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Economic impacts of farmland degradation in the Czech Republic – Case study

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Abstract: To analyse the potential changes in soil characteristics and associated impacts on the land price, the region of South Moravia was selected, strongly threatened by erosion and by claiming the most valuable land in suburban territories due to industrial and housing expansion. For the detailed analysis of the impacts of erosion and land appropriation in the region of South Moravia, the model territories of Brno surroundings with the municipality of Dolní Heršpice and Hustopeče surroundings with the municipality of Starovice were selected. The price of land degraded by potential erosion in the South Moravian region fluctuates between 88 and 2 400 EUR/ha. In the past 180 years, 148 ha of agricultural land in the total value of 822 815 EUR have been used for construction in the location under study in Dolní Heršpice. Further growth of the municipality should involve additional appropriation of agricultural land in the value of 411 000 EUR. In the studied land block of 100.5 ha, located in the Starovice municipality area, water erosion caused degradation in the total value of 92 000 EUR in the period 1978–2013. Extensive losses of fertile agricultural land are to be expected in the future. Their main causes are continuing land appropriation and degradation processes – soil erosion.

Keywords: appropriation of agricultural land; estimated Soil-Ecological Unit; land price; land use; soil erosion

The most extensive global evaluation of agricultural land (land assessment) in the Czech Republic was performed in the 1970s and 1980s. Classification of land was created based on the Evaluated Soil-Ecological Unit (BPEJ) system. This system allows for classification of agricultural soils and their economic valuation based on their differing productive capacity (Nemec et al. 2006; Voltr 2012; Voltr et. al. 2018).

At the beginning of the 1990s, the Research Institute of Agricultural Economics (Výzkumný ústav zemědělské ekonomiky) defined the 'Official Prices of Agricultural Land'. These official land prices relied on the results of the agricultural land fund assessment. Since 2001, these prices have been regularly updated by the Ministry of Finance of the Czech Republic.

The official land price does not take into account the actual economic and marketing estimation of a particular agricultural land plot, which is related not only to its soil-ecological value, but mainly to its value for the owner/user defined by additional technical, territorial, and utility properties of the land plot (soil). These value-related land plot properties cannot be expressed in a general manner. Therefore, for the purposes of this study, we selected the method of land assessment according to the official BPEJ prices (Nemec et al. 2006; Voltr 2012; Voltr et al. 2018).

Since the 1990s, the BPEJ have also been gradually updated, with the aim of assessing changes in the soil and ecological conditions of land plots since the 1970–80s. Use of the temporal data on BPEJ

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price trends, along with the comparison of BPEJ before and after the update, allows for an analysis of development of BPEJ price relationships and development of the price of land (related to changes in the soil properties due to the degradation processes).

Intensive large-area agricultural production starting from the second half of the 20th century in many cases led to the devastation of agricultural land (Thomas 2006; Hartvigsen 2014). In the Czech Republic (CR), water erosion potentially threatens almost 50% of agricultural land (Dostal et al. 2006).

However, erosion and inappropriate management are not the only causes of soil degradation. Development of urban areas with associated infrastructures leads to extensive soil appropriation (Szturc et al. 2017). Between 1990 and 2000 alone, more than 800 000 ha were built on in Europe (European Environment Agency 2006). From 2000 to 2006, Europe lost 1 120 km^2 of natural and semi-natural areas per year (of which, on average, almost 50% was arable or cultivated land) to urban or other artificial land development (European Environment Agency 2016). There is a high probability that large areas (totalling approximately 77 500 km^2) of the European continent will be or have been converted to urban areas between 2000 and 2030 (Seto et al. 2012). In the Czech Republic, the conversion of farmland to urban uses (soil sealing) represents a very serious problem (Janku et al. 2016a). On arable land, in particular, there is a trend of soil loss (approximately 9 100 ha/year, which means approximately 25 ha/day). Since 1927, the Czech Republic has lost over 851 thousand ha, i.e. 22.3% of agricultural soil (Janku et al. 2016b).

This research aimed to estimate the risk of deterioration of the agricultural land quality and quantity in South Moravia and its financial impacts. This region is one of the most fertile ones in the Czech Republic. Despite that, the soil is strongly devalued both by erosion and permanent soil sealing in favour of urban development and infrastructures.

MATERIAL AND METHODS

Assessment of agricultural soil price and quality

Each BPEJ is defined by detailed evaluation of the parameters of climate, soil classification, characterisation of geologic substrates, soil texture, stoniness, water and air – soil regime, depth of the soil profiles, and land plot slopes and their exposure. Each of these parameters has been assigned a numerical code, and each BPEJ is defined by a five-digit code.

