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Estimation of Land Loss in the Czech Republic in the Near Future

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Abstract

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The study presents an estimate of how many hectares of soil will be removed from the farmland fund in the coming years around the biggest towns for non-agricultural use, such as for residential purposes and industrial zones. To estimate suburban area spreading, so called "buffers", i.e. packing zones around towns, were established. For the capital city of Prague the buffer width was set at 3 km, for regional towns at 2 km, and for district towns at 1 km. In this area, as well as on the territory (intravilan) of towns, the estimate of the future acreage removal of farmland for building purposes was calculated. The study also quantifies the changes in acreage of different soil types. The results show a significant decrease in acreage of the best quality soils, primarily because the largest towns are usually built on the best soils, and these towns are spreading much more than small towns. The results were statistically processed for (a) total, (b) each regional town, (c) each district town, and (d) total always separately for urban areas, for suburban areas (buffer zones), and for their combinations. Cambisols represent the soil group with the largest loss of land, followed by Luvisols and Chernosols.

Keywords: land consumption; land protection; land take; soil sealing; suburban areas; urban areas

In the Czech Republic, the conversion of farmland to urban uses (soil sealing) represents a very serious problem. On arable land in particular, there is a trend of soil loss (approximately 9100 ha/year), which means approximately 25 ha/day, or an area equal to 40 football pitches per day (Janků *et al*. 2016). This situation is caused by the expansion of built-up areas, specifically the increase of acreage of residential and industrial zones. This trend is affected by the relatively low price of agricultural land (big difference between the price of agricultural and building land) and by political arrangements – especially because industrial zones are expected to provide jobs.

In the EU, the Member States with high sealing rates (exceeding 5% of the national territory) are Malta, the Netherlands, Belgium, Germany, and Luxembourg. Furthermore, high sealing rates exist across the EU and include all major urban agglomerations, and most of the Mediterranean coast. The latter experienced a 10% increase in soil sealing only during the 1990s.

Several factors may explain the ongoing development of urban sprawl. Many people are settling in peri-urban areas because they can find better quality housing with more living space per capita. There is still a large difference in the average living area per person between cities in the EU-15 and cities in the EU-12: 15 m^2 per person is the average in Romanian cities, compared to 36 m^2 per person in Italian cities and 40 m^2 in German cities (European Commission 2012).

Migration from the city centre to peri-urban areas may also result from a demand for a greener, more attractive, and family-friendly environment. The demographic change gives rise to a series of challenges that differ from one city to another, such as ageing populations, shrinking cities or intense processes of suburbanisation. In some areas of the EU the population has increased markedly in recent years while other areas have been depopulated (Eurostat 2010), and as life expectancy increases, the average

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age of population will rise. Overall, this means more people to house, with higher expectations of the size of homes, despite a notable decrease in the average number of people in a household. The European Environment Agency, however, points out that urban expansion is more a reflection of changing lifestyles and consumption patterns rather than of increasing population (European Commission 2012).

Similar problems with the rapid conversion of farmland are in China. Wang *et al.* (2015) described the land use conditions of Hong Kong from both demand and supply perspectives. They also reviewed the statutory and administrative procedures of land development and allocation together with the involvement of sustainable urban renewal practices.

The problem of arable land conversion is also described in a study by Xu *et al.* (2015). The assessment on the effect of land use policy has a great significance for improving the policy implementation. The conclusion obtained was a result of "General Effect", which revealed that China's National General Land Use Plan (2006–2020) fails to control arable land loss during its mid-term phase.

More specifically, 1 657 868.82 ha of arable land are additionally lost due to the ineffectiveness of China's National General Land Use Plan (2006–2020).

Surbanization is necessary, but entails major public and private expenditures, reduces farmland, and disrupts ecosystems (Harris 2015).

Land use change due to urbanization is one of the most serious environmental problems Europe is facing today, due mainly to the speed of the changes. Their frequency and magnitude increased unprecedentedly in the second half of the 20^{th} century (Antrop 2000). Urban sprawl, which represents a specific form of urbanization, is the most significant driver of land use changes. Urban sprawl is defined as a phenomenon of spreading of extensive forms of built-up areas into a city's agricultural surroundings (Torrens & Alberti 2000; Gayda *et al.* 2005) leading to soil consumption (conversion of agricultural land to developed areas) and soil sealing (covering soil with impermeable material e.g. asphalt, concrete).

