were generated by averaging the groundwater changes occurred within 3 and 6 months respectively. Since absolute value of changes is considered, these maps are independent of whether the groundwater table increases or decreases. The results are not capable to express the expresso of the direction and proportion of the natural and anthropogenic effects):

$$\sum_{t=1}^{T-1} \frac{|GWL_t - GWL_{t+p}|}{T - 1/p},$$

where t means the beginning month of the analysis, T represents the count of monthly estimates considered, p is the selected period of the analysis (3- and 6-month periods), and GWL_t and GWL_{t+p} means the groundwater estimation for the respective time instant.

The results are the most clearly interpretable for the Southern Tiszántúl region where the decrease of elevation is coupled with decreasing sensitivity, changes are rather balanced.

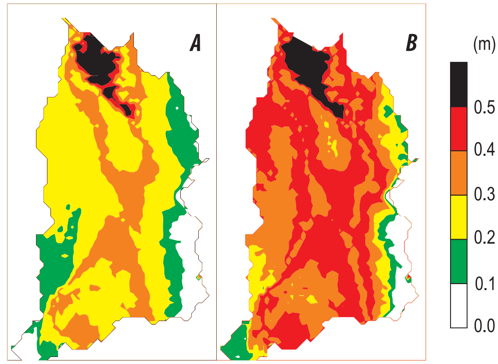

Fig. 10. Sensitivity of groundwater table for Danube–Tisza Interfluve to the environmental impacts. – A = 3-months period; B = 6-months period

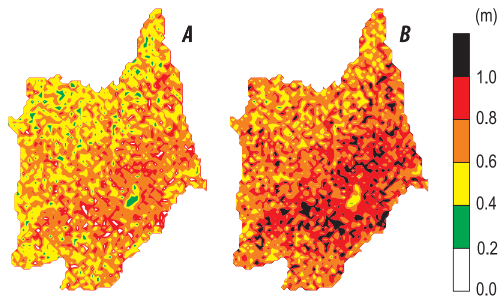

Fig. 11. Sensitivity of groundwater table for Nyírség to the environmental impacts. – A = 3-months period; B = 6-months period

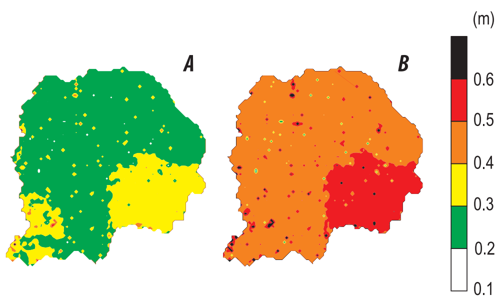

Fig. 12. Sensitivity of groundwater table for Southern Tiszántúl to the environmental impacts. – A = 3-months period; B = 6-months period

Sensitivity map for Danube–Tisza Interfluve reflects the characteristics of its relief: minor changes occur at the lowest parts; major changes take place at those parts surrounded by the higher parts of its neighbouring areas.

Sensitivity of groundwater changes in Nyírség is less characteristic, however, it can be suspected, that sensitivity is more moderate for areas of lower elevation. Local surface relief of the area is more determining. Reasons are better understood if we are analysing the relationship between the amount of groundwater discharge and elevation of the area. As for Nyírség, for most of the periods, there is almost no connection between groundwater discharge and elevation, that is, changes of water surface occur uniformly for the whole area *(Figure 13).* Correlation between elevation and changes in groundwater level can be observed only when the precipitation deviates significantly from the typical amount.

As for Danube–Tisza Interfluve, there is a high correlation between elevation and groundwater changes *(Figure 14).* Calculations verified that groundwater flows towards the lower areas, as Pálfai, I. (1992) and Kuti, L. *et al.* (1998) confirmed it. The extremely humid year of 2010 stands a very spectacular example for realignment of groundwater. Heavy rainfalls on the Eastern part of Danube–Tisza Interfluve made groundwater rising above the surface at the elevation of 92–94 metres and caused extensive inland excess waters.

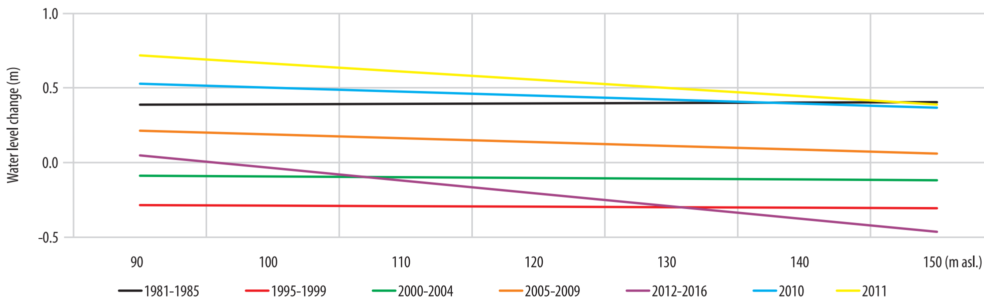

Fig. 13. Relationship between discharge of groundwater and altitude at Nyírség (reference period: 1961–1965).

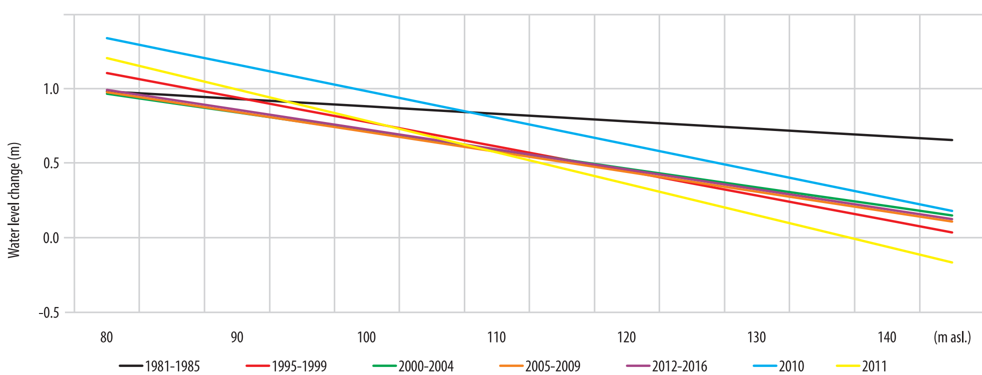

Fig. 14. Relationship between discharge of groundwater and altitude at Danube–Tisza Interfluve (reference period: 1961–1965.

Since the Southern Tiszántúl and Foothills of the North Hungarian Mountains areas show the same correlation between discharge and altitude for each analysed time periods (completely parallel correlation lines), these analyses were omitted from the current study.

Discussion

The research provided important results from several aspects. The results given by the presented GIS-based algorithm are accurate enough to allow different elements of the water-flow comparable. Thereby, real proportions have been assigned to those factors display similar behaviour in the courses of visual analyses. It substantially facilitates to define cause and effect relationships.

Our research successfully demonstrated the importance of the subsurface water flows in spatial and temporal changes of the groundwater resources. Moreover, different consequences of the distinct terrestrial and hydrological conditions have been demonstrated.

It can be said, that *areas more influenced by subsurface water inflow from neighbouring areas* (due to terrestrial and geological conditions), *are less sensitive to extreme precipitation fluctuations and consequently to climate change*. As a result of drought, slow groundwater discharge can be detected in case of these areas, contrarily, long lasting rainy periods trigger a rather fast charge of resources (see *Figures 5* and *6*). Therefore, while the consequence of the climate change in our environment is the more extreme distribution of precipitation (which can be experienced recently and forecasted by certain climate models for the future as well), effects of climate change on these landscapes cause only less prominent modifications.

Our research revealed the complex effect of terrestrial conditions on changes of water resources, too. Due to the unique geographical settings of the sand ridge region of Danube–Tisza Interfluve and Nyírség, shallow groundwater of these areas can be replenished from precipitation solely, hence during dry periods significant drop can be observed in their water resources. However, the environmental background and areal dynamics of the process is substantially differing in these two regions.

The ultimate reason for this is the diverse geometry of the two landscapes. The dominant geometric form on Danube–Tisza Interfluve is the sand ridge with a long, North–South extension and a remarkable steepness of its western slope). In contrast, Nyírség is much more proportionate, its higher regions in East–West and North–South directions are approximately similarly extended.

The different geometry triggers difference in the water resource discharge mostly during severe drought periods. Then almost the whole area of the linearly extending sand ridge of the Danube–Tisza Interfluve is unprotected against the downflow of the groundwater.

The resource change analysis based on elevation zones presents well the close relationship between altitude and groundwater dynamics (see *Figure 14*). In contrast the interior area of Nyírség, since the terrain as well as the groundwater table slope is insignificant. It provides protection against runoff. Thus, (except years of extreme precipitation), there is no significant relationship between the altitude and the groundwater dynamics. Ultimately, on the central area, which includes the utmost part of the landscape, groundwater varying almost uniformly.

On the Danube–Tisza Interfluve, besides the increasing volume of water extraction, the similar degree of decrease of the standing level of the shallow groundwater wells and the initial piezometric level of the confined water may correctly arise the casual relationship between the two water bodies. Based on the measured and calculated data, it can be stated, that the main cause of the shallow groundwater discharge comes not from *"below"* (from drinking water extraction), but from *"above"* (decrease of the precipitation infiltration).

The next stage of the research is going to focus on smaller parts of the currently presented sites. In addition, other landscapes will be involved into the analyses, thus contributing to the establishment of the long-term water management strategy.

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Winning and losing rural localities of the post-socialist economic restructuring: case study of Czechia

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Abstract

Retreat from socialism at the turn of the 1980s and 1990s conditioned significant social, economic and environmental changes for former socialist countries. Transformation from the centrally planned economy under the authoritative regime to market economy and democratic system re-structured also economies of rural areas. As a result, the conversion to capitalism constructed successful rural localities enjoying growing wealth whereas, on the other hand, other rural localities struggle with high unemployment, low incomes and following emigration of qualified people. This paper, on the example of rural space in Czechia, analyses time-spatial development of number of jobs on local level and reveals main factors which have been constructing economically successful and unsuccessful rural localities in the post-socialist period. Based on this, six model responses to post-socialist economic rural restructuring are identified: globally integrated service-oriented, entrepreneurial, industrialised, post-productivist, deindustrialised and post-mining and energy-producing rural localities.

Keywords: post-socialism, economy, restructuring, rural, Czechia

Introduction

Rural space has been for a long time perceived as something stable and unchangeable which (un)successfully avoids modernisation impulses in comparison to dynamically growing urban areas. However, this dichotomy doesn't seem to be legitimated as also rural space constantly undergoes extensive transformations (Woods, M. 2005, 30). The switch from the centrally planned to market economies is the most important transformation which has been discussed since the 1990s in the context of rural areas of Central and Eastern European (CEE) countries. Basic system, institutional and structural changes in national economies (Synek, M. 2004) accompanied such transformation and significantly influenced fortunes of rural localities of these countries (e.g. Swain, N. 1996; Turnock, D. 1998, 2000; Rey, V. and Bachvarov, M. 1998; Dingsdale, A. 2002; Brown, D.L. 2002; Gorlach, K. *et al.* 2008; Pospěch, P. 2014; Jucu, I.S. 2016). Such changes had a large impact not only on agriculture (as it was dominantly stressed in many studies from the 1990s) but also other economic activities located in rural space such as mining, energy production or manufacturing. Yet the level of success or failure of rural economic restructuring has been spatially very unequal – some of the rural localities have reported inflow of new economic activities during the restructuring period whereas other fall into the vicious circles of rural poverty and social exclusion. As a result, rural Europe could be characterised by a new mosaic of rural regions with winners, in-betweens and losers (Terluin, I.J. 2003).

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Many authors attempted to focus on this growing spatial differentiation and suggested various typologies of post-socialist rural localities. However, these attempts are very general – such as empirical typologies of rural space on the European level based on NUTS III regions (e.g. Ballas, D. *et al.* 2003; Baum, S. *et al.* 2004; Copus, A.K. *et al.* 2006; Scholz, J. 2009; Weingarten, P. *et al.* 2010) and national typologies of rural space (with focus on the CEE countries e.g. Beluszky, P. and Sikos, T.T. 2008; Bogdanov, D. *et al.* 2008; Perlín, R. *et al.* 2010; Bański, J. and Mazur, M. 2016; Perger, É. *et al.* 2016). These typologies are usually holistic – focusing on each sphere of rural life, and based on a mix of statistical data. Therefore, their results are hardly transferable into other spatial contexts (contrary to rather theoretical typologies of rural economies which are discussed in the next part of the paper). Also, they dominantly link the post-socialist economic restructuring with agricultural restructuring and stress the processes which deteriorated economic conditions in rural localities but do not focus on processes which enabled economic growth. Notable exception from this point of view is the typology of Czech non-metropolitan regions by Ženka, J. *et al.* (2017) who analysed economic profile of Czech regions located out of the metropolitan areas. Their typology identifies spatial variations in key factors, actors and mechanisms of development. However, in this analysis also urban areas were included therefore the results do not represent exclusively rural areas. Moreover, if these typologies (apart from the typology by Ženka, J. *et al*. 2017) focus on economic development, they are based on sectoral occupation of rural inhabitants with no regards to the fact where their employment is really situated – it means they do not analyse the structure of jobs which are really present in rural areas. As such, these typologies failed to discover what really happened during the post-socialist decades in rural areas.

Therefore, for a better understanding of differentiation of post-socialist rural restructuring (1) more detailed analysis of rural economies (based on very small spatial units) is needed and (2) this analysis must be focused on employment opportunities which are really present in rural areas – it is better to examine economic structure of rural localities based on jobs located there (contrary to employment which is ascribed to rural people but very often practised in urban areas). Within our paper, we introduce the results of such analysis on the example of the post-socialist Czechia. Based on this, first, we identify rural localities with the best and worst economic performance (measured by the number of jobs) during the post-socialist period. Second, after a close look on these winners and losers we indicate distinct processes which have dominantly formed the way of the post-socialist rural economic restructuring in rural Czechia.

Rural localities and uneven economic dynamics

At the beginning of the theoretical discussion, we would like to stress the key spatial concept for the following analysis – concept of (rural) localities. Although Hoggart, K. (1990) and other scholars before the onset of postmodern approaches in rural geography refused the existence of a specific 'rural' locality and suggested to 'do away with rural', the term 'rural locality' is acknowledged by rural scholars and finds frequent use in contemporary rural studies. Its popularity has increased since its integration with definition of rural as a social construction. At the beginning of locality debates there was a question, to which extent are distinctive places results of local and non-local structuring processes. The structuring power of external processes of regional, national and global scale has been acknowledged and the discussion turned to the point what are the capacities of local actors to transform the external influences in order to avoid their negative impacts and generate benefits for a given local community. Reflecting this, the locality is defined as active, semi-autonomous units (Murdoch, J. and Marsden, T. 1995) with a relative openness to external relations. As such, to a limited extent it also gives an opportunity to rural actors to influence the destiny of their own locality (Murdoch, J. and Marsden, T. 1994). On the other hand, Moseley, J.M. (2003) argues that institutional capacities of local communities are still only limitedly able to influence processes from the national or even global level

The concept of locality has been developed in order to grasp the increasingly diverse character of (rural) space as the consequence of intensive penetration of neo-liberal principles into spatial regulation and planning. Many rural scholars (e.g. Murdoch, J. *et al*. 2003; Halfacree, K. 2004; Hodge, I. and Monk, S. 2004; Holmes, J. 2006; Brunori, G. and Rossi, A. 2007; Van der Ploeg, J.D. *et al.* 2008) recognise growing differentiation of rural space and suggest specific models of rural localities which differ from each other based on their social, economic, cultural, environmental and institutional profile. In the next paragraphs, we will focus only on typologies which more deeply analyse diverse economic milieus of rural localities. Typologies of farming systems were excluded (e.g. Van der Ploeg, J.D. *et al.* 2008; Wilson, G. 2010) as we disagree with arguments which ascribe the central role in rural development to agriculture.