Designation of the estimated soil-ecological unit code:
– **X**.xx.x.x. – Code of climatic region (0–9);
– x.**XX**.x.x.– Code of the main soil unit (01–78);
– x.xx.**X**.x. – Associated code of slope and exposure (0–9);
– x.xx.x.**X**. – Associated code of stoniness and soil depth (0–9).

At present, the database of 2 199 BPEJs is maintained and updated by the State Land Office (Státní pozemkový úřad). The database of economic parameters (including official prices of agricultural land and soil yield) is maintained and updated at the Institute of Agricultural Economics and Information (Ústav zemědělské ekonomiky a informací).

The methodology of defining the official agricultural land price is based on the economic characteristics of the particular BPEJ, including parameterised returns of evaluating crops and normative expenses spent for their achievement (Nemec 2006; Voltr 2012; Voltr et al. 2018).

The process of BPEJ estimation consists of the following steps:
– Calculation of the gross annual rental effect (*HRRE*) for particular crops and the total value for the BPEJ;
– Calculation of the official price of agricultural land ($UCZP_{BPEJ}$) for the proposed production focus according to *HRRE*; the estimation made according to the production focus on cereals best corresponding to the existing estimation;
– Set up of the limit of the land price change with regard to the current evaluating regulation;
– Adjustment of the land assessment to the set limit.

The official price of BPEJ is deduced from the adjusted equation for the calculation of perpetual annuity. Due to the variable ratio of inputs and outputs in real time, the long-term average of revenues and expenses needed for their achievement was used in order to calculate *HRRE*. The total achieved $HRRE > 0$ is defined by the following Equation (1):

$$UCZP_{BPEJ} = BCZP + \frac{HRRE \times D}{U} \quad (1)$$

where: $UCZP_{BPEJ}$ – the official price of agricultural land (CZK/ha); *BCZP* – the base agricultural land price (CZK/ha); *HRRE* – the gross annual rent effect for BPEJ (CZK/ha); *D* – total share of non-taxed plant production, where $D = (100 - DP)/100$; *DP* – income tax; *U* – interest rate.

The calculation of BPEJ prices with $HRRE \leq 0$ and further particulars of the presented methodology are described in Nemec et al. (2006); Voltr et al. (2018).

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Economic balance of agricultural land fund devaluation by degradation due to erosion and permanent appropriation

Erosive processes lead to devastation of the soil profile (Lal 2001; Thomas 2006). Comparison of the soil characteristics allows for assessing changes in the soil characteristics and their quantification using the current valid directive. Agricultural land is also devalued by permanent appropriation during urban growth and development of the associated infrastructure. The BPEJ database and historical data on land use allow assessment of the soil loss due to the appropriation, including its price.

The potential changes of soil characteristics brought about by long-lasting erosion effects in the region of South Moravia were evaluated. One hundred and seventy-two BPEJ codes occurring in the South Moravian region, where the soil is susceptible to degradation by erosion (emergence of shallow soil; increasing stoniness; degradation of chernozems; degradation of albeluvisols and luvisols), were used. Soils with 7–12° slope were selected. The selected BPEJs were analysed for potential maximum erosion effects leading to irreversible degradation. Based on the valid land prices, a graphic representation of the potential changes in land prices in the region of South Moravia was prepared.

The availability of relevant data allows for analysis of the historical loss of agricultural land (changes in land use) and trends of arable land loss in particular time horizons. For these purposes, two regions were selected – surrounding the city of Hustopeče and surrounding the city of Brno. Historical data of the 2nd military mapping (2nd mm: 1836–1852), 3rd military mapping (3rd mm: 1876–1878), and aerial photos from the years 1950, 1990, 2006, and 2016 were used for the analysis. Data on land use were processed in the GIS environment. In the area surrounding Hustopeče a territory of the surface area ca 9 000 ha and in the area surrounding Brno a surface area of ca 5 000 ha were evaluated. In these territories we further selected two sites for a detailed demonstration of the impacts of erosion and land appropriation on reduction of the productive capacity of the area (neighbourhoods of Starovice and Dolní Heršpice).