According to Mitchell *et al.* (2015), urban development needs to be more climate-resilient. Their paper proposes ways by which the growth of human settlements can be better managed through responsible governance of land tenure rights, and effective land-use planning to reduce vulnerability, provide adequate access to safe land and shelter, and improve environmental sustainability.

Soil protection policies and governance are facing different obstacles. At the local level, municipalities are facing the conflict of (long term) soil protection versus (short term) economic development. As a result, uncontrolled land take, soil sealing, and urban sprawl are ongoing, regardless of the negative environmental impacts. Management strategies and experiences are thus required for the practical implementation of soil protection strategies at regional and local levels. The Urban Soil Management Strategy (URBAN SMS) project, funded by the European Regional Development Fund (2007–2013), is facing this challenge.

A transnational team of eleven partners from seven Central European countries has implemented comprehensive soil management strategies and tools. As a result, the URBAN SMS project provides useful approaches to protect high quality soils and their functions during urban development. Combined with awareness raising activities and a permanent and unceasing commitment at the European, national, and local levels, these results will lead to better management and protection of soil resources in Europe. A pilot study was also made in the Czech Republic, in the capital city of Prague. Improving the consideration of high quality soils as well as awareness raising at a local level was the focus of the pilot study to limit, and where this was not possible, to compensate soil losses (Anonymous 2012).

The majority of survey respondents feel that the reclamation of land has a significant positive effect on the environment, psyche of habitants, recreational function, and mitigation of dust. These results can provide policy makers with quantitative information to support the design of possible policies for reclamation. Perhaps most importantly, the study revealed the interest of local people in land use, and in the environment.

Van den Daele and Krohn (1998) presented how science contributes not only to knowledge, but also how it is a mode of operation – experimenting with processes of social and technological innovation, while the problems emerging in the process of experimental implementation pose new cognitive challenges for research.

The present authors reacted similarly to the current situation and created an estimate of the expected farmland conversion. In this context, farmland conversion also means a reduction of countryland.

Of course, land conversion also presents the loss of food production, and this fact can have serious

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consequences in the future, especially in combination with climatic changes.

MATERIAL AND METHODS

This project aims to estimate future land take in the context of suburbanization. In general, the development of soil consumption has been driven by urbanization, as analyzed by Stachura *et al.* (2015). A set of 22 cadastres was selected for covering maximum soil quality diversity of the dominant soil types at a driving distance of up to 20 min from Prague.

For the present estimate of farmland conversion, packed zones – so called "buffers" – were established around the biggest towns, where the largest land consumption is assumed. For the capital city of Prague the buffer is 3 km, for regional towns 2 km, and for district towns 1 km around the present city borders. These distances (buffers – 1, 2, 3 km) are only estimates, based on the conversion of land in the suburban areas according to the extent of the towns.

In cases where the buffers overlap, the overlapping area was only assigned to the hierarchically higher unit, i.e. the regional city. This situation occurred in 4 cases, namely: Ostrava – Frýdek-Místek, Pardubice – Chrudim, Liberec – Jablonec nad Nisou, and Ústí nad Labem – Litoměřice. In this case, the reduction of farmland acreage (in ha) was analyzed for bigger towns, the same as the reduction of soil types for these places.

Land use data was based on seamless vector CEC2006, ver. 17/2013 (EEA 2014). As a source of pedological data, Soil Atlas of the Czech Republic at the scale of 1 : 250 000 (Kozák *et al.* 2010 with soils classified according to the Czech taxonomic soil classification system (Němeček *et al.* 2011) was used. For spatial analyses, the program ArcGIS Ver. 10.1 was applied.

RESULTS

The project objective was to estimate the future agricultural land take around larger towns as well as the reduction of soil types at these localities.

Estimate of future agricultural land take. The estimation has been provided for both the capital city of Prague and the regional and district towns.

