LONG-TERM LAND USE CHANGES IN CZECHIA (1845-2010): REGIONAL DIFFERENTIATION AND DRIVING FORCES

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1. INTRODUCTION

Land use and its changes have attracted a considerable attention of the international scientific community during last decade (e.g., Aspinall and Hill, eds, 2008, Geist, ed., 2006, Koomen et al., eds., 2007, Lambin and Geist, eds., 2006). Apart from pragmatic reasons, such as relative abundance of detailed data (remote sensing, cadastral statistics etc.) and the access to powerful research tools (geographical information systems, statistical software etc.), there are strong objective reasons for this interest. Most importantly, because land use encompasses both natural and societal spheres, its research can significantly contribute to the environmental science and to the study of the interaction between nature and society, its causes and impacts (e.g., Meyer and Turner II, eds, 1994). Moreover, the above-mentioned data accessibility enables researchers to utilise land use research to study the nature-society interaction and its development across large areas with a detailed spatial resolution.

Regional differences and spatial pattern are an important aspect of land use/land cover changes (LUCC). Research of spatial differentiation has a long tradition in human geography. Martin Hampl's general **"hierarchy theory"** may serve as an example (e.g., Hampl 2000). According to Hampl, geographical differentiation is scale-dependent. For natural phenomena (e.g., climate), differentiation simply grows from local to global levels (a "J" shaped curve). However, for socio-economic phenomena (e.g., population density, economic performance), the curve is "U" shaped, i.e. the differentiation is the lowest on the intermediate level (ca country) and grows both to the global and local levels. According to Hampl (2000), differentiation of socio-economic phenomena tends to increase in the course of time - history is marked with the processes of selection and concentration. With that the geographical organisation shifts to higher geographic levels - e.g., from a pre-industrial village, to an industrial district and country, to current supranational entities (EU or the whole World). According to Hampl (2000), growing interconnection, competition and consequent selection are the main forces driving these trends. The "necessary" hierarchy is the principle that causes the differentiation, integrates the whole system and binds it together.

As far as land use is concerned, probably the first explanation of its spatial differentiation was offered by von Thünen's **"land rent theory"** in the early 19th century (e.g., Grigg 1995). Later, Karl Marx formed his theory of differential rent, that was further developed for modern land use research by Jeleček (2002). According to Jeleček, intensity and structure of use of a piece of land depends on two forms of **"differential rent"** (DR). DR I reflects natural fertility and geographical position, i.e. more fertile land with better accessibility would be used more intensively. DR II, on the other hand, reflects capital investments, i.e. inputs of labour, energy and materials. In the course of history, DR II strengthens the effects of DR I – more capital is directed into land that already is more fertile and better accessible and thus the differentiation of land use structure and intensity tends to grow.

An interesting explanation of changing land use pattern is offered by Krausmann et al. (2003), using the perspective of **“socio-economic metabolism”**. The authors argue that modernisation of agriculture had profound impacts on the spatial pattern of farming in developed countries. In the pre-industrial agriculture, “livestock keeping and cropland agriculture were intimately related,” and therefore “even in the fertile lowlands there had to be a mix of cropland, grassland and forest” and “in mountainous regions cropland was necessary” (ibid., p.11). Agricultural modernisation has, however, led to specialisation and to a “concentration process that break up previously integrated chains of production, consumption and decomposition of biomass in nearly perfectly closed, small regional loops and cycles” and thus to a “segregation of cropland agriculture, the fattening of oxen, pigs and poultry for meat production and milk-producing grassland agriculture in different regions” (ibid., p.18). In land use terms, this process results into a concentration of arable land into fertile lowlands, and of grasslands and forests into naturally less favoured highlands, mountains and other marginal areas. Traditional mixed agricultural landscape disappears and land use heterogeneity on a local level (municipality) is replaced with local homogeneity combined with heterogeneity on a higher geographical level, e.g., national (Krausmann et al. 2003).

The growth of land use differentiation on various spatial levels (regional, national, continental) was confirmed in numerous studies. For instance, Sporrong et al. (1996) describe increasing intensity of use of arable land in Swedish southern lowlands contrasting with land abandonment and afforestation in the mountainous north of the country. Falcucci et al. (2007) prove that “Italy’s mountainous and hilly areas (...) have changed towards more ‘pristine’ conditions and the coastal areas towards a more human dominated landscape” (ibid., p. 626). Correia (1993) came to similar conclusions for the European Mediterranean, MacDonald et al. (2000) for the mountain areas of Europe, Gabrovec and Kladnik (1997) for Slovenia and Otahel et al. (2002) for Slovakia. Analogous processes occurring on a local level are documented by Hamre et al. (2007) on a case of one Norwegian cadastre. The authors conclude that the observed changes “have practically divided the landscape in two; cultivated grasslands, orchards and horticulture areas in the centre of the area, and semi-natural and abandoned areas situated more peripherally” (ibid., p. 1573).

All these and many other works prove that two contradictory, but mutually interconnected, processes are occurring in the landscapes of developed countries: (1) **intensification** - increasing area of arable land and permanent cultures, plot consolidation and land amalgamation, destruction of semi-natural landscape elements, etc. - in better natural conditions and economically core areas; and (2) **extensification** - grassing-over, afforestation, land abandonment, etc. - in less favourable natural conditions and economically marginal zones. Both these trends have environmentally negative consequences (e.g., decreasing biodiversity), and lead to a creation of a simplified, mono-functional, homogenous landscape (Sporrong et al. 1996, Lipský 2001 and 2010). Growing crop yields in better natural conditions (“Forest transition theory”, Mather and Needle 1998), increasing transport interconnection and competition on a geographically larger scale can be seen as major forces driving these processes.