Characteristics of the model area

South Moravia occupies a surface of 7 188 km^2. Almost 60% of the total area is occupied by agricultural land (83% of it being arable land). The majority of soils are chernozems, mainly on loess. Suburban development of local cities led to the disappearance of a large area of originally agricultural land, which was replaced by industrial and trade centres, extended traffic infrastructure, and housing. Despite the fact that the region is still considered one of the most fertile in the Czech Republic, due to improper management the land not only suffers from land appropriation, but also faces serious problems with the effects of erosive processes on the soil degradation and loss of its productive capacity

Detailed analysis of temporal changes in the price of land was conducted in two municipalities (Figure 1). The municipality of Starovice is an extensively agriculturally managed area situated in the Hustopeče

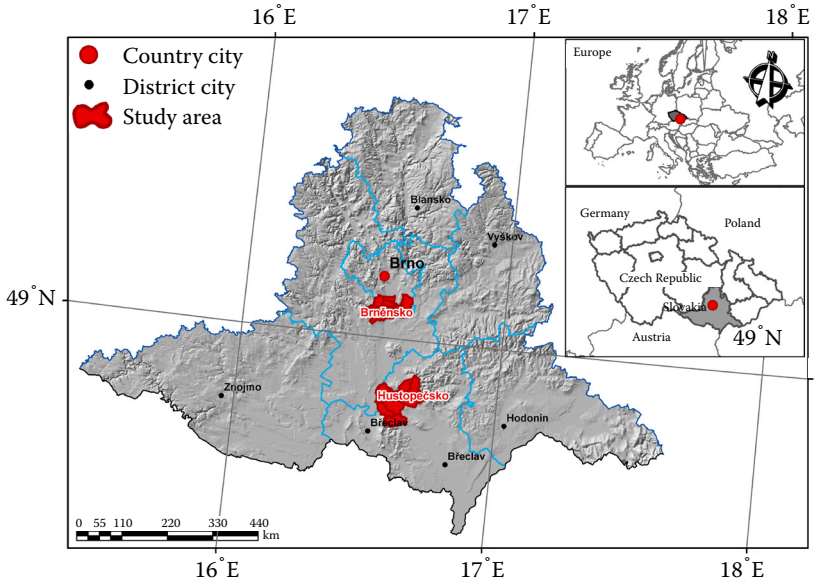

Figure 1. Map of the Czech Republic and the study areas (South Moravian region, territories of Hustopeče and Brno)

Source: own survey

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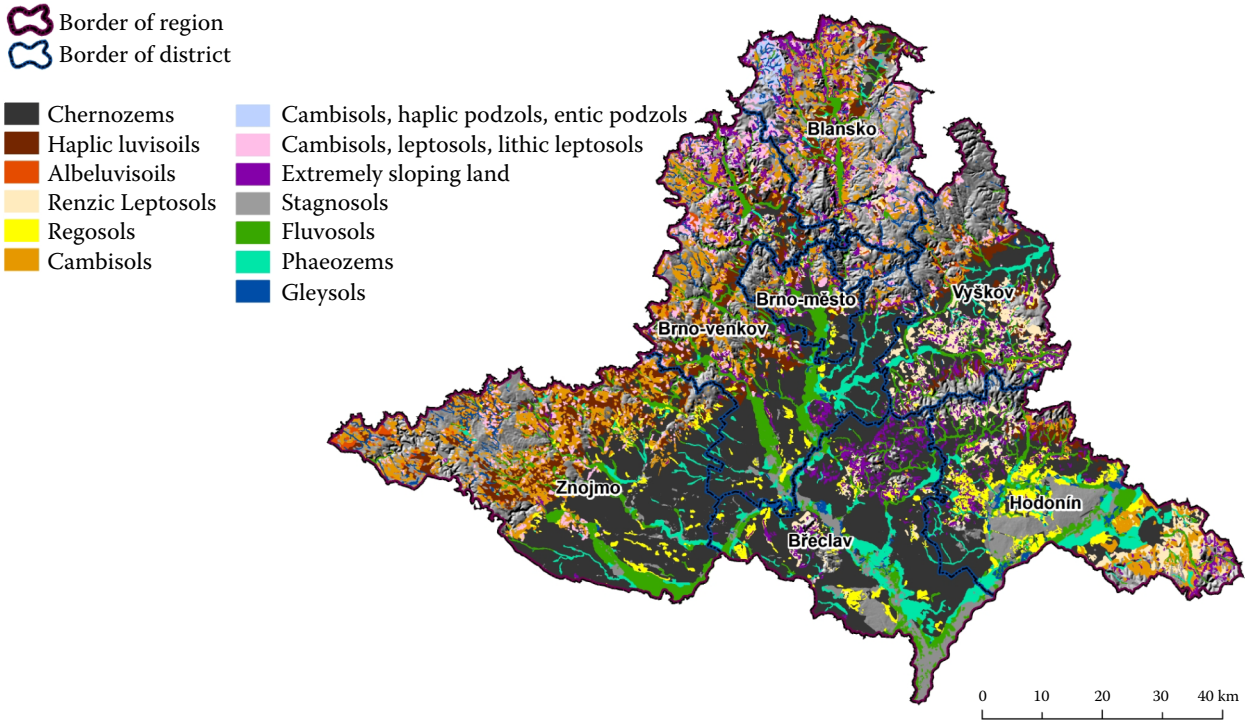