Marini, M. and Mooney, P. (2006) developed typology purely focused on rural economies and suggest three distinctive types. First, *rent-seeking economy* is localised in rather peripheral rural areas whose economies are mostly based on rather large farms and firms in mining and extraction. These actors control high proportion of local land rent and like this they don't have special motivation for further investment in local development. Second, *dependent economies* are based on attraction of external sources (both of public and private origin) which expose them to a higher risk in the periods of fiscal austerity (decline of subventions) or economic downturn (outflow of foreign direct investment). On the other hand, third, *entrepreneurial economies* are based on valorisation of local assets by local enterprises. As such, in comparison of these three types, they are considered as the most resilient.

Woods, M. (2013) who engages with the impact of globalisation processes on rural localities suggests a typology of specific responses to these processes. He defines 9 modes of engagement more or less related to the economic dimension of globalisation process. *Global resource providers* are rural localities rich in mineral and energy resources tightly integrated into global capital and markets. *Branch plant economies* have been dominantly formed through the urban-rural shift in manufacturing driven by FDI since 1980s or 1990s. *Super-productivist farmers* focus on large-scale, industrial and often export-oriented agricultural production. *Global playgrounds* are structured by amenity immigration, growing consumption demand for rural space and related services. *Niche innovators* are based on highly innovative companies or their cluster which use either local endogenous potential or focus on high-tech or service industries. *Trans-border networkers* are localities who use their location with cross-border potential and offers special kind of assets (especially cheaper labour and services). Economies of *global conservators* are limited due to their location in national parks or UNESCO biosphere reservations. *Re-localizers* concentrate on intensification of local circuits of value in agri-food system or via public procurement etc. *Structurally marginalised regions* are regions which are not able to use the positive potential of the globalization process.

Introduced typologies more or less consider the proximity of given rural localities to urban centres as an important factor of rural differentiation. From the economic point of view, it seems to be crucial. However, we can find some counter-tendencies when discussing the economic potential of rural localities based on their position on the urban-rural continuum. Burger, M.J. *et al.* (2015) focus on presence of cultural amenities and discuss the concepts of 'borrowed size' (introduced by Alonso, W. 1973) and 'agglomeration shadows' which typically occur in suburban rural localities. Such localities enjoy 'borrowed size' effects as they host functions which were traditionally located in urban centres and that's the reason why the functional importance of these localities largely exceeds its population importance. On the other hand, the concept of 'agglomeration shadows' is opposed to the former. In their later publication (Meijers, E.J. and Burger, M.J. 2017) they carefully scrutinize the term 'borrowed size' and complement it with terms 'borrowed function/performance' in order to cover the gaps related to the term 'size'. In the context of our paper it means that some suburban rural localities can evidence over-average number of jobs (performance) or service/cultural amenities (function), whereas other localities in similar locations dispose with low number of jobs/less services and high level of work and leisure out-commuting to the neighbouring urban centre.

During the 1980s and 1990s British scholars in the context of rural areas reported urban-rural shift in business activity and employment – first in manufacturing (e.g. Keeble, D.E. 1980; Fothergill, S. and Gudgin, G. 1982; North, D. 1998), later also in the service sector (Keeble, D.E. and Tyler, P. 1995). Within this shift, increased attractiveness of rural areas for relocation of businesses and employment opportunities has been recognized. Most importantly, in some time spans remote rural areas evidenced more dynamic economic development than accessible rural areas (Keeble, D.E. and Tyler, P. 1995). Rural scholars argue that this shift was partly caused by the immigration of former urban inhabitants usually well-endowed with entrepreneurial skills, knowledge, and creativity (Atterton, J. *et al*. 2012) or human, social, and financial capital (Gkartzios, M. and Scott, M. 2014). Anyway, the economic activity of rural entrepreneurs is not isolated within the rural space, instead they employ extra-regional linkages in order to gain knowledge and access to large markets located in urban areas. Therefore, when considering rural entrepreneurship, it is necessary to consider also the urban dimension of everyday business activities of rural people (Mayer, H. *et al.* 2016).

Identifying winners and losers of rural economies: data and methods

Our methodological approach has four important stages:

1. rural municipalities were defined and aggregated into larger spatial units;
2. indicator of number of jobs was quantified;
3. rural winners and losers were identified;
4. economic profile and history of these selected localities were analysed.

First, when analysing larger spatial units, typically statistical (or descriptive by Halfacree, K.H. 1993) definitions of rural space are used. Based on this, a measurable indicator which defines the rurality of a given spatial unit must be determined. For our purposes we have chosen the indicator of population size which was applied on the municipality level (Local Administrative Unit). In Czechia the population size of 3,000 is usually used as a threshold value for identification of rural/urban municipality (such definition was used e.g. by Perlín, R. *et al.* 2010; Chromý, P. *et al.* 2011; Bernard, J. 2012) despite the existence of rural municipalities (based on their physical structure and architecture) with more than 3,000 inhabitants especially in South and East Moravia. In order to follow more easily the spatial pattern of results – municipalities with population less than 3,000 have been integrated in larger spatial units based on administrative districts of municipalities with authorised municipal authority (*obce s pověřeným obecním úřadem - OPOÚ*) which serve for purposes of state administration in Czechia. In 2011 there were 389 administrative areas of OPOÚ in Czechia and five military areas. But in ten of them there was no rural municipality and therefore they were considered as urban and excluded from the analysis. Finally, 379 administrative areas of OPOÚ were analysed – hereinafter within the text they are referred to as 'rural locality' in compliance with the theoretical discussion above.

Second, indicator of number of jobs has been used for our research of the post-socialist economic restructuring. As there is no statistical source in Czechia which would present these data on local level, we had to derive the number of jobs from the formula (this formula was used in other Czech studies e.g. by Hampl, M. 2005 and Hampl, M. and Marada, M. 2015):

$$J_A = EA_A + EA_{A\_in\text{-}com} - EA_{A\_out\text{-}com},$$

where J_A = number of jobs in the municipality A, EA_A = economic active population of the municipality A, $EA_{A\_in\text{-}com}$ = economic active population commuting into the municipality A from other municipalities, $EA_{A\_out\text{-}com}$ = economic active population commuting out of the municipality A.

Concerning the data availability – they are based on the results of Czech censuses from years 1991, 2001 and 2011 (more recent data are not available as the next census is planned for 2021). Year 1991 doesn't fully demonstrate the beginning of the restructuring period (for example in some agricultural cooperatives the transformation started immediately in 1990), yet this year is still very suitable for the description of the economic situation before the main restructuring processes started (the unemployment rate in 1991 was 2.3 per cent, thus, very close to the full employment typical for the communist era). Year 2001 may transparently describe the situation of Czech economy after the impact of main restructuring processes related to the privatisation process and retreat of the state from the national economy and before the start of the intensive inflow of FDI (at that time the unemployment rate reached 9.3%). Year 2011 then demonstrates how rural localities adapted to the challenges of post-socialist restructuring including growing global integration of economy (the unemployment rate was 9.8%).

Indicator of number of jobs has been chosen due to its ability to transparently describe the economic situation of a given locality. Contrary to the (un)employment indicator, it is strictly related to the selected spatial unit and therefore it can better describe the ability of a given locality to sustain or even generate economic growth. Focus on jobs in rural areas is even more important as new jobs creation is a general target of rural development policies for remote rural areas. As Freshwater argues 'Community may be able to improve the degree of social cohesion, they may be able to develop both their physical infrastructure and the level of human capital, but if jobs do not exist, it is unlikely that the community will survive.' (Freshwater, D. 2000, 6). Concerning suburban areas, here the call for new jobs is seemingly not as urgent as in remote rural areas due to their accessibility to employment opportunities located in nearby urban centres. However, their presence (matching with qualification of local people) could decrease the over-dimensional traffic flows, congestions and pollution related to the intensive daily work commuting. On the other hand, in our approach this indicator has also some disadvantages. It doesn't say us anything about the quality of such a job and hereby about its contribution to local economic development. From this point of view, these questions cannot be discussed intensively within this paper, however, some insights in the changing number of jobs are revealed by a more detailed examination of rural winners and losers.

As regards the quality of the data from the censuses – results from the Census 2011 are problematical. In comparison with earlier censuses its results were incomplete – the number of commuting person was lower by about 560 thousand than in 2001 (the total number of commuting people in 2001 was 1.70 million in comparison to 1.14 million in 2011), although the number of economic active employed people hadn't changed much (Hampl, M. and Marada, M. 2015). From this reason, authors had to model the missing data (similarly as Mulíček, O. and Malý, J. 2019) in the categories of in-commuting, out-commuting and economic active residents by their proportional distribution based on the known value of residents living in a given municipality.

Third, rural winners and losers were defined as rural localities which until 2011 had created more than 40 per cent jobs or contrary, lost more than 60 per cent of jobs in comparison with 1991. Based on these threshold values, for 2011 there were 42 rural winners and 25 rural losers *(Figure 1)*.

Last but not least, selected rural winners and losers were examined in detail in order to get information about the structure of local economy, the way of change and key employers both at the end of the socialist period and in the present. Because there is no coherent database of companies or job structure at the end of the socialist period, information was gathered from various sources - websites of relevant municipalities, daily media, older research studies which defined main employers in given rural localities (e.g. Häufler, V. 1984) or by a direct contact with representatives of given rural municipalities. There are no data about jobs structure even for present situation but rural winners were at least analysed by the means of the Bisnode Albertina Database (version 2018) which gathers information about businesses including their location and size in terms of employer number. This analysis serves later as an important input for development of model rural localities.

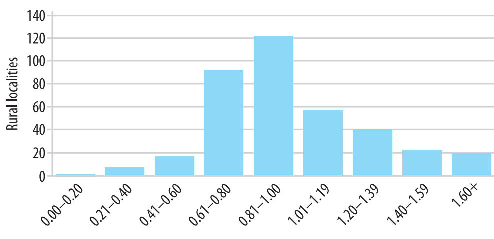

Fig. 1. Frequency of rural localities based on the development of number of jobs in the period 1991–2011. *Source*: Czech Statistical Office 2011; Federal Statistical Office 1993. Authors' own calculation.

Post-socialist economic restructuring of Czech rural space

Economic restructuring since the 1990s have produced different spatial impacts, as post-socialist transformation is a complicated process of institutional changes and behavioural adaptations of people, firms and institutions to new conditions of pluralist democracy and economy regulated by the free-market ideology in which the private companies play the key role. The shift towards market economy marked also the end of levelling tendencies in spatial distribution of sources characteristic for socialist mode of regulation (Dostál, P. 2007). Industrialisation policies of communist regime aimed to balance unequal economic potential among Czechoslovak regions by supporting agricultural and industrial production in smaller towns and rural areas. And indeed, at the end of the socialist period the economic position of small local centres was relatively strong. However, under the newly established capitalist regime, their central position has been weakened or even disappeared due to selective deindustrialisation and tertiarisation processes (Mulíček, O. and Malý, J. 2019). In the new neo-liberal regime Czechia has opened itself to the external world – not only from the physical point of view (more relaxed cross-border regime – removal of 'Iron Curtain' and demilitarisation of Western borderland, implementation of the Schengen Treaty in 2007) but also as regards more fluid and less tangible impacts of trade liberalization and acceptation of European and global values leading to growing global (European) integration of Czech society and economy.

Post-revolution performance of Czech agriculture was influenced by processes of privatization, restitution and transformation of former cooperatives which destabilized agricultural production (e.g. Kabrda, J. and Jančák, V. 2007; Hrabák, J. and Konečný, O. 2018; Žoncová, M. 2018). Moreover, under the influence of the neo-liberalization rhetoric, state subventions decreased rapidly during the period 1989–2000 (Věžník, A. 2002; Bičík, I. and Jančák, V. 2005). This process had a destructive impact especially on farms located in less favoured (sub-)mountain and very often peripheral (Musil, J. and Müller, J. 2008) areas. These areas had been economically lagging already before the socialist period and therefore socialist planners supported local agricultural production massively in order to ensure employment for local people. Nevertheless, such policy was at expense of economic productivity, high subsidization, excessive use of chemicals and consequent negative environmental impacts. Therefore, these were just these areas, where calls for elimination of overproduction and more sustainable agricultural practices were implemented leading to rapid job losses in this economic sector. Economic situation of Czech farms started to improve not earlier than with the accession of Czechia into the EU (Bašek, V. 2010).

Similarly, mining and manufacturing registered decline in terms of their contribution to national employment and GDP (Mulíček, O. and Malý, J. 2019). In socialist countries coal mining had a privileged position as the capital-intensive industries and extensive mode of production of these countries (Pavlínek, P. 2009; Koutský, J. 2011) were based on high amount of inputs including energy. Czechoslovak manufacturing production during the socialism could be characterised by low labour productivity and associated high costs of production, production of products whose technical standard was lagging behind Western standards (Synek, M. 2004). Economies of some rural areas were diversified by old industries (textile, glass and ceramic industry) which dated back to the first waves of industrialization. From this point of view, the situation in Czechia was different than in other CEE countries – Czech rural localities showed high proportion of industrial employment, whereas eastern parts of Poland and Hungary were predominantly focused on agriculture (Ženka, J. *et al.* 2015).

However, growing environmental concerns (Pavlínek, P. 1998) suppressed during the socialist regime initiated new environmental measures and policies. Their impact was particularly painful in rural areas integrated into old industrial regions of northwest Czechia and Ostrava agglomeration (Pavlínek, P. 1998; Klusáček, P. 2005;

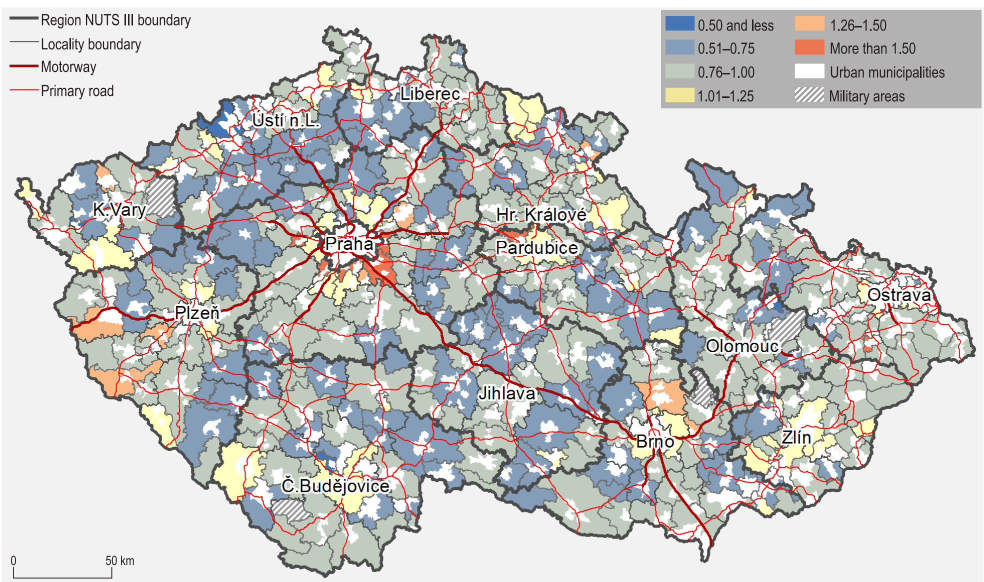

Fig. 2. Change of number of jobs in rural localities of Czechia in the period 1991–2001 (1991 = 1.00). *Source*: Federal Statistical Office 1993; Czech Statistical Office 2001; ArcČR 500. Authors' own calculations. Compiled by the authors.