The results are clearly presented in maps and tables. Figure 1 shows the areas of towns with buffers – around the capital city the buffer width is 3 km, around regional towns 2 km, and around district towns 1 km (suburbanization area).

Agricultural land is generally situated on the territory of towns, which is also determined for built-up areas. This trend is frequently observed in urban plans. In this project, these places are marked in red colour (urban areas), places around towns (suburban areas – in free landscape) are marked in beige. An example is shown in Figure 2.

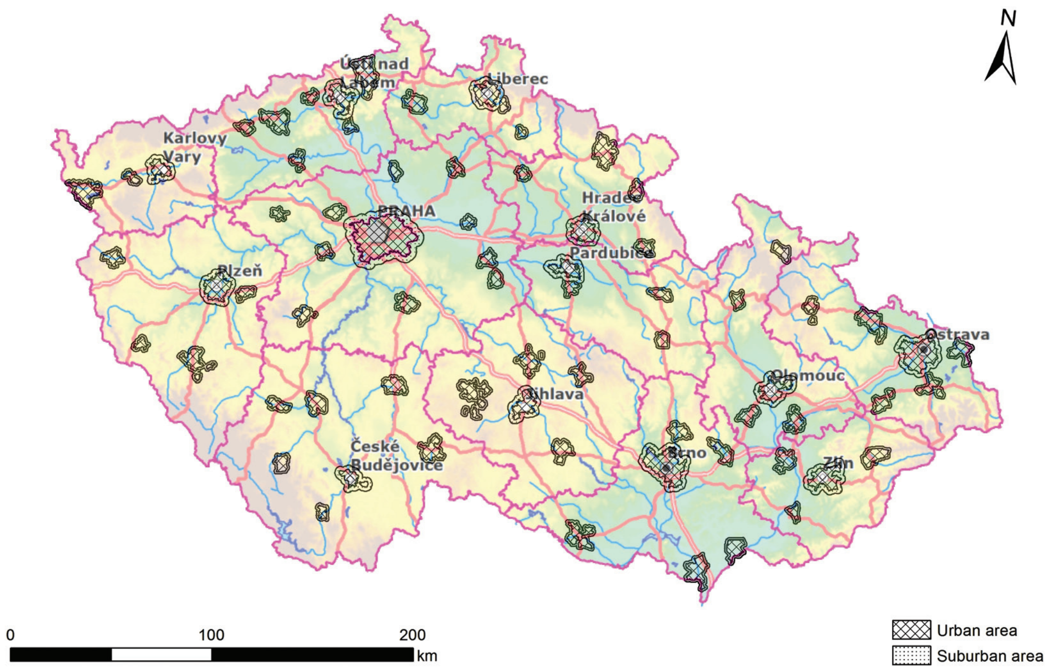

Figure 1. Map of the Czech Republic with urban and suburban (buffered) areas around towns

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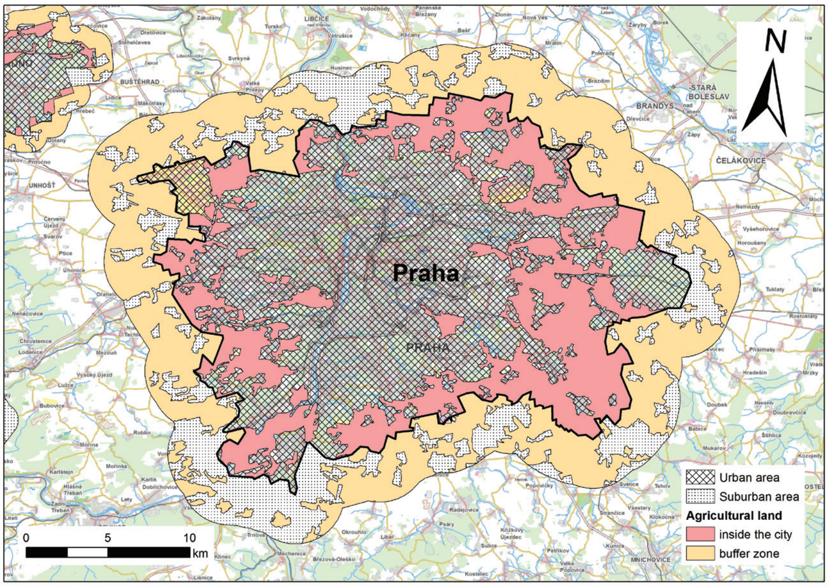