Some works have already proved the existence of this differentiation in Czechia. Romportl et al. (2010) confirm that since 1990 Czech landscape has been a “subject to homogenisation and unification” (ibid., p. 49) with a clear influence of natural conditions on territorial differentiation of main land cover processes. The authors show that afforestation and agricultural extensification occurred in mountains and highlands, agricultural intensification in lowlands and urbanisation in and around the main metropolitan areas.

Lipský (2010) comes to similar conclusions, and focuses on the development of "new wilderness" (abandoned agricultural land under succession) on marginal soils unsuitable for agriculture. Further extensification of land use in Czech mountains and highlands during last several decades was confirmed by Grešlová-Kušková (2013) or Lorencová et al. (2013). The latter authors' use of quantitative modelling and scenarios enables them to predict further spatial differentiation and separation of land cover classes - particularly of arable land and grasslands - in Czechia (Lorenzová et al. 2013, map 3, p. 189). Kabrda (2008 and 2010) analysed changes of the overall pattern of land use in Czechia since the mid-19th century, dividing individual Czech cadastral units into four types of "structure of agricultural land use" (SALU). He found that individual "SALU types tended to separate spatially to create larger and more compact zones, more corresponding to local socio-economic and especially natural conditions" (Kabrda 2008, p. 274). Mareš and Štych (2005), Štych (2011) and Kabrda (2004) used various quantitative methods to reveal the influence of selected natural (altitude, slope, soil fertility) and socio-economic (spatial exposedness, density of population) variables on the spatial pattern of land use changes in Czechia during last one and a half centuries. The results show an increasing concentration of more intensive land use types (arable land, permanent cultures, built-up areas) into more fertile and spatially more exposed regions, and a continuing concentration of less intensive land use types (permanent grasslands, forests) into naturally less favoured and spatially marginal zones. Similar conclusions are achieved by Bičík and Kabrda (2007) and Bičík et al. (2010), who studied the influence of the distance to country boundaries on the intensity and structure of land use changes.

In our article, we would like to bring a robust and exhaustive analysis of the long-term land use differentiation on the territory of Czechia. Our research focuses on the regional dimension of land use and its changes and thus aims at contributing to the already existing knowledge of the spatial pattern of the nature-society interaction and its development (e.g., Hampl 2000). Our main objective is to analyse the changes in the overall differentiation of land use structure in the territory of the Czech Republic (hence Czechia). We cover a period of 165 years, spanning over three centuries from the beginnings of the Industrial Revolution to the current era of integration of Czechia into European and global structures.

This article seeks answers to three broad questions: Firstly, has the overall differentiation of Czechia - in the sense of intraregional differences in land use structure - been increasing? We hypothesise that it has. Secondly, did this development correspond to structural, especially natural preconditions of individual regions? We presume it did. And thirdly, having the concept of "driving forces" of land use changes (Bičík et al. 2001, Jeleček 2002) in mind, what were the main causes of this development?

3. METHODS AND DATA SOURCES

As stated above, our article has three main objectives. Firstly, we aim to assess development of the overall differentiation of land use structure on the territory of Czechia since the mid-19th century - i.e., the changing variability of occurrence of individual land use categories across the country. Secondly, we want to reveal the influence of structural preconditions of individual regions on the changes in land use differentiation, using selected indicators of natural conditions as an example. And finally, we would like to explain the obtained results with the "driving forces" of land use changes (Jeleček 2002). Our approach is prevailingly quantitative. We utilise the extensive "Database of long-term land use changes in Czechia (1845-2010)" and apply selected statistical methods on it.

3.1 DATABASE OF LONG-TERM LAND USE CHANGES IN CZECHIA

The "Database of long-term land use changes in Czechia (1845-2010)", hence LUCC Czechia Database, is a result of a continuous work of a team of geographers (including the authors of this article) from the Faculty of Science, Charles University in Prague. It is based on statistical data from the Cadastre of Real Estates (Land Registry) that has been established as the "Stable cadastre" in the Habsburg monarchy in the first half of the 19th century and since then updated by Cadastral Offices of the respective successor countries (Czechoslovakia and Czechia). Many has already been written on the database (e.g., Bičík et al. 2001, Bičík and Jeleček 2009), therefore, we only provide a short summary.

The Cadastre of Real Estates divides the territory of Czechia into ca 13.000 cadastral units. Because the borders (and thus areas) of some cadastral units have changed since the mid-19th century, others have been split or merged together, the so-called **"Basic Territorial Units"** (hence BTUs) were build from the cadastral units for the purposes of the LUCC Czechia Database. Each BTU consists of one or more cadastral units so that the area of any BTU has not changed by more than 1% since the mid-19th century. There are currently 8.832 BTUs in Czechia with an average area of 893 hectares.

The LUCC Czechia Database contains land use information for **six time horizons** that largely correspond to important milestones of Czech modern history (see Jeleček 2002): 1845 (on the brink of the Industrial Revolution), 1896 (end of extensive agricultural development), 1948 (communist coup d'état), 1990 (the Velvet Revolution), 2000 (after ten years of political and economic transformation) and 2010 (with Czechia being integrated into Western supra-national structures).

For each of the 8.832 BTUs in each of the six time horizons, the LUCC Czechia Database comprises data on areas (in hectares) of seven basic **land use categories:** arable land, permanent cultures, permanent grasslands; forested areas; water areas, built-up areas and "remaining areas". These seven basic categories can be merged into three aggregate ones - agricultural land, forested areas and "other areas" (see tab.1). The only exception is the year 1896 for which there is no information on the internal break-up of the "other areas".

Tab.1 Land use classification in the LUCC Czechia Database

Aggregate category	Basic category	Notes, explanation
Agricultural land	Arable land	
	Permanent cultures	Vineyards, hop-gardens, orchards and gardens
	Permanent grasslands	Meadows and pastures
Forested areas	Forested areas	
Other areas	Water areas	
	Built-up areas	
	Remaining areas	E.g., transport and manipulation areas, quarries and dumping ground, public greenery and playgrounds, unused and idle land, bare land and rocks, etc.