Koutský, J. 2011). Apart from them, rural areas dependent on old industries producing low value added products suffered from growing unemployment as these economic industries has been particularly vulnerable under the neo-liberal conditions of globally integrated economy. As a result, during the first decade of rural restructuring massive job loss could be observed in each of the NUTS III regions of Czechia *(Figure 2)*, whereas in rural localities the economic downturn was more serious (in 2001 by 18% less jobs than in 1991) than in urban localities (job loss by 7%).

On the other hand, since the beginning of the 2000s high inflow of foreign direct investment (FDI) to Czechia driven by lower labour costs, skilled and well-educated labour, long manufacturing tradition, strategic geographical position in the EU (since 2004 Czechia is a member state of the EU) and massive state investment incentives has been observed. Koutský, J. (2011) labels this period as a period of organised re-industrialization and from this point of view, also in Czech rural localities some patterns of urban-rural shift in manufacturing might be observed.

FDI of transnational investors have significantly transformed and developed (at least quantitatively) also the service sector. Their intensive development was partly preconditioned by an under-dimensioned service infrastructure from the socialist period (Szczyrba, Z. 2000). Since the mid-1990s retail chains from Western Europe discover Czechia as a new destination for investment of profits gained on domestic markets (Coe, N.M. *et al.* 2013). The Czech retail market got internationalised and concentrated quickly (Kunc, J. *et al.* 2013) whereas buildings of new supermarkets and hypermarkets and logistics parks intensively transformed landscape of suburban rural localities and commuting patterns within urban agglomerations (Mulíček, O. and Malý, J. 2019). Such suburban rural localities enjoy the 'borrowed performance' (Burger, M.J. *et al.* 2015) effects when the number of jobs per capita significantly exceeds the average number in similar localities and sometimes even the number of local economic active population.

On the other hand, the growth of entrepreneurial activity in services (including creative industries) in these localities has been driven also by local factors – entrepreneurial in-migrants (Ženka, J. and Slach, O. 2018; Píša, J. and Hruška, V. 2019). Our additional analyses of entrepreneurial activity per capita in age +15 for year 2017 (Czech Statistical Office 2018c) showed that among the TOP 20 rural localities with highest levels of entrepreneurial activity 15 were located in the Prague metropolitan area and five in Šumava and Krkonoše Mountains with strong recreational function accompanied by relevant services in retail and hospitality. Strong entrepreneurial activity in recreational rural localities is a consequence of growing purchasing power of medium and upper class residents, individual car-ownership and increasing inflow of foreign visitors since the end of 1980s.

New firms both in manufacturing and services generated new employment opportunities especially in peri-urban and well accessible rural areas *(Figure 3).* In the period 2001–2011 (until the global economic downturn) the growth of employment opportunities was reported in rural areas (by 16%) whereas in urban areas the number of jobs decreased by 4 per cent. One could argue, that the growth of number of jobs in suburban rural localities is given by the growing population of these areas and their entrepreneurial attitudes. However, if we compare the development of number of jobs and economic active population in rural areas, the former is growing quicker in each of the NUTS III regions apart from the Karlovy Vary Region.

Generally speaking, social and economic processes driving post-socialist restructuring have intensively transformed employment patterns in Czechia. From the rural point of view, rapid loss of jobs was reported in agriculture and mining. On the other hand, de- and re-industrialization process had highly unequal spatial distribution. As a result, the industrial employment in Czechia has decreased only slightly since 1990 *(Table 1).*

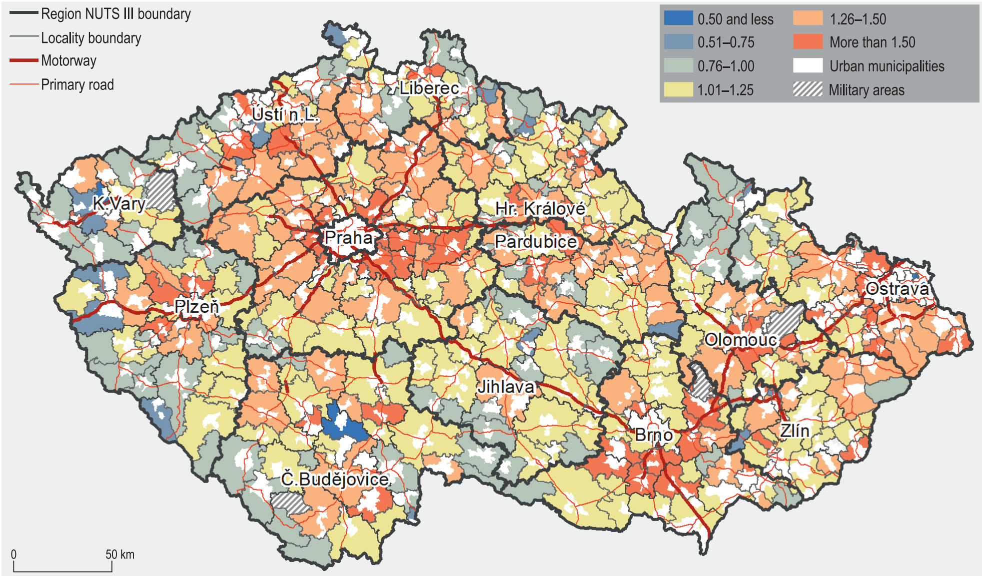

Fig. 3. Change of number of jobs in rural localities of Czechia in the period 2001–2011 (2001 = 1.00). *Source*: Czech Statistical Office 2001, 2011; ArcČR 500. Authors' own calculations. Compiled by the authors.

Table 1. Employment development in basic economic sectors in the period 1990–2017 in Czechia

Sector	1990	2000	2010	2017
Agriculture, fishing and forestry (NACE A)	9.9	4.9	3.1	2.8
Mining and quarrying (NACE B)	3.0	1.5	1.0	0.6
Industry (NACE C–E)	31.3	28.4	27.5	29.9
Construction (NACE F)	8.6	9.6	9.5	7.5
Services (NACE G–U)	47.2	55.6	58.6	58.4
Not found	0.0	0.0	0.3	0.8

Source: Own calculation based on the Czech Statistical Office 2013, 2018a, 2018c.

Models of rural winners and losers of the post-socialist economic restructuring

Based on the transformation of the rural economic orientation and performance, six basic models of rural winning and losing localities can be defined regarding the development of number of jobs during the period 1991–2011 *(Figure 4).*

These models demonstrate key processes and transformations shaping the most (un) successful rural localities (for their overview, see *Table* 2) based on the development of number of jobs. These localities are manifestations of distinctive and relatively dominant economic processes which constructed Czech rural space during the post-socialist period. As they are just ideal models, they don't have their real spatial anchoring in the map – authors are aware that rural localities are always influenced by specific combinations of multifaceted economic processes. That's why examples in the map below *(Figure 5)* point to the localities which are close to the suggested models. Moreover, we don't have the ambition to cover the whole area of Czechia – due to the

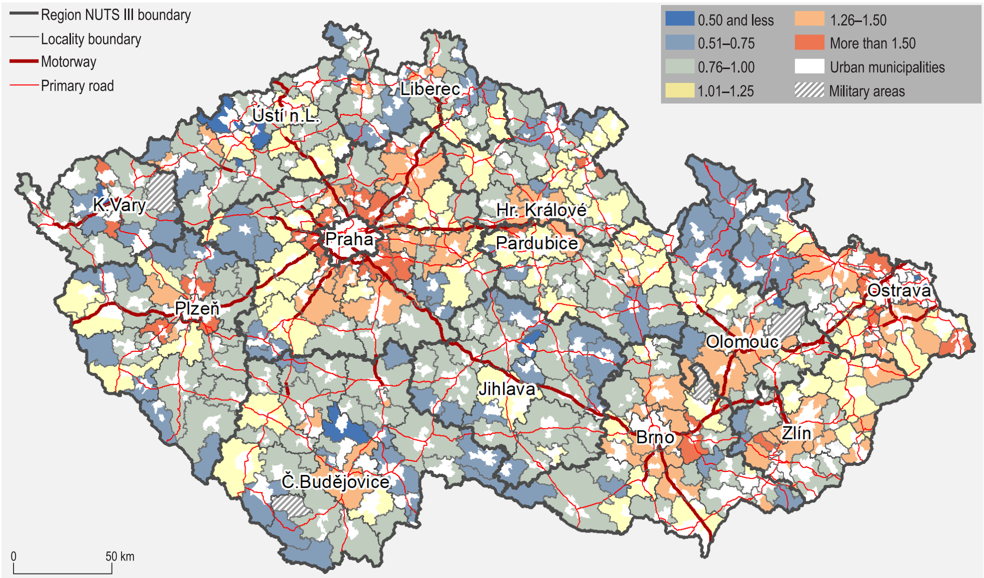

Fig. 4. Change of number of jobs in rural localities of Czechia in the period 1991–2011 (1991 = 1.00). *Source*: Federal Statistical Office 1993; Czech Statistical Office 2011; ArcČR 500. Authors' own calculations. Compiled by the authors.

exclusive focus on rural winners and losers, we haven't developed special models for localities formed by other, spatially less important processes as these processes first, didn't formed the winning and losing localities and second, they were limited only to a small number of rural municipalities. For example, in some rural municipalities slight growth of number of jobs has been reported due to the growth of tourism or cross-border shopping tourism (along the border with Germany and Austria) or contrary, the number of jobs slightly decreased as a result of the de-militarization of border areas (especially along the former Iron Curtain border with Bavaria and Austria).

Models A, B and C could be labelled as winners of post-socialist restructuring as their economic transformation can be considered as relatively successful. Model localities D, E and F are those which have suffered economically due to the failed restructuring of local enterprises.

Model A – Globally integrated service-oriented rural localities: Beneficial geographic location in metropolitan areas (especially in the Prague metropolitan area) along major transport routes is the comparative advantage of these model localities which are largely shaped by commercial suburbanization process. Concentration of plants of transnational companies in logistics and retail can be observed here which enjoy the benefits of their strategic location and large potential market in the core of the metropolitan area. An important factor for the location of logistic firms is also the lack of available land in the city or its high price. These economic activities have brought rapid growth of jobs in localities which used to be strongly dependent on lower number of jobs in agriculture or urban work-commuting during the socialism period. However, these localities (similarly as the following model B) are still dominantly integrated to the urban centre by commuting patterns, as newly created jobs are largely occupied by urban inhabitants and their structure doesn't match with the qualifica-

Table 2. Overview of key models of rural winners and losers of the post-socialist economic restructuring

Indicator	Model A	Model B	Model C	Model D	Model E	Model F
Number of jobs	Growth			Decline		
Location	Well accessible locations in metropolitan areas	Metropolitan areas	Well accessible areas	Peripheral (sub-)mountain areas		Proximity to mineral deposits
Key attributes	Better transport and/or economic accessibility than in urban centres	Proximity to urban centres; High human capital and entrepreneurial talent	Accessibility of cheap labour; Good transport accessibility	Less favourable agricultural areas; Low human capital	Uncompetitive manufacturing activity with low value added; Low human capital	(Former) mineral deposits; Low human capital
Key processes	Commercial suburbanisation	Residential suburbanisation	Inflow of FDI	Post-productivist transition	De-industrialisation; Global competition	De-industrialisation; Growing environmentalism

tion of well-educated suburbanizers (Sýkora, L. and Ouředníček, M. 2007). Moreover, the economic sustainability of these jobs (due to their dependence on decision-making situated abroad) as well as their quality (in terms of average salaries) is disputable.

Model B – Entrepreneurial rural localities: The significant growth of jobs in suburban rural localities of larger urban centres (Prague, Brno, Ostrava and Plzeň) can be explained also by the overall development of small business activity in services driven by well-educated urban newcomers supporting residential suburbanization process. During the socialist period (similarly as in the case of model A) these localities could have been characterised by low number of jobs (mostly in agriculture) and high intensity of work-commuting. New entrepreneurs use constantly growing metropolitan market as its population continues to grow and requires higher capacity of local commercial and public services which further generate new jobs. Also, newcomers offer knowledge intensive business services with high value-added with focus on larger than local market. Overall, these rural localities are characterized by a diversified economy of high local origin and control.

Model C – Industrialised rural localities: In contrast to the previous two service-oriented localities, the economic success of these model localities (situated in well accessible locations with accessible cheap workforce) is based on manufacturing (very often automotive industry). These localities have been a target of rural industrialisation process driven both by FDI and by a successful transformation of former socialist companies. Local economies may be structured by one dominant manufacturing company, cluster of larger manufacturing companies within one industrial park or more diffused cluster of many SMEs. Anyway, their contribution to local development depends on the type of the economic activity and embeddedness of the business activity in the local entrepreneurial milieu. Similarly, as in the case of the A-model localities, their vulnerability might

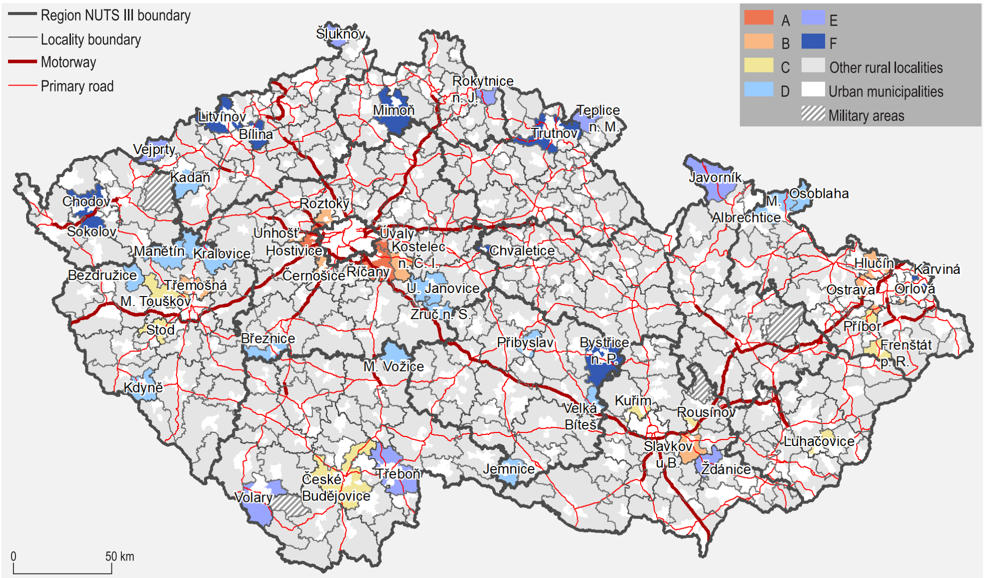

Fig. 5. Overview map of close-to-model examples of winning and losing rural localities of Czechia. *Source*: ArcČR 500, compiled by authors.

be higher due to their dependence on one dominant employer or foreign ownership of local branch plant.

Model D – Post-productivist rural localities: These localities are situated in the (sub-) mountain and peripheral areas of Czechia. The decline of agricultural production and consequent job loss was, of course, a national matter, but in these areas the impact of this process was indeed intensive. Rise of the neoliberal regime and consequent reduction of subsidies to agriculture combined with the growing demand for a better environment in this environmentally sensitive landscape have, thus, significantly affected the ability of newly transformed farms to sustain jobs. Due to their peripheral location (also in terms of the quality of human resources – Bernard, J. and Šimon, M. 2017) these localities have been not able to create new start-ups or attract external investment.

Model E – Deindustrialised rural localities: Unsuccessful transformation of local manufacturing enterprises was another reason of rapid decline in jobs number in these localities. Enterprises in old industries (glass, ceramic, textile) as well as in the wood-processing, metal-working and electromechanical industries appeared as less competitive on the global market. Large decrease in the number of jobs was recorded mainly in the northern part of Czechia which enjoyed rapid prosperity growth during the first waves of the industrial revolution. Similarly to the Post-productivist localities, their isolated location and low human capital of these localities made it impossible to compensate the job loss.