Figure 2. Detailed map of the city of Prague, including the areas of agricultural land inside the city (red colour) and the buffer zone around the border of Prague territory (beige colour)

The estimation of land take, in the case of expansion of towns, is presented in Table 2. In principle, it is assumed that larger cities tend to expand more than small towns. Therefore buffer width was set at 1–3 km following the extent of each town. The buffer of 3 km has been designed for the capital city, of 2 km for regional towns, and of 1 km for district towns (in free landscape). The total acreage of land take makes almost 477 000 ha. From this, within the urban areas (207 000 ha) which are intended mainly for building activities, we cannot calculate for future agriculture use.

However, the present objective is the protection of farmland in suburban areas, the acreage of which for the whole Czech Republic is 269 000 ha.

A study by Janků *et al.* (2016) described the trend of arable land consumption (9 100 ha/year) for the whole Czech Republic. Hence, in 30 years, this represents a loss of approximately 269 000 ha of agricultural land, just around the larger cities, which accounts for about 6% of all agricultural land and 9% of arable land.

The acreage of agriculture land for the year 2013 is presented in Table 1 (http://www.cuzk.cz/Periodika-a-publikace/Statisticke-udaje.aspx).

A more significant problem seems to be the reduction of farmland in suburban areas around bigger cities (Prague and regional cities). The probability of land take is greater in large cities than in district towns. This means that 114 000 ha of farmland is threatened. It accounts for about 3% of all agricultural land, and almost 4% of arable land. The land take estimation associated with the expansion of towns, arranged according to different categories, is presented in Table 2.

Subsequently, these areas were interspersed with the soil map at a scale of 1 : 250 000 in order to determine the soil conditions.

Estimate of future agricultural land reduction by soil types. The results were statistically processed for (a) total, (b) each regional town, (c) each district

Table 1. The acreages of land types for 2013 (in ha)

Type of land	Acreage
Arable land	2 985 792
Hop-gardens	10 312
Vineyards	19 652
Gardens	163 476
Orchards	46 172
Permanent grassland	994 461
Agricultural land	4 219 867

Table 2. Estimation of land take (in ha) in connection to the expansion of towns according to different categories

Towns	Suburban areas	Urban areas	Total area
Prague	24 808	17 421	42 228
Regional cities	89 357	51 293	140 649
District towns	155 195	138 710	293 905
Total (ha)	269 359	207 423	476 782

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Table 3. Estimation of land take (in ha) according to soil groups for Prague (in ha)

Soil reference classes	Suburban areas	Urban areas	Total area
Cambisols	4 354	5 707	10 061
Luvisols	10 202	5 685	15 887
Chernosols	8 476	4 131	12 607
Stagnosols		77	77
Fluvisols	227	859	1 086
Anthroposols	47	335	382
Leptosols	1 450	367	1 816
Regosols	53	261	313
Gleysols	–	–	–
Podzosols	–	–	–
Vertisols	–	–	–
Histosols	–	–	–
Water and quarries	–	–	–
Total	24 808	17 421	42 229

Table 4. Estimation of land take according to soil group for regional towns (in ha)

Soil reference classes	Suburban areas	Urban areas	Total area
Cambisols	33 939	16 124	50 063
Luvisols	22 996	12 894	35 890
Chernosols	9 172	3 967	13 139
Stagnosols	6 909	3 775	10 684
Fluvisols	8 532	7 558	16 090
Anthroposols	1 134	3 323	4 458
Leptosols	382	63	445
Regosols	3 180	1 735	4 915
Gleysols	2 319	1 277	3 596
Podzosols	383	271	653
Vertisols	–	–	–
Histosols	133	60	193
Water and quarries	279	245	524
Total	89 357	51 293	140 650

town, and (d) total always separately for urban areas, for suburban areas (buffer zones) and for their combinations. Groups of large cities, including Prague, have usually been founded at places with better climatic and soil conditions. Especially larger cities use to grow more rapidly. Therefore, better quality soils are more often threatened with soil sealing. This assumption was confirmed by the results in Tables 3–6 (according to Němeček *et al.* 2011).