Source: LUCC Czechia Database

For the purposes of this article, we chose to analyse only four of the seven basic land use categories: **arable land, permanent grasslands, forested areas and built-up areas**. Three reasons underpin this simplification:

(1) The article would become unbearably long otherwise.

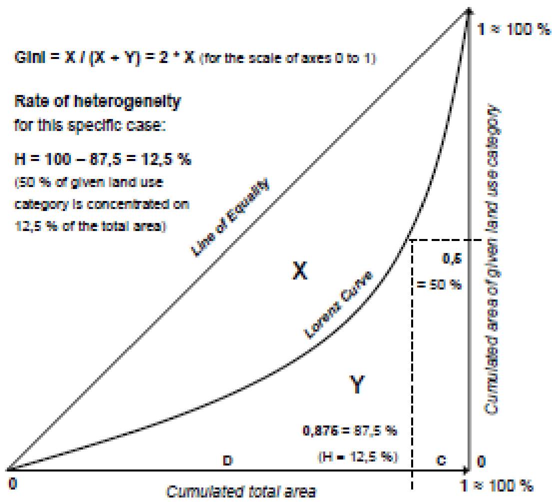
(2) These four categories are fully representative, covering the whole spectrum of land use intensity from metropolitan zones (built-up areas) thru zones of intensive (arable land) and extensive (grasslands) farming to semi-natural sylviculture zones. Moreover, arable land, grasslands and forests are the most widespread land uses in Czechia (see tab.2) and constitute the landscape “matrix” in most cadastral units (see Lipský 2001).

(3) The other three categories are either insignificant in their area (water areas, see tab.2) or internally too heterogeneous. Permanent cultures consist of gardens that nowadays have prevailingly leisure and hobby use and are clustered in and around towns and cities; and of agriculturally productive vineyards, orchards and hop-gardens that can usually be found in favourable natural conditions in the countryside. “Remaining areas” are the most diverse category (see tab.1), consisting both of areas concentrated in and around metropolitan zones (transport network, public spaces etc.) on the one hand, and of areas in the most inhospitable conditions (unused land, bare rocks etc.) on the other.

3.2 APPLIED METHODS: GINI COEFFICIENT AND RATE OF HETEROGENEITY

In the first step, we measured overall differentiation of occurrence of the four selected land use categories across Czechia, and its changes between the six time horizons. We applied two simple methods, Gini coefficient and Rate of heterogeneity, both based on the **Lorenz curve**. A Lorenz curve for a given land use category in a given year was constructed from cumulated areas of the given category in BTUs on one axis, and cumulated total areas of BTUs on the other axis, with the BTUs sorted by the share of the given category on their total area. Shares of land use categories and total areas of BTUs on Czech total (100 %) can be used instead of areas in hectares (see fig.1). In geography, Lorenz curve is used to measure regional differentiation (concentration, inequality of distribution) that increases with the distance of the Lorenz curve from the line of equality (Novotný and Nosek 2009).

Fig.1 Lorenz curve, Gini coefficient (Gini), Rate of heterogeneity (H)



Source: own scheme; see text for explanation

Gini coefficient (hence **Gini**) is a measure of statistical variability, calculated as the ratio of the area lying between the Lorenz curve and the line of equality over the area of the whole triangle lying under the line of equality (see fig.1; Novotný and Nosek 2009). Gini thus ranges from 0 to 1 with higher values indicating higher differentiation (inequality). We approximated Gini from trapezoids and rounded the values to three decimal places, which, thanks to the relatively high number of cases (N = 8.832) is accurate enough for our purposes.

Rate of heterogeneity (hence **H**) is a similar, yet simpler method, devised by Martin Hampl in times when calculating Gini was too laborious (see Hampl 2000 for an overview). H quantifies value at the 50th percentile of the Lorenz curve (Novotný and Nosek 2009). In other words, it expresses the share (%) of the total area covered by BTUs that contain the more concentrated half of the area of the given land use category (see fig.1). H theoretically ranges from 0 % (total inequality) to 50 % (total equality of distribution, no differentiation). H divides BTUs into two sets, each containing a half of the total area of the given land use category - the **"concentrated half"** (hence **C**) with fewer BTUs having a higher share of the given land use category on their area, and the "dispersed half" (hence D) with more BTUs having a lower share of the given land use category on their area (see fig.1). H is estimated from the Lorenz curve (see fig.1) or directly, as in our case, read from a data table.

Gini and H return similar results - with a growing differentiation (concentration, variability), Gini increases from 0 to 1 and H decreases from 50 % to 0 %. H is less precise because it is only estimated from one point on the Lorenz curve, whereas Gini takes into account the whole shape of the curve. On the other hand, H is less abstract and, more importantly, the two resulting sets of BTUs - C and D - can be visualised in a map, which helps us to understand where precisely (e.g., into what natural and socio-economic conditions) do the individual land use categories concentrate and why.