Model F – Post-mining and energy-producing rural localities: Rural localities which were until recently dependent on mining and energy industry could be labelled as absolute losers of post-socialist economic restructuring. These localities were economically dependent on labour-intensive lignite and coal mining, ores extraction (in Czech case especially uranium) and electricity generation (based on burning of coal or lignite). The desire of the socialist state for its self-sufficiency in each aspects of economy led to the mining and extraction of raw materials even though their deposits were poor both in terms of quantity and quality of extracted materials. Mining in some localities was maintained by high state subsidies which, similarly as in the case of agriculture, were stopped after the revolution. Another reason for the job loss was also growing work productivity related to the technological modernization of mines or power stations.

Conclusions

Despite relatively good economic performance of Czech rural localities during the second decade of the post-socialist restructuring, in no way this success has been distributed equally throughout the rural space. Some rural localities which can be labelled as winners (based on our models Globally integrated service oriented, Entrepreneurial and Industrialised rural localities) enjoyed economic growth whereas other localities (Post-productivist, De-industrialised and Post-mining and energy producing rural localities) struggle with economic decline. From this point of view, (de-)industrialisation process can serve as a good example of this highly unequal spatial development. Well accessible rural winners registered growth of number of jobs in modern industries such as automotive contrary to more isolated rural localities which simultaneously suffered from the fall of traditional old industries.

Winning rural localities enjoy the effects of the 'borrowed performance' as they registered rapid growth of employment opportunities both of local (created by entrepreneurial individuals) and extra-local or even global (driven by inflow of FDI especially in services and in manufacturing) origin. From this point of view, urban proximity and/or location along the main transportation axes seems to be a very important factor influencing the ways of rural economic restructuring. On the other hand, the success of Industrialised rural localities may not be permanent. Their one-way orientation on foreign investors is risky, as they are dependent on the managerial decisions of the controlling headquarters situated in foreign countries. Contrary, economies of Post-productivist and Post-mining and energy-producing rural localities suffered from the retreat of the state from the economy during the 1990s which started a vicious circle further reinforced by the brain drain and following weakening of entrepreneurial capacities of local people.

Our analysis didn't prove an important role of tourism for post-socialist rural economies despite the fact that this economic activity is very often perceived as a panacea for local economic problems. Only very small number of rural municipalities in the most attractive locations of national parks evidenced a growth in number of jobs. However, in the context of other CEE countries with higher mountain ranges (High Tatras, Carpathian Mountains and other mountain ranges of the Balkan Peninsula) the results might be different. Similarly, the model of Deindustrialised rural localities might not appear in other countries with different histories of industrialisation than in Czechia and the existence of the Industrialised rural localities is dependent on the overall ability of a given country to attract foreign FDI.

This last remark brings us to the topic of urban-rural shift in employment which has been proved by our analysis for Czechia. This process signalises, first, that it is not correct to consider rural space simply as space where jobs disappear – it is necessary to be aware of the diverse character of rural economies. Second, it confirms the fact, that agriculture is no more the backbone of economies (Terluin, I.J. 2003) even of the most rural regions of Czechia and probably some other post-socialist countries. It is no more possible to view rural economy or rural development through the lenses of agriculture (Hruška, V. *et al.* 2015).

Moreover, this new perspective opens up space for rural geographers of the CEE countries to switch to new (albeit in Western rural geographies relatively well-established) research topics. This study can serve as a point of departure for studies focusing on rural entrepreneurship, entrepreneurial rural in-migration, branch-plant rural economies, 'old industrial rural areas' (Hruška, V. 2018) and similar topics with the whole array of implications for rural development policies and everyday lives of rural people.

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Measuring seasonality at the major spa towns of Hungary

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Abstract

One of the leading tourism products of Hungary is health tourism, where the certain supply segments are influenced by seasonality in different scales. The primary aim of our paper is to survey the seasonality of the 9 spas with the greatest turnover in Hungary with the help of the Gini index. Our research intends to provide an actual picture about the exact measure of seasonality in the highlighted spas of Hungary, due to the overall actuality of the problem and also because no such relevant quantitative research has been dealing with this issue in Hungary yet. The objective reason why these spas were chosen and surveyed is because first of all they are mono profile health tourism centres, where tourists are visiting the settlement exclusively because of the spas, and on the other hand the visitor turnover of the mentioned settlements are significantly higher than the following Hungarian spa towns. We believe that the more we understand seasonality the more we can face with its challenges concerning tourism development. For our seasonality analysis we used the commercial accommodation statistics of the Hungarian Central Statistical Office and to estimate the Gini index we applied the monthly dataset of the guest nights.

Keywords: measuring seasonality, Gini index, health tourism, spa towns, Hungary

Introduction

Taking into consideration both the supply and demand side of the Hungarian tourism industry we can state that its leading tourism product is by no means health tourism. Recently, more than 45 per cent of the guest nights were realized in the rural settlements with spas and if we also include the capital, Budapest, this ratio will exceed 68 per cent (Hungarian Tourism Agency, 2019). Overall, 137 settlements are involved in medical tourism, out of which 14 is qualified as medical places: Balatonfüred, Bük, Debrecen, Eger, Gyöngyös (Kékestető), Gyula, Hajdúszoboszló, Harkány, Hévíz, Miskolc (Lillafüred), Parád, Sárvár, Sopron (Balf) and Zalakaros. So the country possesses numerous traditional, historical spa settlements besides which a great number of spas were developed or were modernised after the regime change (1989) geared to the demand trends of the 21st century.

Due to the unique physical environment and geological basics, the attractions and endowments of health tourism in Hungary are outstanding even in global perspectives. The most important physical geographical factors are the spatial-geological allocation of the Carpathian

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Basin, the high values of the geothermic gradient and the quality of the host rock (Michalkó, G. and Rátz, T. 2010; Aubert, A. *et al.* 2012; Gonda, T. 2016; Csapó, J. and Marton, G. 2017; Stupariu, M.I. and Morar, C. 2018). Based on the geological and physical geographical endowments we can differentiate 4 types of medical factors in the Hungarian spa and wellness tourism: medical waters, medical mud, climate therapy and medical caves and mofetta. These four types of medical factors serve as the primary attractions for the supply factors and establishments in Hungary.

Due to the upper mentioned endowments Hungary possessed 529 spas (380 functioning all year and 149 just seasonally) in 2017. A significant amount of these spas provided complex and mixed services with medical, thermal and experience spa services or they served as swimming pools (Csapó, J. and Marton, G. 2017). The most typical forms of spas were the lidos (234), the experience spas (220) and the medical spas (103) (Hungarian Central Statistical Office – HCSO, 2018) *(Figure 1)*.

The role and importance of health tourism in the tourism industry of Hungary is also demonstrated by the fact that amongst the top 10 visited settlements of the country we find (usually) 7 or 8 spa towns (HCSO, 2018). As the National Tourism Development Strategy states, 12.9 per cent of the inbound visits were motivated by wellness or medical reasons. Visitor numbers to Hungarian spas generate more than 40 million visits per year out of which the thermal and medical spas register around 23.0–24.5 million visitors annually (Csapó, J. and Marton, G. 2017).

The degree of seasonality is of key importance at health tourism resorts as well, since in terms of their functioning, certain supply segments are greatly influenced by the annual dissemination of the visitors (mainly the active, outdoor wellness elements) while others (such as the elements of medical tourism)

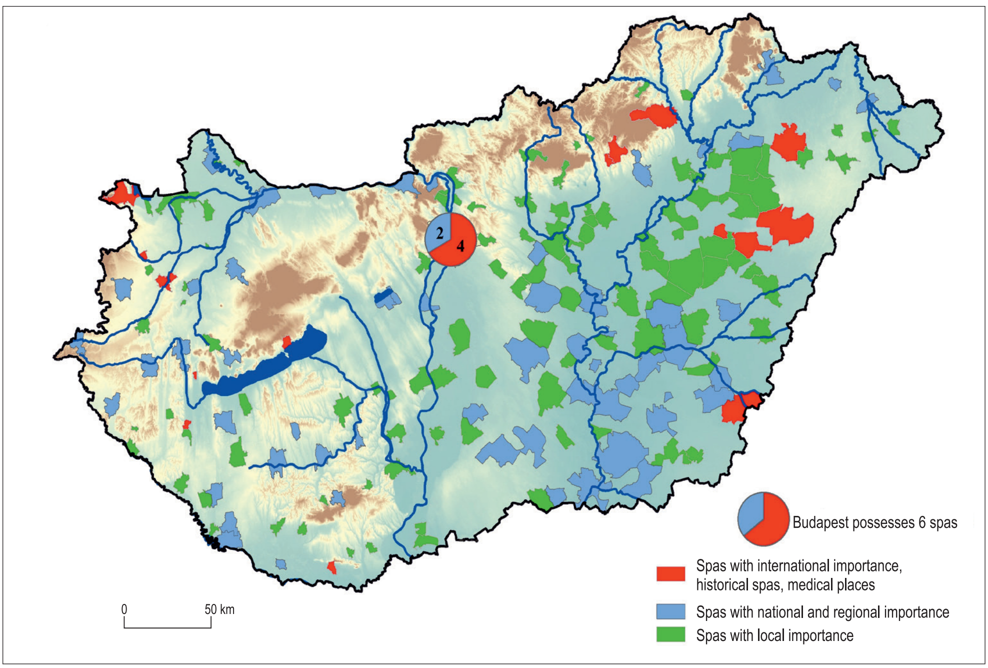

Fig. 1. The spatial allocation and categorisation of spas in Hungary. *Source*: own editing.

is less concerned, however, we can see particular processes of seasonality there as well.

Understanding the role and importance of seasonality in the professional tourism planning and development of the country, the primary aim of our paper is to survey the seasonality of the 9 spas with the greatest turnover in Hungary with the help of the Gini index. The objective reason why these spas (Bük, Cserkeszőlő, Egerszalók, Gyula, Hajdúszoboszló, Harkány, Hévíz, Sárvár, Zalakaros) were chosen and surveyed is because first of all they are mono profile health tourism centres (Michalkó, G. and Rátz, T. 2010) where tourists are visiting the settlement exclusively because of the spas, and on the other hand the visitor turnover of the mentioned settlements are significantly higher than the following Hungarian spa towns (Csapó, J. and Marton, G. 2017).

We believe that one of the most important questions of tourism is the topic of seasonality that divides the tourist flow and the generated consumption to different periods such as accentuated or busy and relaxed or less visited ones. The change of the regularly repetitive popular and non-popular periods rises numerous social, environmental and economic (mostly price, revenue-related) questions both on local, regional, national or even international level for the actors of the tourism industry (Duro, J.A. 2016; Yang, Y. *et al*. 2016; Wang, X. *et al*. 2019). So, according to the authors, understanding the processes of seasonality gives the chance to find the answers on how to reflect the challenges we face concerning modern tourism development, and so the present article stands as an example for these practical investigations.

Based on the above mentioned the present paper surveys the seasonality of a segment of Hungarian health tourism which possesses a longer season than the average in the country; that is also why this tourism product is handled as an accentuated area in the country's tourism industry. As a novelty, our research intends to provide an actual picture about the exact measure of seasonality in the highlighted spas of Hungary, due to the overall actuality of this issue and also because no relevant literature background was dealing with this problem yet. Although, several types of indexes could be used in measuring the numerical performance of tourism or its segments, such as the tourism index (Aubert, A. *et al*. 2013) or tourist function index (Borzyszkowski, J. *et al*. 2016). However, for our seasonality analysis we used the commercial accommodation statistics of the Hungarian Central Statistical Office (for 2018) and to estimate the Gini index we applied the monthly dataset of the guest nights.

Theoretical background and literature review

The initial study of seasonality was executed by Bar On, R.V. (1975) using the seasonality range and the seasonality ratio, which are based on the seasonal indices (as percentages) derived from a multiplicative (monthly) model (Coshall, J. *et al.* 2015). Later researchers of this topic connected the survey of seasonality to the northern, periphery regions focusing on seasonal patterns of tourism arrivals from different regions and countries (Hartmann, R. 1986; Snepenger, D. *et al.* 1990; Butler, R.W. 1994, 2001; Flognfeldt, T. 2001; Baum, T. and Lundtorp, S. 2001), but we can detect analyses of the Mediterranean region's demand anomalies as well (Sutcliffe, C.M.S. and Sinclair, T. 1980; Donatos, G. and Zairis, P. 1991). The impacts and measure of seasonality were surveyed first in the beginning of the 1990s (Hylleberg, S. 1992) and this topic became more popular in the 2000s. Although, Lundtorp, S. (2001) started to illustrate several methods for measuring seasonality, this calculation of the periodical flow of tourists remained fashionable for researchers who also adapted the Gini-coefficient as a tool for tracing the temporal changes of the demand (Lee, C. *et al*. 2008; Bigović, M. 2011; Cisneros-Martínez, J.D. and Fernandez-Morales, A. 2015; Fernández-Morales, A. *et al*. 2016; Roselló, J. and Sansó, A. 2017).

The theoretical review of Cannas, R. (2012) related to tourism seasonality provides a thorough explanation about one of the most well-known problems of tourism mentioning that, according to Butler, R.W. (1994) seasonality is 'a temporal imbalance in the phenomenon of tourism, [which] may be expressed in terms of dimensions of such elements as numbers of visitors, expenditure of visitors, traffic on highways and other forms of transportation, employment, and admissions to attractions' (Cannas, R. 2012, 41 refers Butler, R.W. 1994). On the other hand Allcock, J.B. (1989) defines it as a concentrated tourism flow in a short period of the year which is a kind of physiological feature of tourism. Baum, T. (1999) describes seasonality as a problem, which should be tackled on different planning, marketing and operational levels. According to the definition of Hirschey, M. *et al*. (1993) from an economic point of view there is a rhythmical annual pattern of production, sales, consumption and profitability as indicators. Based on this idea Frechling, D.C. (2001) appraises seasonality as the cyclical fluctuation of a longer period of time, as the subsequent change of the economic indicators. The general approach of Moore, T.W. (1989, 49) concludes this phenomenon as 'movements in a time series during a particular time of year that recur similarly each year'. Butler, R.W. (2001) argues that the complexity of seasonality pictures well that it has an effect on the whole of the elements of supply, such as marketing (packages, pricing, distribution), labour force market (quality labour force, abilities and their sustainability), finance, business (cash balance, pricing, attracting investments), the owner management (suppliers, mediators) and all the elements of operation. Out of the comprehensive works dealing with the basic questions, consequences and measurability of seasonality we can mention Baum, T. and Hagen, L. (1999) and Baum, T. and Lundtorp, S. (2001).

Among the reasons for seasonality Bar On, R.W. (1975) and Hartmann, R. (1986) distinguished two main ones: natural (climate, seasons, distance from the Equator etc.) and institutionalised (cultural and religious traditions, holidays etc.). For the five main reasons for seasonality Butler, R.W. (1994, 332–333) indicates 'climate, particularly seasonal variation, human decision factors, notably social, religious or cultural in origin, the sporting seasons, inertia and tradition'. The institutionalised element of seasonality is traditionally a human activity, often fitted to defined times of period such as religious, cultural, ethnic or social factors. The most frequent of all are the official and school holidays. The author also deals with this problem in 2001 indicating that the natural and institutional reasons for seasonality can actuate each other as well (Butler, R.W. 2001).