Figure 2. Groups of soil types in the region of South Moravia (Czech Republic)

Source: Sowacgis (2019)

area. Land plots have been unified into large blocks on the predominantly sloping area, endangered by erosion. For subsequent analyses, we selected an intensively managed locality of arable land of surface area 100.5 ha.

Dolní Heršpice is a municipality with surface area of 312.6 ha. It is situated in close proximity of the city of Brno. Built-up areas of Dolní Heršpice consist of two parts – the predominantly industrial zone, and the original village. The undeveloped area is covered by blocks of intensively managed arable land.

RESULTS

Potential drop in land price due to degradation by water erosion in the region of South Moravia

The official prices of all BPEJ in the region of South Moravia that are potentially degradable by water erosion up to their basal stage were estimated in this study. The official price of 1 m^2 of land in the Czech Republic ranges from 0.67 EUR for the most fertile chernozems to 0.046 EUR for soils in agriculturally unsuitable areas. In the region of South Moravia, the soil prices range from 0.51 EUR/m^2 (sloped chernozems in warm dry sites – BPEJ code 0.06.4.0) to 0.046 EUR/m^2 (sloped cambisols in cold and wet sites – BPEJ code 8.50.5.4). The spatial distribution of particular soil types is summarised in Figure 2.

The effects of erosion are most pronounced on chernozems, which under the influence of degradation by erosion are transformed into cambisols, rendzic leptosols, and regosols. This process is reflected in a drop of land price by up to two thirds. Figure 3 illustrates the drop in land price due to potential degradation by erosion in the region of South Moravia.

The drop in the land price is expressed in categories, where:

- Category 1 – the land price drop by 0–20.0%;
- Category 2 – the land price drop by 20.1–30.0%;
- Category 3 – the land price drop by 30.1–40.0%;
- Category 4 – the land price drop by 40.1–50.0%;
- Category 5 – the land price drop by 50.1–60.0%;
- Category 6 – the land price drop by 60.1–70.0%;
- Category 7 – the land price drop by 70.1% and more.

The highest erosion risk involves soils in the most fertile areas – sloping chernozem areas in the districts of Břeclav and Hodonín. The northern territories of the South Moravian region are also at risk of erosion. These effects are mostly manifested by shortening of the soil profile in cambisols and by the occurrence of skeletal shallow soils unsuitable for agricultural manage-

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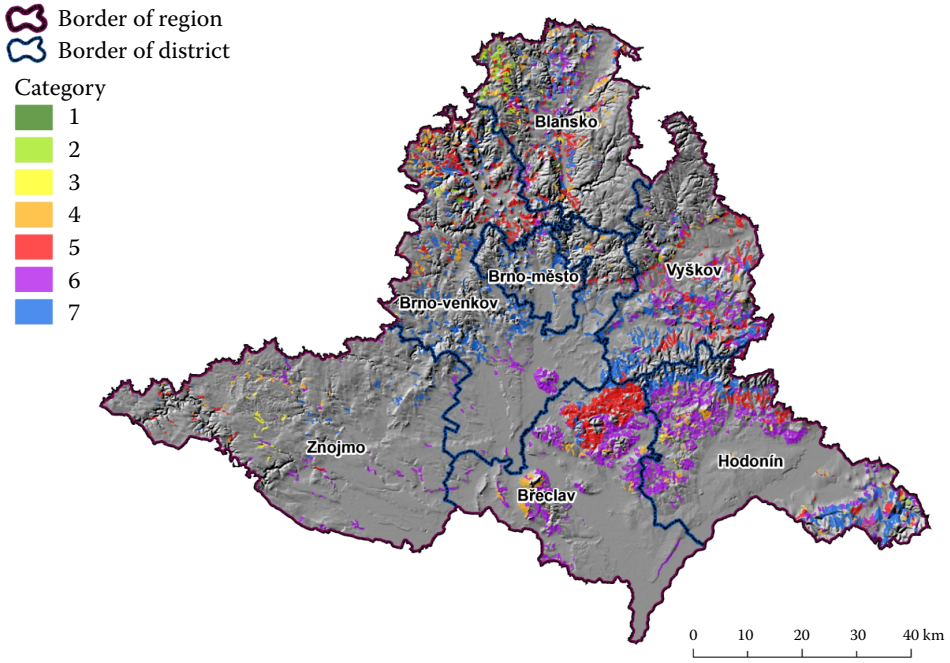