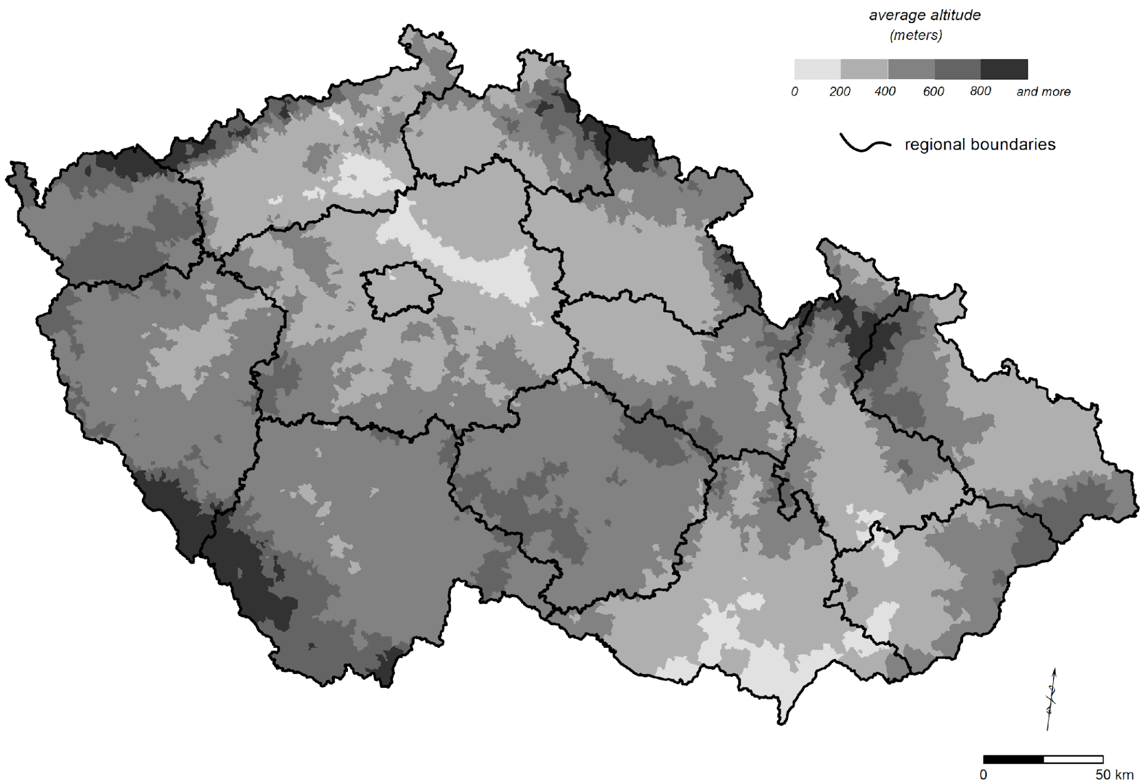
We calculated Gini and H for the four selected land use categories in the six time horizons. Consequently, we visualised the "concentrated halves" of BTUs (Cs) in four maps, each map for one land use category. Three sets of BTUs are displayed in each map. The first set contains those BTUs that lay in C both at the beginning and at the end of the studied period (1845 and 2010) - these BTUs can be seen as stable "cores" of concentration of the given land use category. The second set comprises those BTUs that have "left" C (i.e. BTUs that were in C in 1845 but not in 2010) and the third set contains those BTUs that have "entered" C (i.e. BTUs that were in C in 2010 but not in 1845). There should be more BTUs in the second set than in the third one because the number of BTUs in C should be decreasing with the hypothesised increasing land use differentiation. These two later sets reveal the exact spatial aspects of the changing land use distribution - they show us into which localities have the individual categories tended to concentrate and from where have they tended to disappear. Our aim then is to interpret the spatial pattern of the occurrence of those various sets of BTUs.

3.3 SELECTED CHARACTERISTICS OF NATURAL CONDITIONS: ALTITUDE AND SLOPE

In order to assess more accurately the spatial pattern of changing land use differentiation and impacts of structural preconditions of individual regions on it, we included two indicators of natural conditions into our analysis - average altitude and average slope (inclination) of BTUs. These two variables serve as examples of a wide range of quantifiable "proximate factors” (Mather 2002, Lambin and Geist 2007) influencing land use pattern. Both have a strong impact on anthropogenic, particularly agricultural use of Czech landscape (e.g., Mareš and Štych 2005, Štych 2011 or Kabrda 2004). Altitude is a main cause of differentiation in climate and soil types, and thus in soil fertility and crop yields, whereas slope has an impact on accessibility and general usability of individual plots.

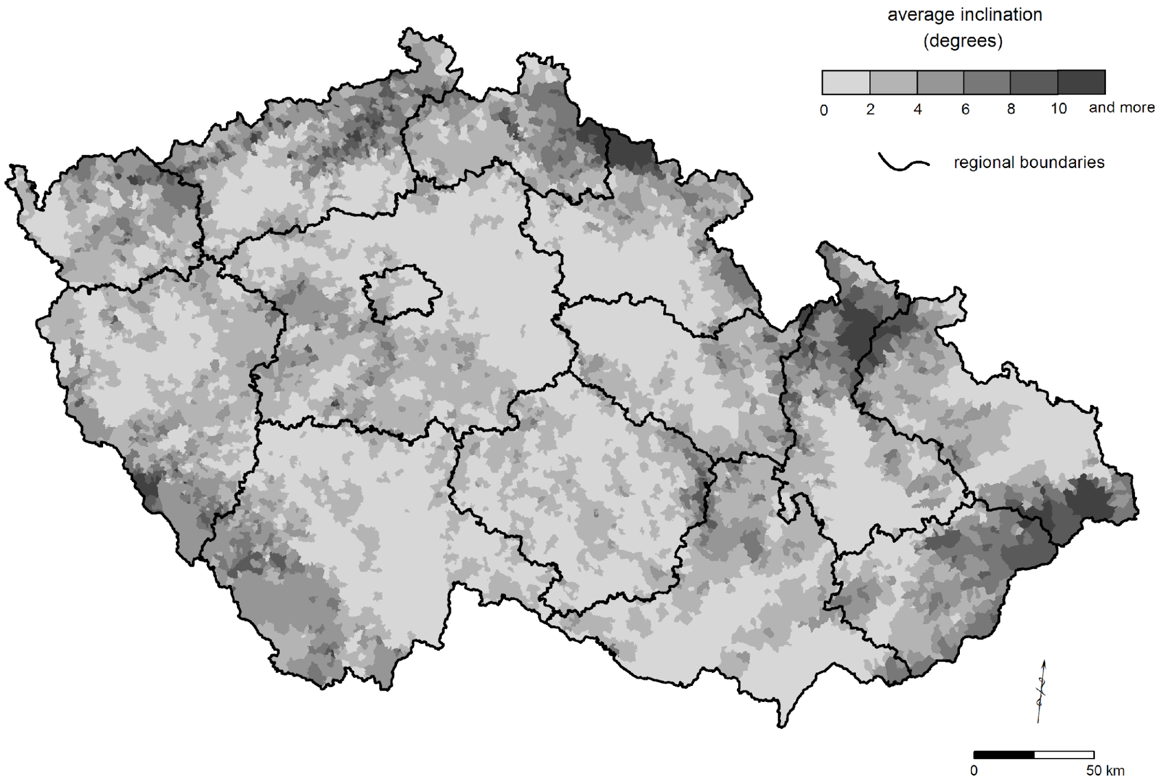
Average altitudes and slopes of BTUs were calculated from a digital terrain model (DTM) of Czechia using interpolation (Spline) in ArcGIS (see Štych 2011, p. 71 for details). DTM was derived from contour lines (50 metres interval) from ArcČR 500 dataset. The territory of Czechia was divided into squares of 50 × 50 metres in order to calculate average altitude (metres above the sea level, m.a.s.l.), and into squares of 250 × 250 metres to calculate average slope using Slope function in ArcGIS (degrees, °), respectively. Average altitude and slope of a BTU were then calculated as an arithmetic mean of all pixels located within it, using Zonal Statistics in ArcGIS (Štych 2011). The results can be seen in fig.2 and fig.3. Average altitude for the whole Czechia is 442,6 m.a.s.l. and average slope is 2,9°.