According to the climatic definition Hylleberg, S. (1992, 4) states that 'seasonality is the systematic, although not necessary regular, intra-year movement caused by changes in weather', moreover climate can result further significant alterations in certain destinations (Amengual, A. *et al*. 2014). Besides weather (temperature) Hylleberg, S. (1992) also mentions the calendar effect (holidays) and timing (school holidays) as the three most important reasons for seasonality indicating that out of them we can find stable dates, holidays (Christmas), continuously changing, but predictable ones (Easter, Chinese Lunar New Year) and unpredictable ones (such as weather).

The institutionalised reason is more complex and less predictable than the natural one, since it is influenced by culture, religion, ethnic and social factors, the destination, the tourism product or the marketing activities. Butler, R.W. (2001) states that seasonality appears most of all as a problem in tourism which should be handled, however, in some circumstances (such as in remote seasonal rural destinations) it can provide a favourable solution in employment for instance (Flognfeldt, T. 2001). We can also mention among the institutionalised reasons the habits, traditions or the sports seasons so it is obvious that seasonality has been researched from the points of view of sport (Higham, J. and Hinch, T.D. 2002; Kiss, R. 2014) and recreational activities (Hartmann, R. 1986; Butler, R.W. 1994) as well. These researches are highlighting that the uneven distribution at the high season is one of the most convincing problems of recreation and tourism causing ineffectual source utilisation, potential profit loss, social-ecological capacity pressure and administrative difficulties (Manning, R.E. and Powers, L. 1984). The high-level of tourist fluctuation results in a huge negative impact on the environment which has also been one of the key issues in recent seasonal tourism studies (Cisneros-Martínez, J.D. *et al.* 2018).

In the case of the destinations allocated in peripheries the problem of seasonality appears more drastically (Baum, T. and Hagen, L. 1999) where first of all the topic of season elongation is surveyed (Koenig-Lewis, N. and Bischoff, E.E. 2005; Cannas, R. 2012). The significance of this topic is also strengthened by the data of the Eurostat (2016) that one out of four travels of the Europeans was realised between July and August; and if we have a look at the time length of the travel this concentration is more dynamic. Stupariu, M.I. and Morar, C. (2018) focused on the customers' fluctuation in a shorter period of time, more precisely, the weekly and monthly streams of tourists' flow in neighbouring spas, which created operational issues at tourism enterprises with high seasonality (Connell, J. *et al*. 2015). Accordingly, accommodations, restaurants or spas were defined by Coshall, J. *et al*. (2015, 1604) and were named as 'one of the most protracted problems facing managers in the tourism sector'.

Alongside the changes in travel patterns over the past few years, the new trends indicated the strengthening of the spa and medical tourism product (Ramírez de Arellano, A.B. 2007; Connell, J. 2013; Rodrigues, H. *et al.* 2019). The overall market positions of both wellness and medical tourism has been influenced by the demographic changes (especially in the developed countries) of the last decades, increase in the discretionary income, growing need for recreation and regeneration or simply by financial reasons (Horowitz, M.D. *et al*. 2007; Lunt, N. and Carrera, P. 2010; Csapó, J. and Marton, G. 2017).

Despite the excellent potential, Hungary has to face a growing competition on the international health tourism market. Therefore, the assessment of the competitors is a key task of tourism development (Michalkó, G. and Rátz, T. 2010; Michalkó, G. *et al.* 2012). In the global content, every country or destination can be regarded as a competitor possessing a health tourism supply of partially or completely international importance. The direct competitors of Hungary are European countries with special attention to its neighbours, specifically, Austria, Slovenia, Slovakia and Romania offering spas of national and international importance and/or other health tourism services, which have undergone significant improvements in the last decade (Lew, A. *et al*. 2008; Yeung, O. and Johnston, K. 2017; Stupariu, M.I. and Morar, C. 2018).

Although with a different supply structure, alongside the neighbouring countries, the Czech Republic and Italy have outstanding thermal and medical tourism propositions with international importance on the tourism market. Wellness tourism, the other pillar of health tourism, shows an even more varied picture as natural resources play less significant role. Apart from Hungary's direct neighbours and the other competing destinations, Poland and Russia need to be regarded as serious competitors in terms of existing and future wellness tourism potential (Lew, A. *et al*. 2008; Csapó, J. and Marton, G. 2017).

Nevertheless, health tourism is a rather popular scope in researches in the country especially in domestic (Hungarian) publications much less work has been carried out in English. Besides the comprehensive work of Smith, M.K. and Puczkó, L. (2017) we can highlight spatial and structural papers (Aubert, A. *et al.* 2010, 2013; Michalkó, G. and Rátz, T. 2010; Jónás-Berki, M. *et al*. 2015), tourism oriented real estate development (Michalkó, G. and Rátz, T. 2010) and demand analyses (Smith, M.K. and Puczkó, L. 2015), guest flow analyses (Sulyok, J. and Mester, T. 2014) or papers and researches dealing generally with well-being and quality of life (Smith, M.K. and Diekmann, A. 2017) or taking into consideration regional aspects (Rátz, T. and Michalkó, G. 2011; Sprah, L. *et al*. 2014).

Such works analysing the seasonality of Hungarian tourism are present only in a limited number of publications in the Hungarian scientific literature which is especially interesting as the country's tourism flow is concentrated both in space (Budapest and Lake Balaton) and time (summer high season). Sulyok, J. and Kiss, K. (2006) analysed seasonality in general in the country while Sulyok, J. and Mester, T. (2014) were focusing on the turnover of commercial accommodations in connection with seasonality. Dávid, L. and Tóth, G. (2009) published a research on seasonality on the example of a Hungarian mountain range (Mátra mountains) and Marton, I. *et al*. (2001) analysed thermal tourism as a possible tool for the elongation of the season. Our research continues the product centred approach of the upper mentioned publications focusing on the least seasonal tourism product of the country.

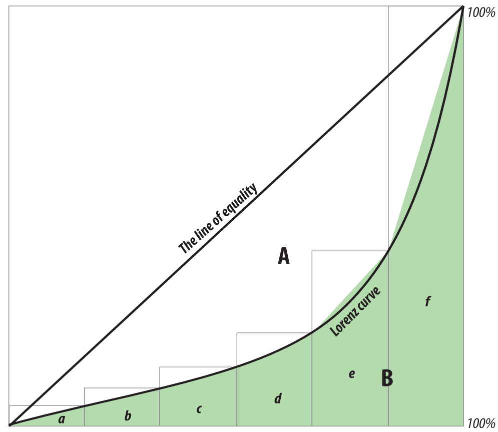

Fig. 2. The estimation of the area under the Lorenz curve (B) with trapezoids (grey areas) when the frequency variable is discrete (e.g. months). Horizontal axis = the ratio of the certain months related to all the months (in %); Vertical axis = the ratio of guest nights related to the number of the total (annual) guest nights (from the months with the smallest turnover to the one with the greatest, cumulated). *Source*: Own editing, 2016.

Materials and methods

The Gini index (Gini, C. 1912) is basically based on the Lorenz curve, which shows the distribution of a studied variable (e.g. income or health, or in our case: guest nights) *(Figure 2)*. The value of the Gini index is the ratio of the area closed by the 45-degree line (the line of equality) and the Lorenz curve (A) correlated to the size of the complete area of the triangle symbolising the total inequality (A+B), so G = A/(A+B). The size of the area representing complete inequality is A+B, so 0.5, accordingly G = A/0.5, and G = 2A. So, the area of the Gini index is twice the area closed up by the 45-degree line and the Lorenz curve (A).

If the analysed variable where we look at the frequency is continual, then from the perspective of geometry, the area between the Lorenz curve and the line (A), or the area under the Lorenz curve (B) can be determined with integral calculus. This, however, happens only at the rarest of cases, in practice we usually meet a discrete variable, as in our case, when we examine the distribution of guest nights based on monthly data. In this case, the area under the Lorenz curve can be given with an approximate estimation as the sum of the trapezoids fitted with one side to the curve (see *Figure 2*, where area 'B' is approximately the sum of the area of the grey trapezoids: a + b + c + d + e + f).

The Gini index is widely applied to measure the seasonality of tourism since it represents the seasonal inequalities of tourism flow with a quantitative method (Fernández-Morales, A. 2003; Fernández-Morales, A. and Mayorga-Toledano, M.C. 2008; Bigović, M. 2011; Sulyok, J. and Mester, T. 2014). Since we would like to measure the seasonality from the inequalities of a 12 months data set we can use the following formula in order to calculate the Gini index (Sulyok, J. and Mester, T. 2014):

$$G = 1 - \sum_{i=1}^{12} (X_i - X_{i-1}) \cdot (Y_i + Y_{i-1}) ,$$

where i means the certain months, X_i is the cumulated share from the 12 months and Y_i is the share of the cumulated guest nights from the annual total guest nights of the months lined up in an increasing sequence by the number of guest nights.

For our seasonality analysis we used the commercial accommodation statistics of the Hungarian Central Statistical Office (2018) and in order to estimate the Gini index we applied the monthly dataset of the guest nights. According to the HCSO the two main type of the accomodations are the business accommodations and the non business accomodations. Business accomodations can be divided into two further categories:

1. commercial accommodations (hotels, special hotels, e.g. health, wellness, garni and apartment hotels; pensions, campings, holiday homes, hostels and youth hostels);

2. other business accommodations (standalone buildings or a demarcated part thereof intended not solely for the purpose of accommodation services, where the number of rooms used for this purpose is not more than 8, and the number of beds is not more than 16).

According to the HCSO, the non-commercial accommodations are 'accommodation for holiday and youth tourism and mountain shelter' (HCSO, 2019).

In our study we studied only the commercial accommodations. These statistics are available from 2000 which is rather fortunate since the first great wave of state-supported investments in the spa towns started from this year. It is also important to add that only the monthly guest nights of the commercial accommodations is available in the Hungarian statistics while no relevant data is available concerning the visitor number of the spas or the other business accommodations, that is the basic reason why we chose statistical data of the commercial accommodations in our calculations. The Gini index can only be used with monthly or even more refined data. The guest nights of the commercial accommodations are also an adequate indicator because it records well the formation of the tourism activity in the analysed destination. Seasonality can be counted based on other data (number of the guests, accommodation receipts) as well, however, traditionally the calculation of this index is based on guest night datasets.

It is important to note that while in 2016 the commercial accommodations of the studied spa towns had 36,000 bed places, the other business accommodations had almost an additional 26,000 beds. In that year, the total number of the guest nights in the commercial accommodations in the studied spa towns were higher than 4.5 million, while in the other business accommodations they were not quite than 765,000 (16.6% of the commercial accommodations). Nevertheless, the performance of the other business accommodations is not negligible, but it is not critical in assessing the seasonality of the spa towns. The capacity and overnight stays of other business accommodations indicate that seasonality is likely to be higher for this type of accommodation, given that these accommodations typically do not operate all year round. However, no data are available to verify this expectation.

The novelty of the research is that the authors focus and draw the attention on the importance and applicability of the Gini index in terms of tourism seasonality surveys and also that no such research has been carried out so far in order to numerically support the seasonality of the tourism of the accentuated spa towns in Hungary. The results of our surveys are not only useful for the academic world, but when seasonality is presented by exact mathematical calculations than useful data are provided for the stakeholders and decision makers of the spas and the municipalities in order to understand one of the greatest issues of the Hungarian tourism industry, the temporal and spatial allocation of the tourists.

Results: the evaluation of the seasonality change of the major Hungarian spa towns

According to our results the seasonality of the analysed spa towns decreased overall in the last 16 years. If we study the commercial accommodation data of the spa towns all in one, they show a 27.7 per cent decrease of seasonality in all the 9 spa towns between 2000 and 2016 *(Figure 3).* While in 2000 the value of the Gini index was 0.279 (taking into consideration all the analysed spa towns), it decreased to 0.171 by 2016.

The decrease, however, was not balanced. In the analysed period there were years when seasonality increased in the commercial accommodations of the spa towns. 2005 was such a year where seasonality grew slightly (2.3%) compared to the previous year's results, but such era was between 2008–2010 and 2013 and 2015 where seasonality grew by 12.5 and 8.8 per cent respectively, compared to the previous year's data. At the same time from 2000 to 2016 the decrease of seasonality can be detected in numerous years. We identified the greatest decrease in 2011 and in 2014 (–12.7% and –14.9% respectively, compared to the previous year's data), but the 8.5 per cent decrease in 2004 was much higher than the average. Since the decrease of seasonality was characteristic for more years than the increase, we detected an overall 30 per cent decrease in the Gini index, and so in seasonality, between 2000 and 2016.

Fitting a linear trend to the aggregated data of the spa towns we see the slightly decreasing trend of seasonality (see *Figure 3*). The insertion of the linear trend line is relatively good, the value of the R^2 coefficient of determination is 0.68. The average degree of the annual decrease of the Gini index is –1.7 per cent.

Seasonality formed quite differently in the certain spa towns. The Gini index decreased the least in Hévíz (–9.2%), Hajdúszoboszló (–16.7%), Harkány (–18.0%) and Gyula (–24.5%) which it is also due that these 4 traditional spa towns possessed a developed commercial accommodation background already in 2000. That is why in these settlements' seasonality did not decrease at such measure than in those spa towns where the certain developments started after the millennium. Since these settlements represent a significant guest flow in comparison to the others, they influence quite significantly the formation of the combined

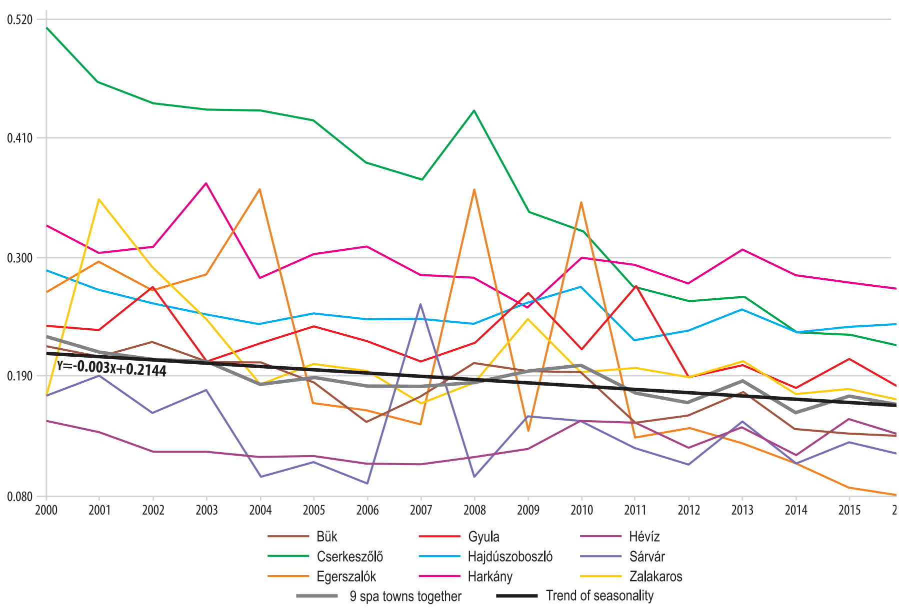

Fig. 3. The formation of seasonality of the analysed spa towns. *Source*: Based on HCSO database, own calculation.

Gini index as well. Nevertheless, seasonality decreased the most in Egerszalók (–70.1%), Cserkeszőlő (–57.2%) and Zalakaros (–50.7%) as well as we could detect a significant decline (more than –30%) in Bük and Sárvár between 2000 and 2016.

The formation of seasonality is worth compared with the formation of the capacities, especially because on the national level in the researched period the number of the rooms of the commercial accommodations grew with 31 per cent and the number of the beds by more than 20 per cent. A much faster increase was experienced in the analysed 9 spa towns (*Table 1*). The number of beds grew from 24,400 (2000) to 35,700 (2016) so almost with 50 per cent, which is more than twice the national increase. Analysing the towns one by one it turns out that in Egerszalók this increase was more than 60 per cent, however, it started from a very low basis data.