Figure 3. Drop in the land price due to potential degradation by erosion illustrated on the example of South Moravia (Czech Republic)

category 1 – land price drop by 0–20.0%; category 2 – land price drop by 20.1–30.0%, category 3 – land price drop by 30.1–40.0%; category 4 – land price drop by 40.1–50.0%; category 5 – land price drop by 50.1–60.0%; category 6 – land price drop by 60.1–70.0%; category 7 – land price drop by 70.1% and more

Source: own survey

ment. The land prices in these localities are not as high as in the southern parts of the territory. A more detailed summary of potential financial losses due to erosion (expressed in percentage of area classified to the particular categories in individual South Moravian districts after reclassification of soil units) is provided in Table 1.

The largest part of agricultural land in the South Moravian region is occupied by soils with potential

Table 1. Potential drop of land price due to erosion in the South Moravia region districts

District	Category (%)							
	1	2	3	4	5	6	7	Total
Blansko	0.31	1.46	0.47	1.71	3.90	2.18	2.61	12.64
Brno-city	0.02	0.00	0.04	0.02	0.18	0.22	1.51	2.00
Brno-suburbs	0.12	0.17	0.13	1.67	4.51	2.56	7.09	16.26
Břeclav	0.00	0.00	0.02	1.33	8.06	11.34	0.79	21.55
Hodonín	0.01	0.42	0.21	1.15	3.61	13.85	8.24	27.49
Vyškov	0.02	0.14	0.04	0.52	4.80	5.07	5.92	16.50
Znojmo	0.00	0.00	0.29	0.46	0.37	1.54	0.89	3.55
South Moravian region (total)	0.49	2.20	1.19	6.87	25.43	36.77	27.06	100.00

category 1 – land price drop by 0–20.0%; category 2 – land price drop by 20.1–30.0%, category 3 – land price drop by 30.1–40.0%; category 4 – land price drop by 40.1–50.0%; category 5 – land price drop by 50.1–60.0%; category 6 – land price drop by 60.1–70.0%; category 7 – land price drop by 70.1% and more

Source: own survey

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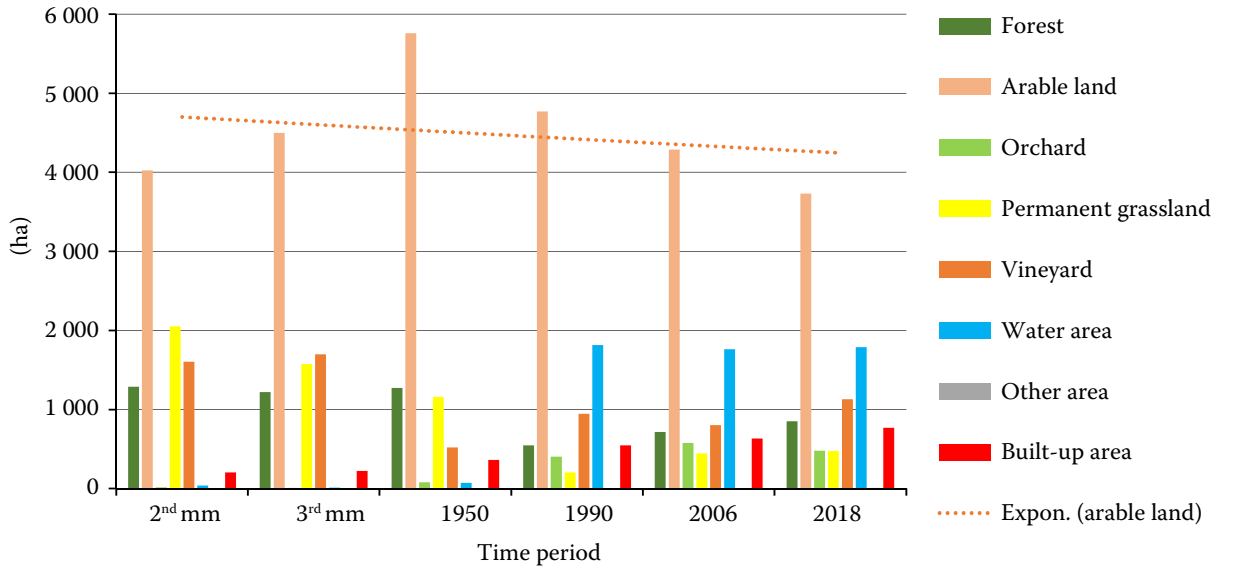