Fig.2 Average altitude in the BTUs of Czechia (m.a.s.l.)



Source: ArcČR 500, own calculation

Fig.3 Average slope in the BTU of Czechia (°)



Source: ArcČR 500, own calculation

Two principal lowlands can be found in Czechia (fig.2), one in the northwest of the country (northern Bohemia) and the other in the southeast (southern Moravia). These two lowlands are separated by Bohemian-Moravian Highland, also known as the “Inner Periphery”. The whole country is then almost completely encircled by a ring of mountains and highlands. Slope (fig.3) is relatively closely associated with altitude, with some exceptions, e.g., in southern Bohemia and Bohemian-Moravian Highland, which are quite high but rather flat; or in the generally more rugged Carpathian east of the country. Pearson’s correlation between altitude and slope on the level of BTUs reaches R = 0,44 (Štych 2011, p. 73), also suggesting that locally the relation between these two variables is not entirely straightforward.

For our purposes, we calculated average altitudes and slopes of the sets of “concentrated halves” (Cs) of BTUs for each land use category in each time horizon. A gradually decreasing altitude and slope of C for arable land and built-up areas and an increasing altitude and slope of C for grasslands and forests would prove the hypothesised growing concentration of these categories in the respective local conditions and thus an increasing influence of natural factors on land use differentiation.

4. RESULTS

Before we get to the analysis of changing land use differentiation, we have to look briefly at the overall land use development in Czechia in the period 1845-2010 (see tab.2). For more information see e.g., Bičík et al. (2001), Bičík and Jeleček (2009) or Jeleček (2002).

4.1 OVERVIEW OF LAND USE CHANGES IN CZECHIA

Arable land, grasslands and forests are the most widespread land use categories in Czechia (tab.2). The extent of **arable land** reached its long-term peak in the late 19th century, marking the final phases of extensive expansion of agriculture (Jeleček 2002). Then the share of arable land started to decrease continuously, as a result of agricultural modernisation that led to a fast growth of intensity (yields) and thus a lesser need for land, and imports of foodstuff and feed (Grešlová-Kušková 2013). This trend was sped up by the expulsion of Czech Germans (more than a quarter of total population of Czechia, Bičík et al. 2001) from Czech borderland after the WW2, which caused a large-scale landscape abandonment. The decline in the area of arable land continued after the Velvet Revolution due to a transformational slump in agricultural production and new environment-friendly agricultural policies, including supports for grassing-over on arable land and maintenance of grasslands, especially in Less Favoured Areas (LFAs). As a result, arable land disappeared from more than 13 % of Czech territory between 1896 and 2010 (tab.2) and this trend is likely to continue (Bičík and Jeleček 2009).

Tab.2 Land use changes in Czechia 1845–2010 (%)

	1845	1896	1948	1990	2000	2010
Arable land	48,2	51,6	49,9	41,0	39,1	38,3
Permanent cultures	1,1	1,5	1,9	3,0	3,0	3,0
Permanent grasslands	17,4	14,1	13,0	10,5	12,2	12,5
AGRICULTURAL LAND	66,8	67,2	64,7	54,5	54,3	53,7
FORESTED AREAS	28,9	29,0	30,2	33,3	33,4	33,7
Water areas	1,4	n/a	1,1	2,0	2,0	2,1
Built-up areas	0,6	n/a	1,1	1,6	1,7	1,7
Remaining areas	2,3	n/a	2,9	8,6	8,6	8,9
OTHER AREAS	4,3	3,9	5,1	12,2	12,3	12,6
TOTAL	100,0	100,0	100,0	100,0	100,0	100,0

Source: LUCC Czechia Database

Similarly, **permanent grasslands** had suffered a long-term decrease of their area, caused by changes in agricultural practices, including a conversion of animal husbandry that can be simplified as a move from hay to silage and from pastures to stables (Krausmann et al. 2003). However, there occurred a crucial reversal of this trend in the 1990s (tab.2, Jeleček 2002): the area of grasslands is now increasing thanks to the above-mentioned decline of crop farming and new state and EU policies. The long-term decrease of the area of agricultural, mostly arable land, has also led to the “forest transition” (Mather and Needle 1998), i.e., to a stable increase of **forested areas** that nowadays cover more than a third of Czech territory (tab.2). These trends can be seen as prevailingly environmentally positive, for they should, at least in theory, reduce the risk of soil erosion or floods and support carbon sequestration and ecosystem services in general (Lorencová et al. 2013).