The number of accommodation capacity grew significantly in Sárvár as well, from 900 places in 2000 to nearly 3,000 by 2016. In Zalakaros the capacity of the commercial accommodations grew with 88 per cent, in Cserkeszőlő 68 per cent, while Bükk and Hévíz grew their capacities with 50 per cent. This increase meant in Hévíz nearly 2,500 new bed places with which the town emerges from the other spa towns. If we do not analyse the increase ratio than concerning the absolute numbers of the capacity of the commercial accommodations Hajdúszoboszló is leading with more than 8,000 bed places.

Taking into consideration the increase of capacities (supply) the increase of the demand is much faster. The number of nights at commercial accommodations grew from 2.6 million in 2000 to 4.6 million (+75%) by 2016. Except for Harkány, the demand grew at every analysed spa town with remarkably high data at some settlements *(Table 2).* In Egerszalók, this increase was more than 270-fold since as a new spa there were practically very low commercial guest nights in 2000 which grew to more than 200,000 by 2016. The number of guest nights almost quadrupled in Sárvár (2000: 130,000; 2010: 485,000) and tripled in Cserkeszőlő (2000: 44,000; 2016: 147,000). At the same time the increase was not so remarkable from a high basis. In Hévíz the number of guest nights grew by 33 per cent, but it means a 259,000 increase in absolute numbers compared to as in 2000. In Hajdúszoboszló, the increase was 47 per cent with an absolute increase of 300,000 guest nights. The greatest increase in absolute numbers could be detected in Bük (+340,000 guest nights) preceding Hajdúszoboszló (+300,000), Zalakaros (+297,000) and Hévíz (+259,000).

Table 1. The change of the capacity of the commercial accommodations in the analysed spa towns, in bed places

Spa towns	Number of bed places in commercial accommodations		Growth in bed places in number between 2000 and 2016	Growth in bed places in % (2000 = 100%)
	2000	2016		
Egerszalók	18	1,106	1,088	6,144
Cserkeszőlő	730	1,230	500	168
Sárvár	927	2,874	1,947	310
Zalakaros	2,267	4,254	1,987	188
Gyula	2,620	2,966	346	113
Harkány	3,401	2,371	–1,030*	–30*
Bük	3,533	5,262	1,729	149
Hévíz	4,892	7,386	2,494	151
Hajdúszoboszló	6,032	8,231	2,199	136
Total	*24,420*	*35,680*	*11,260*	*146*

*Harkány: decrease. *Source*: Hungarian Central Statistical Office (HCSO) 2018, and own editing.

Table 2. The change of the guest nights in commercial accommodations in the analysed spa town

Spa towns	Number of guest nights in 1,000		Growth of guest nights between 2000 and 2016, in 1,000	Growth of guest nights in % (2000 = 100%)
	2000	2016		
Egerszalók	0.7	200.3	199.6	27,258
Cserkeszőlő	44.1	146.7	102.6	333
Sárvár	129.7	485,4	355.7	374
Zalakaros	203.7	500.3	296,6	246
Gyula	222.0	366.7	144.7	165
Harkány	224.2	191.7	–32.5*	–15*
Bük	360.7	700.8	340.1	194
Hajdúszoboszló	638.0	937.8	299.9	147
Hévíz	796.8	1,056.1	259.3	133
Total	*2,619.9*	*4,585.9*	*1,966.0*	*175*

*Harkány: decrease. *Source*: Own editing.

Conclusions

The seasonality of the guest flow of the spa towns is much smaller than the seasonality of tourism in general in Hungary. This is an important phenomenon in the tourism industry of such a destination where the majority of tourists are still visiting Hungary concentrated both in time and space. While the Gini index of the guest nights at commercial accommodations on the national level is 0.25 than this aggregate value is more than 30 per cent less, in 2016 (0.17 at the analysed spa towns). We can conclude that the spa town function results expressly favourably to seasonality.

The other important lesson is that the investments and developments in the last 16 years effectively decreased the seasonality of the guest flow of the spa towns. These developments typically included investments in supply covering mainly the tourism infrastructure and supra-structure of the spas and also the accommodation and guest catering structure of the settlements, with a special emphasis on the development of tourism services as well. The drop of seasonality was the greatest at the spa towns carrying out significant investments and developments (Cserkeszőlő, Egerszalók) which is partly due to the statistical impact and partly it shows that the implemented investments managed to extend the season.

The experiences of the 'new spa towns' are confirmed by the data of the traditional ones (Hévíz, Hajdúszoboszló). In these latter ones seasonality did not decrease at the same level as in the case of the new ones, since they had from earlier times those supply elements which were promoting their requisition during the complete year. The new investments strengthened the four seasons-long supply, so the decrease of seasonality was not remarkable. In the future significant decline of seasonality is not expected in the case of the new spa towns so we should not forecast further significant decrease in the Gini index on the national level either, because of the former realisation of the four seasons-long supply.

Comparing the dynamics of the demand and supply we can also see that in the spa towns the increase of the capacity of the commercial accommodations (+50%) was significantly exceeded by the increase of the demand (+75%). Therefore, the utilisation of the available capacities is less seasonal, so the demand requisitioned the capacities in a much more expanded time scale in the season. Since the decrease of seasonality took place besides a significant increase of commercial accommodation capacity, the expansion of the turnover possibly made an impact on the anticipated return of the investments as well. This finding is supported by the rise of the occupancy rate of the commercial accommodations: the average occupancy rate of the rooms in the 9 spa towns was 44 per cent in 2009, and 56 per cent in 2016. This increase of room occupancy in the commercial accommodations increased almost continuously in the reviewed period except for Harkány, where no spa improvements have been made in the reviewed years.

Based on the findings of our study we can state that in the analysed period demand has increased significantly and in parallel, seasonality has declined in the studied spa towns. It seems to be proved that the extensive developments of the spa towns were successful, the accommodation capacity and the number of guest nights were growing in a remarkable extent and the utilization of the capacities also increased slightly.

As for some limitations of the study the authors think that, as a future research direction, the detailed analysis of changes in individual settlements should be further analysed to obtain a more accurate picture on the settlement level as well. Parallel with this, the guest data of other accommodations would also be required to test seasonality (to obtain the more detailed picture). We consider the present study as a simple quasi-longitudinal study, but we cannot clearly explain here that there is a correlation between the implemented developments and the spa towns' tourism and seasonality. This topic could be a further issue in these researches. As the last aspect of further research directions we should also measure the improvements in the quality of services in the spa towns and as an explanatory variable it should be built into a larger model, parallel with other parameters, such as the changes in income or concerning the economic cycle.

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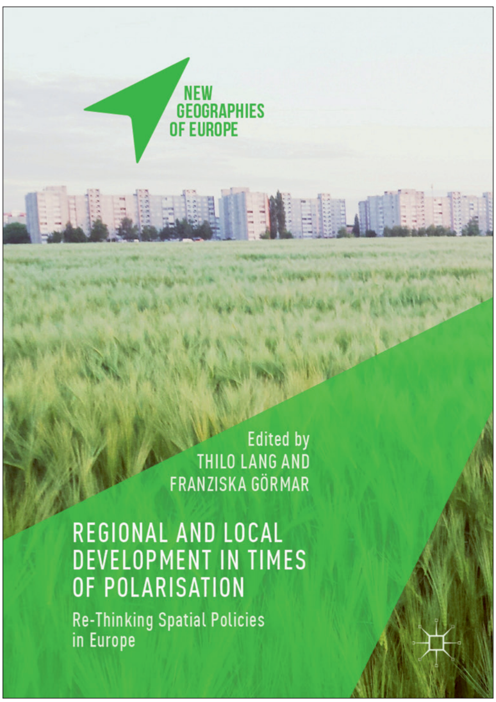
BOOK REVIEW SECTION

Lang, T. and Görmar, F. (eds.): Regional and Local Development in Times of Polarisation: Re-Thinking Spatial Policies in Europe. Singapore, Palgrave Macmillan, 2019. 382 p.

The neoliberal turn in the late 1980s and its effects on the regional development and cohesion policy of the European Union are widely discussed issues in academic forums. Though the European Union still addresses spatial equity through redistribution by "strengthening of its economic, social and territorial cohesion" and "reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions" (European Union 2012, p. 127), embracing neoliberal ideology has led to new approaches in European and national policy making. Post-2000 events such as the 2008 economic crisis and the implementation of the Lisbon Strategy, the Europe 2020 Strategy and its Territorial Agenda have strengthened the promotion of neoliberal principles including regional competitiveness, innovation and economic growth. Under these circumstances, a total sum of 13 new Central and Eastern European (CEE) member states joined in 2004, 2007 and 2013, and their incorporation posed new challenges to EU cohesion policy due to institutional and infrastructural weaknesses and low levels of economic development in certain areas. The development of the European Community has been spatially uneven since its very foundation in 1957, but the above policy changes have led to increasing regional polarisation in the last three decades. It is now proven that community- and national-level policies affect regions very differently, even if these policies are designed to ensure equal treatment across space. In addition, the outcomes and success of these policies largely depend on the quality of governments at various territorial levels (European Commission 2017). Therefore, it is crucial to understand how uneven development and regional polarisation in Europe work out at different scales and at different places, and how policy making and governance shape these processes.



Such issues with regard to European cohesion and regional policy are in the scope of the current edited volume. It was published as part of the "New Geographies of Europe" series, which draws on contemporary research exploring the production and reshaping of space from a comparative and interdisciplinary perspective. The editors of the book are both outstanding researchers in the field of regional development and policy. Thilo Lang is head of department at the Leibniz Institute for Regional Geography, Leipzig, and lecturer at the Global and European Studies Institute of the University of Leipzig, while Franziska Görmar is project manager and research fellow at the same institute. Including them, altogether 32 authors contributed to the 15 chapters of the book, among whom several disciplines and scientific domains are represented, i.e. geography, regional economics, spatial planning and policy, sociology and political science, international studies, urban studies, social anthropology as well as political science. It is also notable that within the group of authors, there is a balance between experienced scholars and early-career researchers and PhD-students.

This book discusses socio-spatial polarisation and uneven development from a critical point of view, using spatial justice (Harvey, D. 1973; Soja, E. 2010) as a core concept, paying special attention to CEE regions. Its main objectives can be summarised in three points. First, to problematise the concept of European regional and cohesion policy, and to reveal the underlying mechanisms of policy making at various scales and in different geographical and institutional contexts. Second, to discover in which ways socio-spatial polarisation is reproduced in global financial capitalism, with special attention to how power relations and institutional frameworks contribute to this process. Third, to scrutinise how policy should respond to polarisation processes, and to search for alternatives to the neoliberal mainstream.

The book has a sum of 391 pages, from which – not considering bibliographic data, acknowledgement, contents, notes on contributors, lists of figures and tables – the chapters cover 382 pages. Besides the introductory chapter, the book consists of four major parts. The first part engages with European power structures and investigates their role in the reproduction of socio-spatial polarisation. Within this part, Chapter 2 is a conversation between Ray Hudson and John Pickles based on their seminal works. The two scholars emphasise that uneven development is inherent to capitalist economies, and it goes hand in hand with power asymmetries and democratic deficit, which manifest themselves in policies favouring urban growth centres. Therefore, they call for an explicitly political economic geography because geographers need not only to understand uneven and combined development and polarisation processes, but to promote and support more progressive forms of capitalism and more just alternatives to economic development.

In Chapter 3, Costis Hadjimichalis investigates how imaginations of peripherality shape development theories and policies, and how theories and policies contribute to deepening unevenness and peripherality. The author points to some conceptual and methodological limitations of the dominant understanding and measurement tools of unevenness, discussing the impacts of neoliberalism on EU regional policies, especially their reorientation towards regional competitiveness, innovation and growth. According to Hadjimichalis, this is a source of discrepancy with regard to cohesion funds: they seek neoliberal macro-economic policies that impose austerity, while pursuing solidarity and economic and social cohesion. He criticises European elites because they have de facto accepted the idea of "multi-speed Europe" (p. 73) and uneven development. Unfortunately, Hadjimichalis continues, against the hardly accountable EU political elites, mainly extremist right-wing and populist political forces have stood up with more success. Therefore, in his conclusion, he calls for an alternative to current elitist policy making and the neoliberal mainstream in the EU.

In Chapter 4, Merje Kuus makes three points. First, she points out that European spatial planning has become transnational, inasmuch as it is mainly shaped by cross-border networks and interpersonal relationships. Second, though European policy making is transnational, national belonging still matters: diplomats' attitudes are rooted in their national political cultures, and while there are uniform protocols and communication in the EU, national habits are hard to discard. For doing 'Brussels diplomacy', special skills are required, and richer countries have considerable advantage in this respect: with better universities they can train better professionals and diplomats. That is why Kuus argues that transnational policy making contributes to the reproduction of unevenness amongst member states. Third, engaging with research methodology, she suggests that European policy making cannot be successfully analysed along rigid EU/member states and member state/member state boundaries, but transnationality should be firmly considered in research strategies.

Chapters in the second part discuss European and regional policies and their impact on territorial cohesion within and between EU member states. Chapter 5 (Rhys Jones, Sami Moisio, Mikko Weckroth, Michael Woods, Juho Luukkonen, Frank Meyer and Judith Miggelbrink) contains a critical analysis of the idea of territorial cohesion, and a discussion of conceptual and policy benefits of the idea of spatial justice. The authors argue that cohesion policy is an elusive and complex concept, giving space to various interpretations or even to manipulations for the purpose of national and regional development priorities. Therefore, placing the concept of spatial justice into the centre of development policies would facilitate wider regional social coalitions, focusing on the capabilities of the given area, and not only considering regions as mere recipients of external financial and institutional support. In Chapter 6, Bradley Loewen and Sebastian Schulz investigate how EU cohesion policies work in four countries: Czechia, Estonia, Hungary, Slovakia. Their analysis corroborates the existence of discrepancies between cohesion and innovation policies in the case of CEE regions. The main reason behind this phenomenon is the high level of polarisation, since more developed regions have more potential to benefit from innovation policies due to their more sophisticated institutional frameworks. The main conclusion of this chapter is that the relationship between the European Innovation Policy and the Cohesion Policy should be made transparent for which the authors provide two alternatives. The first one is separating the two policies, so the Innovation Policy could become the EU's economic policy and the Cohesion Policy could refocus on infrastructure and social investment in underdeveloped regions, while the second alternative considers Innovation Policy as the economic strategy of the Cohesion Policy, with equal standing alongside social and environmental strategies.

In Chapter 7, Stefan Telle, Martin Špaček and Daniela Crăciun analyse the objectives of European development strategies at different territorial levels. First, they compare the Lisbon Strategy and the Europe 2020 Strategy, and second, they examine all the cross-border development programmes launched in Czechia and Germany in the 2007–2013 and 2014–2020 financial periods. According to their results, at the macro level there is a shift between the Lisbon Strategy and Europe 2020 in their objectives from employment and social issues towards growth and innovation, considering productivity and efficiency the bases of better cohesion. Regarding cross-border programmes, the authors observe divergence between old and new member states: while the former promote neoliberal, competitiveness-centred policies, the latter rather intend to achieve growth and cohesion through employment and labour market participation. Therefore, the authors' recommendation is that differences in national interests and development paths need to be considered in European policy making. Furthermore, regulations on cross-border cooperation should be more flexible and better promote institutional capacity building. In Chaper 8, József Benedek, Ştefana Varvari and Cristian Marius Litan focus on Romania's Growth Pole Strategy for the 2007–2013 period. On the one hand, adopting quantitative methods, they analyse the impacts of growth poles on regional inequalities. On the other, they conduct a qualitative analysis to discover how the idea of growth poles is echoed by the objectives of Romanian development strategies. Their results point to the failure of the Growth Pole Strategy, inasmuch as it has not reduced regional inequalities in Romania. The authors' conclusion is that the Growth Pole Strategy is a "good example of the Europeanisation process" (p. 188) but general guidelines and principles of European spatial planning documents should have been adopted in a more critical way, taking national peculiarities into account.