Figure 4. Temporal development of land use and trends of arable land loss in area surrounding Hustopeče

2^{nd} mm – 2^{nd} military mapping (1836–1852); 3^{rd} mm – 3^{rd} military mapping (1876–1878); Expon. (arable land) – exponential trend of arable land loss

Source: own survey

price drop of 60–70%. The same applies for the districts of Břeclav and Hodonín. In districts Vyškov and Brno-venkov, the largest area is covered by soils where the land price drop is 70% and more. In the Blansko district, most of the agricultural land is covered by soils with potential price drop by 50–60%. In Znojmo and Brno-město districts, the changes in BPEJ price relations are not so pronounced – the areas are mostly flat.

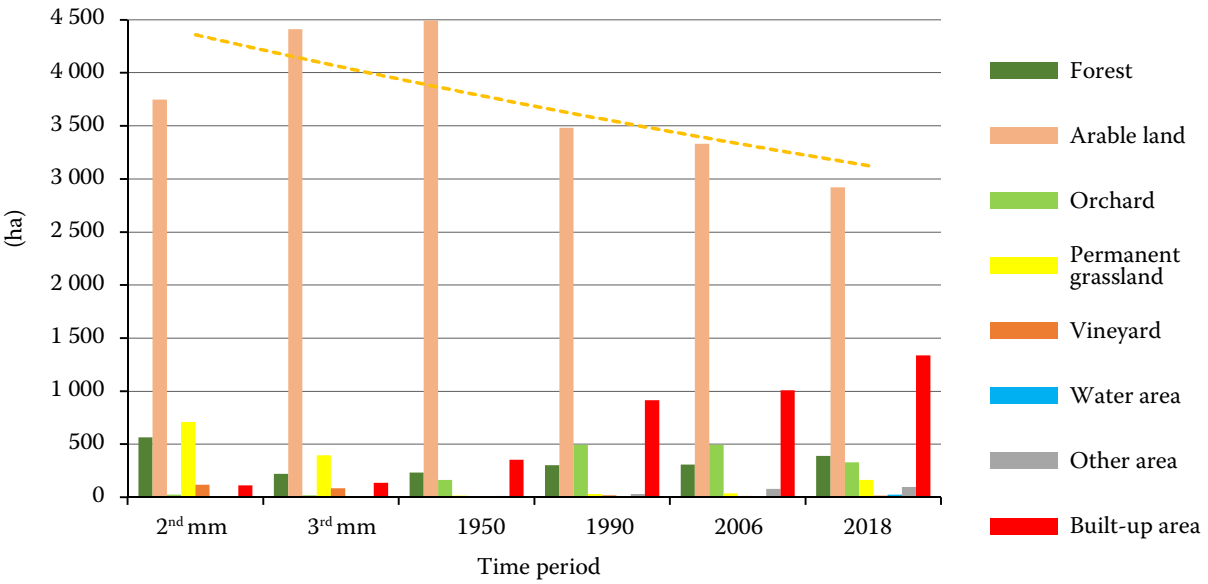

Figure 5. Temporal development of land use and trends of arable land loss in the area surrounding Brno

2^{nd} mm – 2^{nd} military mapping (1836–1852); 3^{rd} mm – 3^{rd} military mapping (1876–1878); Expon. (arable land) – exponential trend of arable land loss

Source: own survey

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Development of land use in the areas surrounding Hustopeče and Brno

Localities surrounding Brno are dominated by growing built-up areas in relation to the development of the city and associated infrastructure. The area surrounding Hustopeče shows higher diversity in land plot types, including water surfaces associated with the construction of the Nové Mlýny reservoirs. However, the loss of arable land is visible in both these territories, additionally accompanied by a reduction in its quality due to the soil degradation by erosion and inappropriate management (Figures 4–5).

Evaluation of the degradation processes in model localities Starovice and Dolní Heršpice

The model site of Starovice (model land block) was analysed as to the impacts of the erosive processes on the soil quality. The differences in the surface area and price of particular BPEJ before and after their updating were compared. The original land assessment through BPEJ was done in 1978; the update of BPEJ in 2013. This comparison allowed us to calculate the financial losses of the land value due to improper management in the last 40 years.

The 2013 update redefined surface areas of the original soil units, re-evaluated soil characteristics affected by the degradation processes, and introduced new soil units (Table 2).