However, a larger part of the ex-agricultural land has been turned into land use categories associated with urban areas and intensive human activities in general - permanent cultures (especially gardens), **built-up areas** and, most importantly, **“remaining areas**”. The massive spread of “remaining areas”, that nowadays cover more than 12 % of Czechia (tab.2), is particularly alarming. On the one hand, they contain various impervious, sealed and generally highly artificial surfaces that add up to the negative environmental effects of the growth of built-up areas. On the other hand, “remaining areas” include a range of forms of unused and underused land (tab.1) that symbolises an increasing neglect of landscape and a lack of interest in its use. The highest growth of “remaining areas” occurred during the era of communism, but continued after it as well (tab.2) in the form of residential and commercial suburbanisation, new infrastructure development etc. (Bičík and Jeleček 2009). Currently, losses of agricultural land, especially of the most fertile soils, constitute a major Czech environmental problem (Spilková and Šefrna 2010).

4.2 ARABLE LAND

Let us turn our attention now to changes in regional pattern of land use. Tab.3 confirms the gradually increasing differentiation of distribution of arable land across Czechia. In 1845, a half of Czech arable land was concentrated in 35 % of the total country area, whereas in 2010 it was only in 29 % (tab.3). Differentiation of the share of arable land in Czechia has been particularly growing in the two periods of the most radical economic and political changes (1948-1990 and 1990-2000).

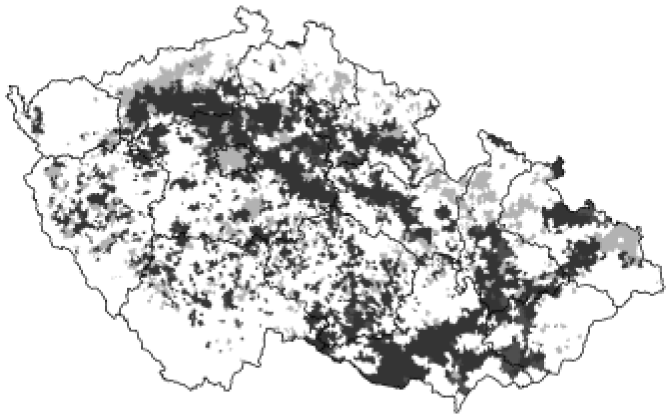
Tab.3 Changing distribution of arable land: Gini, H, average altitude and slope for the concentrated half of BTUs (C)

	1845	1896	1948	1990	2000	2010
Gini	0,234	0,232	0,242	0,317	0,350	0,356
H (%)	35,02	35,08	34,48	30,30	28,77	28,51
Altitude (m.a.s.l.) of C	383	373	372	369	363	362
Slope (°) of C	2,21	2,12	2,08	1,73	1,68	1,67

Note: Average values for all BTUs in Czechia: altitude 442,6 m.a.s.l., slope 2,9°
Source: own calculation, LUCC Czechia database

Arable land generally lies in above-average conditions - in lower and flatter areas (tab.3). The influence of natural conditions on the distribution of arable land has been growing - arable land has continued to concentrate into lower altitudes and, more significantly, into less steep areas (tab.3). The total area of Czech arable land has been decreasing (tab.2), and the influence of slope on the spatial pattern of this process was crucial - arable land has tended to disappear dominantly from more rugged, broken terrain. In 1845, average slope of the “concentrated half” of the total area of arable land was 2,2°, whereas in 2010 it was 1,7° (tab.3). This process was strongest in the socialist period (1948-1990), probably as a result of large-scale mechanisation of agriculture that rendered the use of steeper lands as arable fields technically impossible (Kabrda 2004).

Fig.4 Changing distribution of arable land: BTUs that lay in the concentrated half (C) both in 1845 and 2010 (dark grey), BTUs that entered C between 1845 and 2010 (medium grey) and BTUs that left C between 1845 and 2010 (light grey)



Source: own calculation, LUCC Czechia database

Fig.4 confirms that arable land is primarily concentrated in lowlands. This pattern has been strengthened since 1845. Most of the few BTUs that “entered” C can be found within or on the edges of the two main lowlands (eastern Bohemia, central Moravia) and they are almost invariably adjacent to the “stable” BTUs. Therefore the two “core” regions of arable land in Czechia are now spatially more compact (fig.4). On the other hand, the number of BTUs that “left” C is larger. These BTUs lie prevailingly in average natural conditions in highlands and at the foothills of mountains, especially in the northern part of the country (fig.4), where the once-abundant arable land has tended to be grassed-over, afforested or abandoned. In metropolitan zones (e.g., around the cities of Prague and Ostrava) arable land was developed, and, similarly, also the regions with large-scale surface coal-mining (e.g., NW Bohemia) suffered from a massive destruction of agricultural landscape in the era of communism (1948-1990).

4.3 PERMANENT GRASSLANDS

The differentiation of distribution of grasslands is distinctly higher than this of arable land (compare tab.3 and tab.4). Permanent grasslands have also undergone a stronger spatial concentration. The share of Czech territory comprising a half of the country’s grasslands has shrunk from 31 % in 1845 to 22 % in 2010 (tab.4). The differentiation of the share of grasslands was rising steadily between 1845 and 2010, with the peak in the socialist period again.