In Chapter 9, Zsuzsanna Pósfai and Csaba Jelinek discuss the effects of Hungarian housing policies on socio-spatial polarisation for the post-2000 period. Here, the reader is introduced to the dual character of post-socialist Hungarian housing policy: each policy introduced after 1990 either supported relatively well-off middle classes, officially providing equal access for everyone ('liberal' elements of Hungarian housing policy), or served to cater to the housing needs of the least affluent people ('socialist' elements). Although the currently dominant liberal housing policies are considered geography-blind by many, the authors demonstrate that these policies have considerable spatial effects and they reproduce pre-existing socio-spatial inequalities. Their main argument is that Hungarian liberal housing policies serve to channel financial resources towards better-off middleclass households, while marginalising low-income households. Therefore, public policies contribute to the social and spatial polarisation of Hungarian society. Increasing financialisation and the new housing schemes (together with the current economic upturn) have led to the rocketing of property prices, particularly in urban centres, while housing markets in many rural and underdeveloped areas have been left without considerable external resources.

The third part of the book focuses on micro-scale strategies adopted by regional and local actors – e.g. individuals, enterprises, communities—to cope with the effects of polarisation. Chapter 10 (Aura Moldovan) discusses the demographic and economic challenges faced by Romanian rural communities (Sălaj/Szilágy County), with special attention to selective out-migration. In particular, Moldovan scrutinises why people choose migration as a strategy to cope with the negative consequences of peripherality, and how out-migration influences local political leaders and their development strategies. From this chapter, it turns out that the group of out-migrants is not homogeneous and many of them are still attached to their place of origin after making a living elsewhere. The most important lesson from this chapter may be that selective out-migration increases the dependency of the affected communities on EU support and thus local leaders are often pushed to adopt special application strategies to accumulate financial resources. In Chapter 11, Sorin Cebotari and Melinda Mihály present two development projects implemented in peripheral communities in Hungary and Romania. It is showed that officially both projects are community initiatives but due to the extreme low level of civic activity in these areas, they are practically initiated and managed by the local mayors. The authors' conclusion is that broader public participation in local projects would be a key step towards the empowerment of such communities and could be an antidote to peripheralisation. Therefore, the concept of community and the role of local communities in development need to be revisited, and new policy-making mechanisms should be developed, involving regional and local actors.

In Chapter 12, Martin Graffenberger scrutinises the innovation strategies of two low-technology enterprises located in peripheral Estonian and German regions. The main question addressed by Graffenberger is how intra-firm capacities and network relationships can counterbalance the unfavourable effects of peripherality. Based on these two cases, the author argues that for enterprises operating in peripheral regions, a two-folded strategy might be fruitful: on the one hand, building multiple and diverse internal capacities (e.g. diversifying production portfolio; technological absorption), on the other hand, establishing multi-scale external cooperation (with local, regional, national and international partners). In Chapter 13, Bianka Plüschke-Altof and Martiene Grootens investigates the role of local actors' agency, using the concepts of leadership and place-making as analytical lenses. Though the authors agree that image building may function as a possible solution to challenges of regional polarisation, they also emphasise the limitations of such strategies: the idealisation and responsibilisation of local leadership can turn into the blaming and scapegoating of those who are less willing or able to participate. In addition, agency-based approaches may draw the attention from the structural conditions of peripheralisation. Finally, the authors emphasise the responsibility of researchers in the discursive re-making of peripheries, and they recommend a more dynamic and processual understanding of place and periphery.

In the last part of the book, the main results of the preceding chapters are summarised and recommendations for policy makers and researchers are provided. First, Garri Raagmaa, Erika Nagy, Franziska Görmar and Thilo Lang discuss the main contributions of the book in six points: (1) the regional policy paradox in the EU (i.e. growing regional polarisation despite financial support for less-developed regions); (2) the recent administrative (re-)centralisation trends in Eastern Europe; (3) globalisation and regional industrial restructuring causing further polarisation, in which CEE developed to a semi-periphery, specialised in labour-intensive activities; (4) the mechanisms that produce inequalities; (5) the production of inequalities through social practices and discourses; and (6) methodological considerations and issues related to researchers' positionality. In the last chapter, Sorin Cebotari, Tomas Hanell and Thilo Lang formulates policy recommendations for EU, national and regional/local actors. These point to (1) the need to place spatial justice into the centre of EU cohesion policy; (2) the involvement of regional and local actors in policy making; (3) the role of national-level governments to participate in establishing support infrastructure at lower territorial levels; (4) the significance of fostering human capital at the local level (e.g. by allocating resources for training in EU-funded projects); (5) the ways of how policy making and programming should be promoted at the local level.

To conclude the review, the volume "Regional and Local Development in Times of Polarisation. Re-Thinking Spatial Policies in Europe" undoubtedly holds a great scientific value. Uneven development and regional polarisation are multi-scalar and complex processes and the editors of the book successfully tried to grasp this complexity. Their efforts are mirrored by the diversity of the studies in terms of the scale of analysis (from the European to the local/micro), the applied methods (e.g. content analysis, qualitative interviews, computer-assisted text analysis – CATA, statistical methods) and the actors involved in the research (e.g. EU policy makers, entrepreneurs, local political leaders). They not only discuss the symptoms and impacts of regional polarisation but also engage with the reasons and the power relations and political structures behind, making a step forward to understand contemporary capitalism and transform it to a more progressive one. Nowadays, it is especially important to think about such issues, seeing the signs of the possible next economic recession (e.g. Brexit, slowdown of the German economy, the USA-China trade war), and considering the preliminary policies of the EU for the 2021–2027 period (among which innovation and competitiveness will probably remain key elements). Therefore, I wholeheartedly recommend this book, not only for scholars in the fields of regional development and policy, spatial planning and geography, but for all those who want to better understand the spatial dynamics of contemporary Europe.

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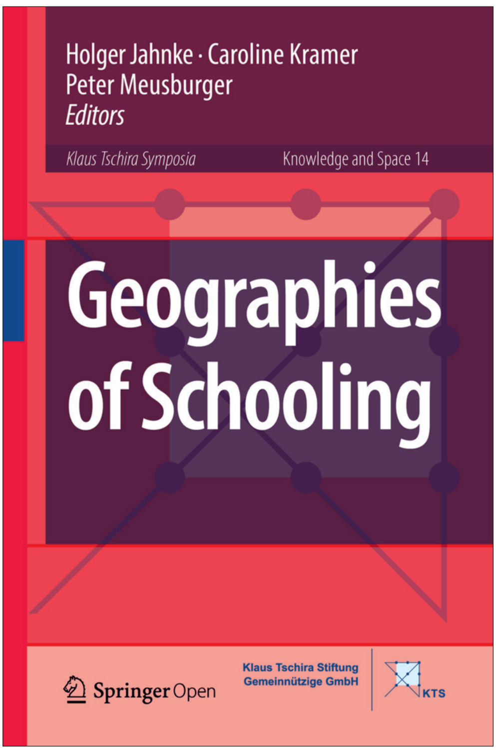
Jahnke, H., Kramer, C. and Meusburger, P. (eds.): Geographies of Schooling. Cham, Springer, 2019. 359 p.

The goals and roles of education are changing in time and space. Education can be seen as a tool responsible for the acquirement of social norms, labour market skills, local and/or national identities, just to mention a few. Spatial patterns of this system constitute the main focus of geography of education, a field that has witnessed a number of shifts in terms of theories, research questions and methodologies. During the decades following its institutionalisation in the 1960s, geography of education was applied for regional educational planning, but with time critical approaches were introduced by a number of scholars, which resulted in the appearance of a wide range of new research questions (Meusburger, P. 2015). The directions of the changes in geography of education are similar to those in other domains of human geography, as research in this field was stimulated by the political economy approach, the 'cultural' and 'relational' turns. With the 'spatial turn' that occurred in other social sciences, geography of education is of interest for a number of disciplines such as educational science, sociology and anthropology (Holloway, S. *et al.* 2010; Holloway, S. and Jöns, H. 2012).



The current volume represents this variety due to the approaches taken and the collaboration between scholars with different disciplinary backgrounds. As part of the Knowledge and Space book series, "Geographies of Schooling" is an outcome of the "14th Symposium on Knowledge and Space", held in Heidelberg in 2016. Although the series has already covered similar questions, "the geography of schooling has not yet been directly addressed in the series with a clear focus on the spatiality of schools, teaching, and formal learning processes in its different forms" (p. 2.). The volume is dedicated to Peter Meusburger, who was one of the editors of the book and he was the main initiator and organiser of the symposia as well, until he passed away in 2017.

In the introductory Chapter 1, Holger Jahnke and Caroline Kramer provide a thorough overview of the volume. After placing the book in the academic context of geographies of education and learning, they turn to the analysis of each chapter, which makes the reading and interpretation of the volume more efficient. As they highlight, the book presents different perspectives on school systems. One among them considers schools as tools used by politics to transform or oppress certain groups of society. Another perspective apparent in a number of chapters focuses on the neoliberal restructuring of school systems which results in an entrepreneurial idea of schools and growing disparities according to the availability of local resources. Schools are also investigated as social micro-systems, where a number of key actors are of interest for the authors. A pedagogic or educational aspect is also present in the volume, where "teaching and learning practices in and around schools become the focus" (p. 3).

Jahnke and Kramer summarise the ways spatiality is analysed in the book. They highlight four key spatial dimensions: (1) the question of geographical scale and rescaling from the point of view of responsibilities and allocation of financial resources; (2) the urban-rural divide; (3) the spatial and social embeddedness of schools in their specific locations; (4) the closure of small rural schools which results in the spatial centralisation of the school system and the intensification of pupils' commuting. After the summary of the approaches and research methods, Chapter 1 also provides brief descriptions of the individual chapters. To avoid repetition, I only give here short insights into the research questions covered throughout the 17 chapters and 4 parts of the book.

Part I includes studies on the consequences of educational policy reforms and rescaling responsibilities on institutional and regional/urban restructurings. Jahnke critically examines the impacts of educational reforms initiated by the German federal government in the second part of the 2000s. As he presents, although the original goal was to strengthen the role of primary education in social mobility, rural areas characterised by population decline and weak supply of local resources find themselves disadvantaged – and so do the pupils who live there – compared to their better-off and urban counterparts. He illustrates these processes through two case studies from Schleswig-Holstein, based on expert interviews and statistical data. Thomas Coelen and his associates present initial findings of a research project concerning the connections between educational and urban development policies in Germany. Besides providing an extensive overview on the existing academic work and policy strategies within the topic of educational landscapes, they summarise the most important results of their empirical research. Based on expert interviews and policy document analysis they claim that schools and education are not only being seen as important tools to foster social integration, but they tend to become the only targets of urban development plans.

In his contribution, Herbert Altrichter applies the conceptual framework of governance in the analysis of school system reforms in German-speaking countries. He scrutinises in detail the transformation of the school system in Austria, and points to the emergence of a new hierarchy among schools in the last decades. David Giband analyses in Chapter 5 the changing approaches to educational planning in France from the 1980s up until nowadays. He focuses on the rescaling of responsibilities connected to the coordination and operation of the educational system. Giband points to the dependence of local educational institutions on the state and the regional level, which is changing in nature but still is important. He doubts that the processes outlined can be seen as neoliberalisation and decentralisation, despite they are considered to be so quite often.

Part II consists of chapters focusing on how certain national school systems affect, and are used to influence, either the improvement or oppression of particular social groups and parts of the urban network. Ferenc Gyuris studies in detail the interconnectedness of political/ideological transitions and the transformation of school provision and schooling in Hungary from the early 20th century until the last decades of state socialism. With a special focus on rural areas, he shows how the changing educational and regional development policies affected schools both in quantitative and qualitative terms. Silvie Rita Kučerová and her associates provide a complex analysis of the alteration of the education system in the territory of the current Czechia in the second half of the 20th century. After some theoretical considerations on the role of education in society, they analyse the changing spatial distribution of elementary schools using quantitative data and give an explanation on the major processes and mechanisms that drove the restructuring of the educational system.

Laura Schaefli, Anne Godlewska, and Christopher Lamb study in Chapter 8 the representation and imagination of indigenous people and colonialism in contemporary Canadian textbooks. They also look at the role of these texts in affecting students' perceptions about these questions based on a large-scale survey. In the last chapter of Part II, Ranu Basu considers schools as places of social interaction where various state policies can be observed in practice. In particular, she investigates how officially propagated formal geopolitical and welfare policies turn out to be violently oppressive and neoliberal. She applies postcolonial and feminist theoretical frameworks to critically analyse two case studies, one from Toronto, Canada, and another one from Guantánamo, Cuba.

Studies in Part III emphasise the importance of the local context in how small rural schools transform due to policy reforms implemented on other scales. Rune Kvalsund analyses in Chapter 10 the transformation of the school system in Norway with a focus on the changing interpretation of the school as an institution. He underpins his argument with several social theories through which he sheds light on a changing policy attitude what has led to the current state of affairs. As he observes, small rural schools are expected to become similar to large urban schools in the most important aspects. However, it is claimed that rural communities generally do not benefit from this way of transformation. Caroline Kramer applies a multiscale analytical framework in order to reveal the main mechanisms behind the formation of small rural schools in different settings. She puts her research in an international context first and then analyses the changing situation of rural schools from the early 1990s until 2015 in Baden-Württemberg, Germany and Vorarlberg, Austria.

In Chapter 12, Andrea Raggl focuses on small rural schools in Vorarlberg, similarly to Kramer, but her contribution is more concerned with the viewpoint of teachers and pupils regarding teaching and learning conditions. Her investigation is based upon 20 qualitative case studies. Samantha Hillyard and Carl Bagley analyse the role of the head teacher in local communities through two case studies from rural England. They build upon the theories of Lefebvre, Halfacree and Bourdieu in interpreting the empirical evidence of their ethnographic research.

Authors of Part IV approach geographies of schooling from the point of view of the changing role and embeddedness of schools in society and how these institutions constitute a social sub-system. As the chapters of this part put the actors of the school system (such as pupils, teachers, parents, and organisers of informal education) in the focal point of their investigation, the role of different social axes (for example age, class, gender) are highlighted. Chapter 14 focuses on the changing educational policies of contemporary England and the way they are affecting class and gender relations. Sarah L. Holloway and Helena Pimlott-Wilson claim that the 'roll-out neoliberal state' made clearly observable steps towards influencing parents' way of childcare activities (through for example: expanding before and after school childcare; guidance for parents for home learning; growing role in extracurricular activities). They argue that the state aims to control social reproduction by implementing these reforms. Christian Reutlinger examines pupils' spatial practices and imaginations of their school and its neighbourhood. His contribution is based on the analysis of imaginative maps and essays drawn and wrote by children from two different locations in St. Gallen, Switzerland.

Anne Sliwka and Britta Klopsch argue in Chapter 16 for expanding the spaces of learning beyond secondary schools through involvement of numerous actors from both inside (teachers, students) and outside of schools (for example parents, employees of public institutions, companies etc.) in order to make education more interesting and useful. Their work provides general theoretical considerations but also includes real-life illustrations from different parts of the ('First') world. They promote further development and a more widespread application of this model in secondary education. In the final chapter of the volume, Jürgen Schmude and Sascha Jackisch investigate the reasons for, and consequences of, quantitative (the number and share of women) and qualitative (the way society evaluates teaching) feminisation of the teaching profession from the 19th century up until nowadays in Baden-Württemberg, Germany. The authors scrutinise the processes in the wider society (such as class relations, legislative changes, labour market transformations) as the drivers of these changes.