According to the Valuation Decree currently valid in the Czech Republic, each BPEJ code was assigned a land price (converted to EUR) (Table 2).

The total surface of the studied land block is 100.5 ha. The price of this land block before the update was 511 744 EUR. After the update, there was a significant drop in the soil price and quality, mainly due to long-lasting effects of erosive processes, by more than 92 000 EUR. For example, the proportion of washed-off chernozem (code 0.08.xx) before the update was less than 12% of the land plot surface, and after the update it was increased to almost 44% of the land plot. The total surface of the most valuable soils – modal chernozems (0.01.xx) – was reduced after the update from 78 to 31%, mainly due to degradation to other, not so rich soil types (washed-off chernozems – 0.08.xx; leptosols and regosols – 0.19.11 and 0.22.xx; fluvisols and pelic chernozems – 0.05.11 and 0.06.10).

In the model site of Dolní Heršpice, analysis was focused on the demonstration of the impact of farmland loss by its appropriation for the purposes of urban development. Using data on the land use in particular temporal ranges, we assessed the surfaces of appropriated agricultural soil in relation to the particular soil types (categorised evaluated soil ecological units – BPEJ). This assessment was done for three periods (2nd mm – 1850; aerial photo – 1950–2016; 2016 – Landscape Plan). The situation according to the Landscape Plan (LS plan) reflects future development of the locality according to the valid LS documentation (Table 3, Figure 6).

The most extensive appropriation involved the most valuable soil types – deep modal chernozems on loess, hydromorphic and pellic chernozems, washed-off chernozems, haplic luvisols and fluvisols (2.01.00, 2.08.10, 2.10.00, 2.56.00). The total soil loss due to building in the period from the 2nd military mapping (1836–1852) to present day (2016) represented 148.85 ha from the entire area of 312.6 ha. Expressed by the price according to the current price regulations, it means a sum of 822 815.51 EUR. According to the Landscape Plan, the future soil sealing should concern an additional 70 ha of land in total value of 411 078.26 EUR.

Table 2. BPEJ price according to the valuation decree valid in the Czech Republic in model locality Starovice

	BPEJ	Area (m^2)	Price for 1 ha (EUR)
Time period 1978–2013	0.01.00	99 668.14	6 110
	0.01.10	687 698.24	5 440
	0.04.01	96 804.53	2 670
	0.08.10	101 692.59	4 300
	0.08.50	18 908.37	3 670
	total	1 004 771.86	511 744.376
After updating (2013)	0.01.10	256 949.51	5 440
	0.04.01	57 283.18	2 670
	0.05.11	7 198.31	2 730
	0.06.10	100 072.03	4 270
	0.08.10	362 516.25	4 300
	0.08.50	77 597.56	3 670
	0.19.11	9 666.19	3 630
	0.22.10	128 054.39	2 380
	0.22.52	5 434.44	1 720
	total	1 004 771.86	419 162.859

BPEJ – Evaluated Soil-Ecological Units

Source: own survey

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Table 3. Appropriation of individual BPEJ and total price of lost soil

BPEJ	Price for 1 ha (EUR)	2nd mm–1950			1950–2016			2016-LS		
		ha	%	total price (EUR)	ha	%	total price (EUR)	ha	%	total price (EUR)
2.01.00	6 900	0.00	0.00	0	0.65	0.49	4 485	17.76	25.33	122 544
2.01.10	6 200	0.00	0.00	0	6.36	4.80	39 432	0.00	0.00	0
2.03.00	7 200	0.27	1.65	1 944	0.04	0.03	288	0.76	1.08	5 472
2.08.00	4 700	4.82	29.63	22 654	34.61	26.10	162 667	15.46	22.05	72 662
2.10.00	6 300	5.23	32.15	32 949	23.01	17.36	144 963	13.53	19.30	85 239
2.56.00	5 600	5.95	36.57	33 320	67.87	51.19	380 072	22.32	31.84	124 992
Total	–	16.27	100.00	90 867	132.58	100.00	731 948.51	70.11	100.00	411 078.26

2nd mm – 2nd military mapping (1836–1852); LS plan – landscape plan; BPEJ – evaluated soil ecological units; ha – hectares of appropriated soil unit from the whole area; % – percents of appropriated soil unit from the whole area