Tab.4 Changing distribution of grasslands: Gini, H, average altitude and slope for the concentrated half of BTUs (C)

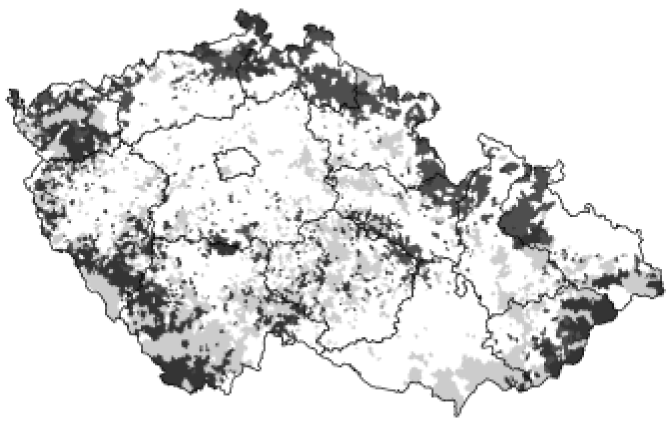
	1845	1896	1948	1990	2000	2010
Gini	0,282	0,326	0,340	0,408	0,441	0,441
H (%)	31,20	28,78	28,11	24,30	22,26	22,22
Altitude (m.a.s.l.) of C	504	529	530	522	534	532
Slope (°) of C	3,18	3,43	3,48	4,24	4,49	4,49

Note: Average values for all BTUs in Czechia: altitude 442,6 m.a.s.l., slope 2,9°
Source: own calculation, LUCC Czechia database

Grasslands predominantly occupy below-average natural conditions with higher altitudes and steeper slopes (tab.4). Again, this feature has been gradually strengthened since the 1840s, particularly in regard to slope. The total area of permanent grasslands in Czechia has decreased (tab.2) and the spatial pattern of this was strongly driven by slope - in 1845, BTUs comprising the “concentrated half” of Czech grasslands had average slope of 3,2°, whereas in 2010 it was 4,5° (tab.4). The era of socialism (1948-1990) is interesting. The influence of altitude (and thus of climate and soil fertility) on the distribution of grasslands decreased slightly (tab.4), suggesting a lack of interest in the effectiveness of farming and general irrationality of (spatial) decision-making in the centrally-planned economy. On the other hand, the influence of slope rose rapidly (tab.4), likely due to the above-mentioned mechanisation of agriculture.

Fig.5 confirms the concentration of permanent grasslands into worse natural conditions, i.e. into the border mountain ranges and parts of the central Bohemian-Moravian Highland. The map also shows a massive regional redistribution of grasslands between 1845 and 2010, much stronger than this of arable land (compare fig.4 and fig.5).

Fig.5 Changing distribution of permanent grasslands: BTUs that lay in the concentrated half (C) both in 1845 and 2010 (dark grey), BTUs that entered C between 1845 and 2010 (medium grey) and BTUs that left C between 1845 and 2010 (light grey)



Source: own calculation, LUCC Czechia database

Distribution of the vast number of BTUs that “left” C suggest a strong shrinkage or virtual disappearance of grasslands from lowlands (southern Moravia, central Bohemia) and lower highlands (parts of Bohemian-Moravian Highland, eastern and southern Bohemia). On the other hand, the BTUs that “entered” C between 1845 and 2010 are less numerous and can be found mostly in mountains and higher highlands, particularly in the northern part of the country (fig.5). As a result, the area covered by BTUs comprising the “concentrated half” of Czech grasslands is now spatially more compact and more confined to worse natural conditions. This can probably be attributed to radical changes in farming practices in the course of industrialisation of agriculture, i.e. to a spatial separation of crop farming and animal husbandry (Krausmann et al. 2003). Pastures and meadows are now not needed on intensive farms in better and average natural conditions, and, similarly, arable land is no longer profitable in less favoured areas.

4.4 FORESTED AREAS

The differentiation of distribution of forested areas is rather high (compare tab.5 with tab.3 and tab.4) but, surprisingly and in contrary to our expectations, it has been decreasing (tab.5). This process, that could be with certain simplification described as “homogenisation” or even “diffusion” (because of the growth of the total area of forests in Czechia, tab.2), was however, rather small and thus should be interpreted cautiously. In 1845, a half of Czech forests was concentrated in 24 % of the country’s area, whereas in 2010 it was in 26 % (tab.5). Moreover, the overall decrease in the differentiation was mostly confined to the period 1896-1990 and before and after that it more or less stagnated (tab.5).

In general, changes in both Gini and H between 1845 and 2010 were smaller for forests than for arable land and grasslands (compare tab.5 with tab.3 and tab.4). It suggests that forests are more stable not only in their total extent (tab.2) but also in their regional distribution. This is understandable because the transitions within the agricultural land (between arable land and grasslands) are technically simple, easily reversible and can be seen as a matter of year-to-year decisions. To the contrary, a transition between agricultural land and forest is technically complex, hard to reverse, with long-term consequences and requiring more robust decision-making and reasons.

Tab.5 Changing distribution of forests: Gini, H, average altitude and slope for the concentrated half of BTUs (C)

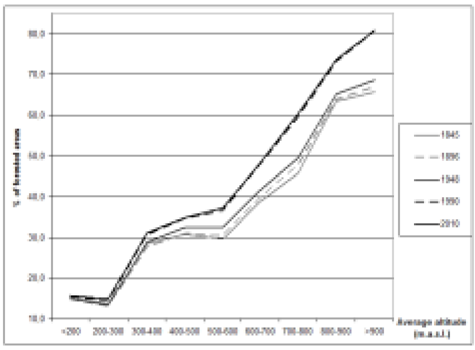
	1845	1896	1948	1990	2000	2010
Gini	0,416	0,422	0,406	0,388	0,388	0,384
H (%)	23,78	23,62	24,52	25,58	25,57	25,72
Altitude (m.a.s.l.) of C	513	520	522	542	544	544
Slope (°) of C	4,73	4,82	4,89	5,22	5,22	5,22