Cambisols represent the soil group with the largest loss of land, followed by Luvisols and Chernosols. Cambisols are soils of average quality, but it is the most abundant soil type in the Czech Republic. Luvisols and Chernosols are high quality soils.

Table 5. Estimation of land take according to soil groups for district towns (in ha)

Soil reference classes	Suburban areas	Urban areas	Total area
Cambisols	69 486	65 424	134 911
Luvisols	26 020	24 794	50 814
Chernosols	22 907	15 226	38 133
Stagnosols	16 510	15 532	32 042
Fluvisols	11 015	9 481	20 496
Anthroposols	1 780	3 327	5 107
Leptosols	4 406	2 996	7 402
Regosols	1 803	973	2 776
Gleysols	426	275	701
Podzosols	425	177	602
Vertisols	224	152	376
Histosols	85	62	147
Water and quarries	107	291	397
Total	155 195	138 709	293 904

Table 6. Estimation of land take according to soil groups for the Czech Republic (in ha)

Soil reference classes	Suburban areas	Urban areas	Total area
Cambisols	107 779	87 256	195 035
Luvisols	59 218	43 374	102 592
Chernosols	40 554	23 324	63 878
Stagnosols	23 419	19 384	42 803
Fluvisols	19 774	17 897	37 671
Anthroposols	2 961	6 985	9 946
Leptosols	6 238	3 426	9 663
Regosols	5 036	2 969	8 004
Gleysols	2 745	1 552	4 297
Podzosols	808	448	1 256
Vertisols	224	152	376
Histosols	218	122	340
Water and quarries	385	536	921
Total	269 359	207 423	476 782

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DISCUSSION

Based on data published by the European Environment Agency in the context of Corine Land Cover for the years 1990, 2000, and 2006, Prokop *et al*. (2011) estimated that the land take between 1990 and 2000 was around 1 000 km^2 per year in the EU, which represents an area larger than the city of Berlin – or 275 ha per day. Settlement areas increased by nearly 6%. From 2000 to 2006, the rate of land take decreased slightly to 920 km^2/year (252 ha/day), while the total settlement area increased by further 3%. This corresponds to an increase of almost 9% between 1990 and 2006 (from 176 200 to 191 200 km^2). It is important to note that in the same period the population increased by only 5% (paradox of "decoupled land take"), though there was a wide difference in population growth across Europe and within regions. The total sealed soil surface area in 2006 was estimated to be around 100 000 km^2 or 2.3% of the EU's territory, with an average of 200 m^2 per citizen (European Commission 2012).

Historically, urban settlements have mainly been established on the most fertile areas. Many European states face the problems with rapid losses especially of better quality soils. Rapid decreases in the amount of best quality soil are observed in the Czech Republic as well. The biggest cities with the largest soil loss due to land take were founded on the highest quality soils (Kozák *et al*. 2010).

Sprawling cities tend to consume the best agricultural lands, forcing agriculture to move to less productive areas or to upland locations (Nizeyimana *et al*. 2001). The expansion of the city of Guadalajara, for example, has led to the consumption of the richest soils along the Henares River. The expansion of Madrid into surrounding areas has resulted in a rapid and irreversible soil loss (Rodríguez & Gonzalez 2007).

The city of Nanjing, China, expanded at an annual rate of 7% between 1984 and 2003. Over the total occupied area, the loss of soils of the first and second highest quality class exceeded 60% (Zhang *et al*. 2007).