As can be seen, the volume brings together studies from authors with different national and disciplinary background. In my view this diversity is an important source of the academic value of the book, as it fosters interdisciplinary and international academic communication. Some kind of cross-fertilisation is apparent throughout the volume as some of the theories and approaches were applied by more authors from different disciplines, and some chapters were written jointly by authors from different fields. However, further potentials still remained unexploited. On the one hand, even if we can find some attempts to make reference on studies outside of the authors' field, it is not a typical strategy. On the other hand, the ties of international collaboration could have been made stronger by initiating multiple international authorship.

In my impression, from an East Central European perspective, this open access volume has the potential to encourage new ways of dealing with the geographies of schools and schooling, even by adopting and applying theories primarily elaborated in western contexts. Since the fall of the Iron Curtain, the countries of the region have undergone remarkable social and economic restructuring and are currently exposed to processes of neoliberalisation. This way of transformation is also visible in the evolution of the schooling systems, which makes the policies noticeably consonant, and the processes comparable in western and post-socialist settings.

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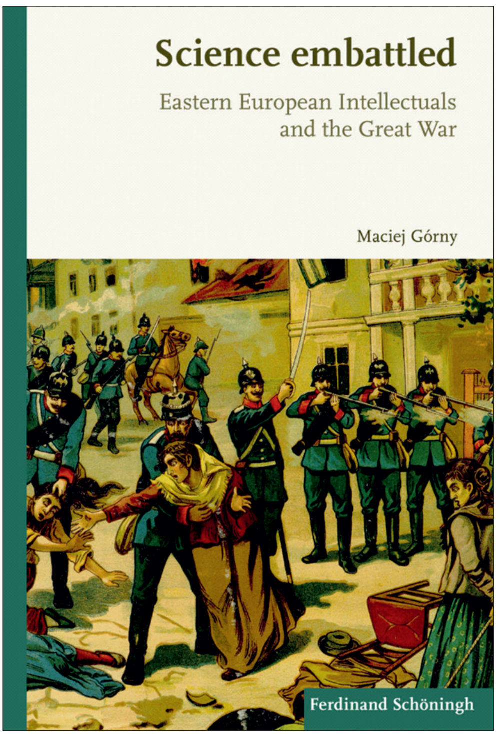
Górny, M.: Science Embattled: Eastern European Intellectuals and the Great War. Paderborn, Verlag Ferdinand Schöningh, 2019. 386 p.

Drawing to various degrees on Polish, Ukrainian, German, Austrian, Czech, Hungarian, Slovak, Serbian, French, British, Italian, Romanian, Russian, Finnish, Bulgarian, and American sources, Maciej Górny's masterful study provides a critical overview of the significant contributions that intellectuals from Central, Eastern, and Southeastern Europe made to the war effort in multiple countries during World War I. As a history of ideas, Górny's work focuses in particular on the '*Krieg der Geister*' – or 'war of the spirits' – that was waged in parallel with the military struggles on all fronts during the war. Noting that, until very recently, this war of ideas has been studied only in its Western European manifestations, Górny argues that the involvement of Eastern European intellectuals "paralleled that of their colleagues in the West," and that these intellectuals also "matched" Western scientists "both intellectually and with regard to social standing" (p. 4). Górny asserts that the similarities between the war of ideas on the Eastern and Western fronts "far outweigh the differences," and that though the differences that existed were not insignificant, a careful comparative study of the roles that Eastern European intellectuals played is both warranted and necessary (p. 4). Such a study, he contends, not only addresses a significant lacuna in the historiography of World War I, but also contributes to a growing body of scholarship that interrogates the complex history of cultural and intellectual transfer in the region in the first half of the 20th century.



Though the principal focus of his analysis is on geographers, anthropologists, and psychologists and psychiatrists, Górny dedicates the first two chapters to an examination of the broader context within which scientific ideas and practices developed both prior to and during the war. Chapter One examines the history of national characterology, in particular as this evolved as a transnational phenomenon over the course of the 19th century. As Górny points out, intellectuals throughout Europe were increasingly drawn into debates over national character in the decades leading up to World War I, and not always for explicitly political reasons. As a category of description, the idea of national character as a means of better understanding self and other was well established as a social and cultural discourse across Europe, and numerous scholars working in multiple disciplines shared a broad "desire" to know not only "other countries and societies," but also "one's own community" (p. 9). Perhaps not surprisingly, the most common category that was invoked as a means of understanding national character was race. Górny, however, also identifies gender as another common – even central – category, especially as this played out in terms of racial hygiene and perceptions of either sexual health or deviancy. Alongside race, attitudes towards gender and sexuality helped to shape emergent conceptualisations of national character, and thus provide an important lens for understanding the 'war of the spirits' as this erupted during World War I.

Despite the growing popularity and political utility of national characterology as a field of study (a utility that was recognised by nation states as early as the Franco-Prussian War of 1870–1871; see his thoughtful discussion in the Appendix), Górny argues that scholars themselves tended to remain above overtly nationalist 'perversions' of human sciences prior to World War I, and instead cleaved to prevailing notions of scientific neutrality and objectivity that served as the benchmarks of professionalism in any discipline seeking legitimacy as a science. Just as Steven Seegel (2018) argues in *Map Men: Transnational Lives and Deaths of Geographers in the Making of Modern East Central Europe*, Górny reminds us that scientists widely regarded themselves as part of an international fraternity defined in terms of shared disciplinary standards and a largely uniform, and often collaborative, commitment both to the pursuit of 'truth' and to the universality of knowledge and intellectual progress. This very real community of scholars – one that was arguably even more pronounced amongst Eastern European intellectuals because of their reliance on the West for mentorship and training (see p. 244) – was put under considerable and often irreconcilable strain during the war. As Górny illustrates in Chapter Two, a considerable number of intellectuals contributed quite willingly and unapologetically to state-backed propaganda efforts during World War I, in part because of the emergent market for short works aimed at a rapidly growing patriotic readership, but also because of earlier disciplinary commitments to questions of national character and identity. Noting that even non-nationalist intellectuals joined the war effort without requiring significant encouragement, Górny concludes that the often enthusiastic participation of scholars in the 'war of the spirits' was not a "marginal phenomenon," but rather a central feature of "intellectual warfare" (p. 52).

Though he acknowledges the obvious patriotism that motivated scholars and scientists across multiple disciplines, Górny nevertheless agrees with the current scholarly consensus that the 'war of the spirits' waged during World War I "took place independently" of the propaganda machines of warring states (p. 90). Though clearly influenced by state-sponsored nationalist discourse, intellectuals throughout Europe exercised what Górny calls "limited creative autonomy" when taking on the task of disseminating knowledge and information that was seen as essential to the war effort. As he contends, it would be misleading to equate the 'war of the spirits' exclusively with wartime propaganda. "Both operated according to their own dynamics," he argues, "and although they inspired each other, they remained autonomous" (pp. 51–52).

As in Western Europe, the 'war of the spirits' in Central and Eastern Europe and the Balkans contributed greatly to the professionalisation and elevated status of the human sciences during World War I, especially when the methods and conclusions of leading scholars and prevailing schools of thought aligned with the political and military goals of the state. However, despite the important commonalities with Western Europe, developments in the East demand a partially separate treatment, not only because the history of intellectual warfare in Eastern Europe has been generally neglected in the historiography until quite recently, but also because the differences that do exist force scholars to think in more nuanced terms about the 'intellectual combat' that was waged during the war.

First and most obviously, by including Central, Eastern, and Southeastern European developments into an intellectual history of World War I, historians are compelled to rethink the periodisation of the war itself. Having arguably begun with the First Balkan War in 1912, World War I lasted longer in the East than it did on the Western Front. With actual combat in parts of Eastern Europe and the Balkans only coming to an end in 1922–1923, the 'war of the spirits' not only spanned a broader period, but also largely "anticipated the post-war situation" within the region (p. 91). Moreover, the lines of intellectual warfare did not align as neatly with the military fronts in Eastern Europe as they did in the West. Beyond "criss-crossing the territories of major powers," intellectual combat in the East not only brought supposed allies into conflict with one another, but also required the support of established authorities in the West to help legitimate the scientific claims, and thus also the nationalist causes, of Eastern European and Balkan scholars (pp. 90–91).

One of the most important claims that Górny makes is that the war had a constructive and even formative impact on disciplines that were still relatively new at the beginning of the twentieth century (a fact that was as true for Western Europe as it was for Eastern Europe). Looking first to the nascent discipline of geography (Chapter Three), Górny underscores the multiple opportunities that opened up for geographers upon the outbreak of hostilities in Europe between 1912 and 1914. Given the usefulness of geography to nation building, geopolitics, and military strategy alike, geographers were able to present themselves as being indispensable to the fulfilment of a wide range of state interests. As Górny argues, the "ethnopsychological" characterisations of the nation and its neighbours that had become commonplace by the fin de siècle "found new life" during the war (p. 119). Oriented increasingly toward the nation, geography rose to prominence throughout Europe during World War I, and by "providing geographers with new responsibilities," not only "hastened" the professional careers of individual scholars (p. 123), but also sharpened discipline-specific skills and spawned innovations that greatly enlarged what Ferenc Gyuris (2014) usefully calls the methodological 'tool kit' that geographers would continue to draw upon throughout the interwar period.

As it did for geography, World War I served as a critical juncture for anthropology, in large part because anthropologists began thinking more exclusively of the nation in racial terms, but also because the war contributed to the growing visibility and perceived importance of anthropology as a discipline useful to the state. Despite lingering questions of professionalisation within the field and the lack of an obvious military application of the discipline, anthropology nevertheless coalesced as a science during the war, in part as a result of racially-linked 'scientific' studies conducted on sizable prisoner of war populations, but also because anthropologists could be mobilised both to promote the importance of racial hygiene, and to measure the effects of malnutrition on the people (especially in the Central Power Nations near the end of the war). Anthropological arguments proved useful, moreover, in the 'war of the spirits,' and this for two main reasons. First, and perhaps most obviously, race as a category could be mobilised to construct disparaging and often monstrous images of enemy nations, and could thus be employed to exclude these nations "symbolically … from the civilised European community" (p. 205). In this light, the discourse of 'Mongolisation' mobilised primarily on the Eastern and Balkan fronts (pp. 173–196), coupled with widespread fears of racial miscegenation and degeneration (pp. 196–205), proved particularly potent as intellectual weapons.

However, as Górny points out, racial argumentation also proved useful in a second way, in that it was often employed by combatant nations either to delineate wider communities of kinship and potential friendship beyond the nation state, or to legitimise and consolidate strategic ties with allied nations. The case of Turanism in Hungary, which overlapped significantly with geographical arguments, is provided by Górny as a good example of the former, while theories of Bulgarian ethnogenesis serve as a useful illustration of the latter. Bulgaria's entry into the war on the side of Germany and the Austro-Hungarian Monarchy sparked a renewed interest in racial theories that highlighted the supposed Germanic roots of Bulgaria's national origins. German scholars like Georg Buschan, for example, "took pains to remind his readers" that, though "the racial character of Bulgarians was significantly mixed … the incidence of tall blondes in Bulgaria suggested a remnant of Gothic blood" (p. 207). Gancho Tsenov, "the *enfant terrible* of Bulgarian historiography" took such thinking even further by promoting a racial theory that not only reduced Germanic and Bulgarian origins to Thracian roots, but also positioned the Bulgarians as "the most ancient of all European nations" (p. 208). As Górny concludes, the war itself, and in particular the intellectual battles that were waged alongside military engagements, provided a space for anthropologists "to partake in a discourse more venerable than their own." "Without the 'war of the spirits,'" he suggests provocatively, "there would have been no 'war of the races'" (p. 210).

Alongside arguments related to national space and the body, questions of mind and the relative mental capacities of combatant nations were also front and centre in the 'war of the spirits' that was contested by intellectuals in Central and Eastern Europe and the Balkans during World War I. Whereas geography "described the shape of the national organism" and anthropology looked "under the skin" to discover the biological determinants of racial health and national difference, the disciplines of psychology and psychiatry focused on "the problem of mentality," and gave voice to theories that articulated the purported "spiritual specificity of the national organism" (p. 244). As Górny suggests at the beginning of Chapter Five, psychologists and psychiatrists throughout Europe seemed at the outset of hostilities to be perhaps the least likely to engage in intellectual warfare along nationalist lines. Noting that prior to the war "there were almost no attempts in professional journals at fashioning hierarchies of psychological health by nationality," Górny argues convincingly that this changed significantly once fighting broke out, and that after 1914 notions of "mass hysteria and susceptibility" were mobilised by practitioners and theorists alike in order to develop and promote nationalist conceptualisation of ethno-pathology (p. 228).

However, these developments within the still new fields of psychology and psychiatry did not go uncontested from within the discipline. While critics of the politicisation of geography and anthropology remained rather marginal within their respective disciplines, prominent figures like Sigmund Freud were critical of the role that their colleagues were playing in the catastrophic struggle between the world's 'most civilised' nations. Though Freud himself did not remain above the fray entirely, Górny points to a critical essay published in 1915 in which he very accurately observed that science had forsaken its "dispassionate impartiality," largely because scientists themselves had weaponised their respective disciplines in order "to do their share in the battle against the enemy." As Freud lamented, "the anthropologist has to declare his opponent inferior and degenerate, [while] the psychiatrist must diagnose him as mentally deranged" (p. 238).

Though Freud restricted his critique to anthropologists and psychiatrists, his critical assessment of the complicity of professional scientists in the 'war of the spirits' can obviously be applied to geographers, especially in Central, Eastern, and Southeastern Europe, where the geopolitical stakes were arguably higher than in the West, especially after the war. Hungary provides Górny with a particularly acute example of this, and though he does not draw extensively on Hungarian sources, he does a good job of situating the work spearheaded by Pál Teleki both during and after the war within a broader international context, one that underscores the complicity of geographers in the nationalist projects that exploded throughout Europe during World War I. Hungarian specialists might find the author's treatment of the Hungarian case a bit thin, and will no doubt question the veracity of his occasional reference to a common Austro-Hungarian "project," or to the shared imperial "aims" of the Austro-Hungarian Monarchy during the war. However, to get hung up on what Górny might be missing with regards to the Hungarian case would be to miss the broader importance of his study more generally. Working in the same vein as scholars like Seegel, S. (2018), Trencsényi, B. *et al.* (2016, 2019), and others (see, for example, Lebow, K. *et al.* 2019), Górny insists that the point of a study like his is not necessarily to probe deeply into individual cases, but rather to seek out the broader trends and patterns that infused 'nationalist' science with a common set of ideas, methods, and applications. In this he is without a doubt successful, and beyond making an important contribution to a growing body of work on the intellectual history of Central, Eastern, and Southeastern Europe, his study opens up the possibility for new and exciting research on a wide array of topics.

Expertly translated into English by Antoni Górny, Maciej Górny's *Science Embattled* is a remarkable scholarly achievement, and serves as a testament to the importance of comparative and transnational approaches to the history of World War I in particular, and to studies of disciplines like anthropology, psychology, and geography more generally. This is not to suggest that examinations of individual countries or intellectuals are no longer warranted or useful. In fact, quite the opposite is true, especially in cases like Hungary which, because of the difficulties posed by language, are at risk of being left out of comparative analyses like this one. As noted above, Hungarian specialists need to continue to think in broader terms, and to produce work that situates the Hungarian case within regional, continental, and global contexts. Like other recent studies, Górny's work leaves no doubt that this is both a productive and necessary way forward. Given its ambitious scope and originality, I am certain his book will become essential reading in multiple fields, and that a number of disciplines – historical geography and the history of geography among them – will be all the richer for it.

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