Note: Average values for all BTUs in Czechia: altitude 442,6 m.a.s.l., slope 2,9°
Source: own calculation, LUCC Czechia database

Forested areas prevailingly lie in less favoured natural conditions with higher altitudes and, more importantly, steeper slopes (tab.5). Interestingly, despite the decrease in the differentiation of their distribution, the influence of natural conditions has been further growing as predicted. In other words, the afforestation (tab.2) was prevailing in higher and especially steeper regions - in 1845, the average slope of all BTUs with the “concentrated half” of Czech forests was 4,7° whereas in 2010 it was 5,2° (almost twice the country’s average, tab.5). Again, this trend was strongest during the socialist period (1948-90), probably as a result of the mentioned mechanisation of agriculture, and also of the post-war expulsion of Czech Germans from the border mountain ranges, that left many of those areas unused and open to afforestation or spontaneous succession (Bičík et al. 2001).

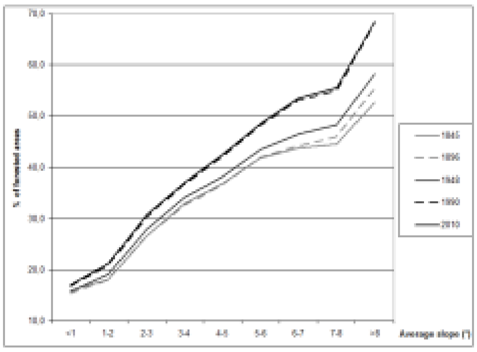
The decreasing differentiation of distribution of forests coupled paradoxically with their continuing concentration in below-average natural conditions requires further examination. Therefore, we calculated average share (%) of forested areas in groups of BTUs defined by their average altitude (fig.6) and average slope (fig.7).

Fig.6 Changing share of forested areas (%) according to average altitude of BTUs



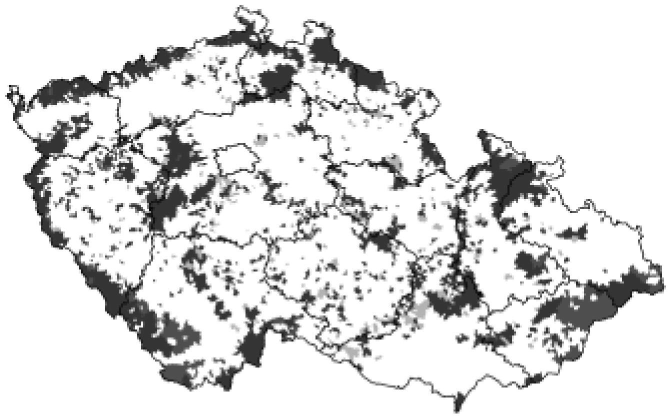
Source: own calculation, LUCC Czechia database

Fig.7 Changing share of forested areas (%) according to average slope of BTUs



Source: own calculation, LUCC Czechia database

Fig.8 Changing distribution of forested areas: BTUs that lay in the concentrated half (C) both in 1845 and 2010 (dark grey), BTUs that entered C between 1845 and 2010 (medium grey) and BTUs that left C between 1845 and 2010 (light grey)



Source: own calculation, LUCC Czechia database

4.5 BUILT-UP AREAS

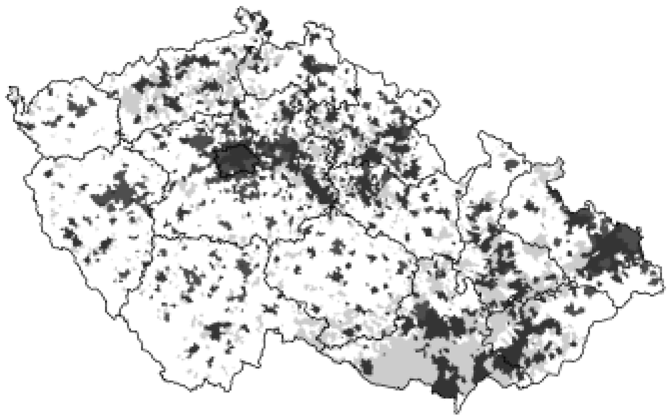
Tab.6 Changing distribution of built-up areas: Gini, H, average altitude and slope for the concentrated half of BTUs (C)

	1845	1896	1948	1990	2000	2010
Gini	0,280	n/a	0,356	0,426	0,432	0,433
H (%)	31,00	n/a	25,67	21,33	20,86	20,80
Altitude (m.a.s.l.) of C	351	n/a	324	326	328	329
Slope (°) of C	2,38	n/a	2,08	2,18	2,19	2,20

Note: Average values for all BTUs in Czechia: altitude 442,6 m.a.s.l., slope 2,9°
Source: own calculation, LUCC Czechia database

Tab.6 confirms the gradually increasing differentiation of distribution of built-up areas across Czechia. In 1845, a half of Czech built-up areas were concentrated in 31 % of the total country area, whereas in 2010 it was only in 21 % (tab.3). Differentiation of the share of arable land in Czechia has been particularly growing in the two periods of the most radical economic and political changes (1948-1990 and 1990-2000).

Fig.9 Changing distribution of built-up areas: BTUs that lay in the concentrated half (C) both in 1845 and 2010 (dark grey), BTUs that entered C between 1845 and 2010 (medium grey) and BTUs that left C between 1845 and 2010 (light grey)



Source: own calculation, LUCC Czechia database

5. DISCUSSION AND CONCLUSIONS

- Discussion and interpretation of the results of land use changes/differentiation
- Discussion of driving forces with focussing on societal driving forces
- Comparison of the results with similar studies from other countries in Europe or out of Europe
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