An analysis carried out by the European Commission's Joint Research Centre (Gardi *et al*. 2011) shows that in the period 1990–2006, 19 EU Member States lost a potential agricultural production capability equivalent to 6.1 million t of wheat, roughly equivalent to a sixth of the annual harvest in France, the largest European wheat producer (European Commission 2012). According to the Research Institute of Agricultural Engineering, the average yield of wheat is 6 t/ha in the Czech Republic (http://www.vuzt.cz/index.php?I=A37). Since 1990, the trend of arable land take in the Czech Republic is 25 ha/day (9100 ha/year) (Janků *et al*. 2016). It means, almost 55 000 t of wheat got lost.

For example, in the Czech Republic, the period 1990–2006 represented a loss of land equivalent to approximately 880 000 t of wheat.

In general, urbanisation and urban sprawl are considered "natural processes". However, it seems neccessary to find a compromise between investor interests and soil protection.

In some EU countries, e.g. in Austria, Belgium (Flanders), Germany, and Luxembourg, quantitative limits for annual land take have been determined. However, the limits are only indicative and can be used as monitoring tools.

In Germany, for example, the achievements are regularly evaluated. However, results show that without binding measures and programmes, indicative targets alone are currently insufficient (European Commission 2012). A mix of legal-planning and economic-fiscal responses is less efficient because of a lack of economic-fiscal strategies for protecting the soil (Artmann 2014a, b). A mix of economic-fiscal and land use planning instruments are supposed to be particularly efficient in reducing land take (Nuissl & Schroeter-Schlaack 2009). Since the implementation of the 30-ha target in Germany, a decrease in land take from 130 ha/day in 1997–2003 to 93 ha/day in 2006–2009 could be observed (Artmann 2014a). However, the German Federal Environmental Agency (2010) assumes that these trends result from the global economic crisis and its effects on construction activities. In some European countries like Slovakia, Poland or Bulgaria, fees must be paid when agricultural areas are sealed. The fee increases upon the soil quality (European Commission 2012). The Czech Republic has a similar system. When sealing agriculture areas, fees are also paid according to the quality of soil. However, this system is not fully effective because many exceptions have been observed.

The role of soils in supporting ecosystems and natural capital needs greater recognition. The lasting legacy of the International Year of Soils in 2015 should be to put soils at the centre of policy, supporting environmental protection and sustainable development (Smith *et al*. 2015). A number of large

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existential environmental challenges have been recognized for the sustainable development of humanity and planet Earth. These are Food Security, Water Security, Energy Security, Climate Change Abatement, Biodiversity Protection, and Ecosystem Service Delivery (Bouma & McBratney 2013).

When one analyzes these environmental challenges, we can recognize that soil has a part to play in all of these (Herrick 2000). It represents a crucial task for society (not only for farmers and environmentalists), and this task is important for influencing water retention in the soil. Removing land for construction purposes increases the risk of water scarcity every day. Lack of water is related to food production, price, availability, and social problems (Janků *et al*. 2016).

CONCLUSIONS

Currently, a lot is talked about soil protection and about soil protection law. The amount of farmland taken in recent years is alarming. The opinion of not only soil scientists, ecologists, and farmers, but also philosophers and journalists about the importance of soil is in contrast to the interests of developers, builders, architects, and a large part of politicians, especially local governments.

While one side argues that soil is irreplaceable and necessary for human life (production function, recreational, cultural), the other side very often argues for unemployment reduction (construction of industrial complexes, even only warehouses) and the need for additional housing etc. preferably on greenfield sites rather than revitalized brownfields.

The price of farmland and building land differs significantly. Even the opinion is promoted, that only converting farmland into building land, by only even administrative record (change of spatial plan) represents appreciation of land.

We operate in a market environment and the value of anything, if it is not expressed in monetary terms, is ignored.

The soil is irreplaceable and essential for life. We need it, and we will need it especially for future generations.

Agricultural land surrounding cities is usually fertile; however, it is often underpriced and is generally given weaker regulatory protection than forests or natural areas. As to the appreciation of the value of soil, our urbanized society has a more direct relationship with air and water than with the soil which is buried under our feet. This is sometimes reflected in decision-making processes, including land planning, which may not fully consider the costs related to urban sprawl in combination, for example, with an ageing population (European Commission 2012).

The project was designed not only to decipher the future farmland reduction, but also to warn beforehand on the irresponsible use of land.

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