Source: own survey

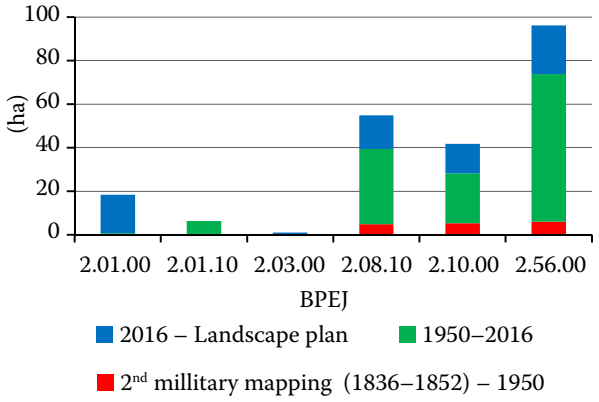

Figure 6. Graphical representation of appropriated Evaluated Soil-Ecological Units (BPEJ)

2.01.00, 2.01.10 – chernozems on the plain; 2.03.10 – phaeozem on the plain; 2.08.10 – degraded chernozem on the plain; 2.10.00 – haplic luvisol on the plain; 2.56.00 – fluvisol on the plain

Source: own survey

DISCUSSION

Land assessment by means of the BPEJ system allows for quantification of the economic impacts of degradation processes – soil erosion and soil sealing by means of appropriation of land. This method can be used to assess losses in the complex value of a territory, but not for market-price valuation. The market prices of agricultural land are often not directly related to the soil value (Sklenicka et al. 2013). They are dependent on a number of parameters – attractiveness of the location, user and owner interests, state and private investor initiatives. Most landowners rent the agricultural land to agricultural subjects who farm on extremely large land blocks that are economically advantageous for agricultural management, but often contribute to the degradation of the agro-ecosystems (Popescu 2010; Sklenicka et al. 2013; Janovska et al. 2017). A significant role is also played by the restructuring of agriculture, focus on other commodities than food, and the system of global subsidies (Balmann 2008).

The average market price of agricultural land varies significantly from year to year regardless of location, size, and category of the plot of land, but since 1993 the price has been generally rising (Vrbova and Nemec 2005). In the period 2011–2016, the land prices in the Czech Republic recorded a 3-fold growth, which is the highest increase in the entire EU. Despite the growing prices of agricultural land, especially in the last two years, land in CR is often significantly cheaper compared to other EU countries. At present, the market price of land in CR ranges around 5 000 EUR/ha varying mainly with geographic location and proximity to towns (Curtiss et al. 2013).

The highest price of agricultural land in the European Union can be found in the Netherlands, where the price level fluctuates around 50 000 EUR/ha. Very high prices, over 20 000 EUR/ha, are reached by agricultural land in Denmark, Italy, Great Britain, and Germany, where prices range between 15 000 and 20 000 EUR/ha. In Spain, the price of agricultural land fluctuates around 10 000 EUR/ha. France shows a continuously growing trend in the agricultural land price, which from 5 000 EUR/ha in 2007 raised to more than 6 000 EUR/ha (European Environment Agency 2016).

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As for the prices of agricultural land in central Europe (V4), the lowest prices are in Slovakia (3 009 EUR/ha), in Hungary the price is 4 368 EUR/ha and in Poland the estimated price is 9 699 EUR/ha (Eurostat 2019) .

CONCLUSION

The territory of the Czech Republic is characterised by a significant proportion of ploughed-up land, and particularly by the unification of the original proprietary land plots into large production blocks (Janovska et al. 2017; Devaty et al. 2019). The erosive processes bring about reduction of the BPEJ prices, causing economic losses to the landowners, with direct impact on further land use. This situation was presented on the example of the region of South Moravia, where the largest surface is occupied by soils at risk of potential devaluation (price drop) by 60–70% (due to the long-term effects of erosion). These facts are mostly ignored by society, which does not acknowledge them. Unfortunately, the long-lasting trend of soil degradation can have a negative effect (from the aspect of economic damage to landowners and farmers) on the reduction of productive agricultural land, with direct impact on the food safety of the state.

Analysis of the land use changes in model areas surrounding Hustopeče and Brno points to a permanent trend of loss of arable land, usually due to urban development. Detailed analysis of one block of arable land (100.5 ha) in Starovice has calculated the direct and irreversible damage to the soil quality and price due to erosion to more than 92 000 EUR.

The results of the assessment of land appropriation in the locality of Dolní Heršpice show that the most pronounced loss of arable land due to permanent urban development was mainly observed during the last decades. Since the 1950s until present day, this area (of 313 ha surface) has witnessed construction on almost 133 ha of valuable agricultural land. According to the Landscape Plan, future loss of soil by appropriation should concern an additional 70 ha of land. These results present a general trend of agricultural land loss in suburban areas.

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