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The Inclusion of Ecosystem Service in Land Valuation and Impact on Cadastral Land Value – a Case Study

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Abstract

In the Czech Republic, a system of evaluated soil-ecological units (ESEU) is used for soil valuation, where the price is determined on the basis of production potential. In practice, the production potential of soil is also very important for spatial planning because it is used to determine the protection class of agricultural land with regard to the possibility of designating it for non-productive purposes. This paper focuses on the application of an econometric model to determine the effect on soil value in selected cadastral areas when the effect of the non-productive function of soil in the form of retention is taken into account. This is effectively an ecosystem service calculation, as only the production function is included in the ESEU price in the Czech Republic. For the purposes of the paper, three alternative scenarios are chosen in which the production price includes the price for the non-production function in the form of retention, in the amounts of 5%, 10% and 20%. The results show that even a 5% inclusion of soil retention has a significant impact on its price and, more precisely, on its value. The difference between the original value and the shadow value with the greatest effect of water retention at the 20% level is approximately CZK 12.3 million for the Ivančice site and approximately CZK 20.6 million for the Lysá nad Labem site, which indicates the importance of changing the current government methodology. The higher increase for the Ivančice site is due to the higher proportion of more productive ESEU and, at the same time, the higher retention capacity of the main soil units (MSU), which is absolutely necessary for the valuation of agricultural land in the main production areas of the Czech Republic. The results confirm that in these most valuable areas, the increased share of ecosystem components would lead to the greatest increase in the price of agricultural land, which can be considered as an adequate and meaningful result, if only in the context of comparing agricultural land prices between EU Member States. The water retention capacity of the soil is a qualitative indicator of the non-productive function of the soil and is increasingly supported as such.

Keywords

Soil, ecosystems services, hydrological characteristics, econometric modelling, SUR model, land valuation.

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Introduction

The concept of soil ecosystem services has received considerable attention in the scientific literature and media in recent years. The monetary valuation of these services, called for by many governments and international organisations, is often described as a necessary condition for the conservation of the natural capital represented by soil (Baveye, Baveye and Gowdy, 2016).

Ecosystem services are defined as the benefits that people derive from ecosystems. The application of the ecosystem services concept is intended to promote the development of policies and instruments that integrate social, economic and environmental perspectives. In recent years, the concept has become a paradigm for ecosystem management (Seppelt et al., 2011; Iliopoulos and Damigos, 2024). Programmes of payments for ecosystem services (PES) have proliferated in recent decades, exchanging value for land management practices designed to provide or secure ecosystem services - there are over 550 active programmes worldwide and an estimated US$36-42 billion per year (Salzman et al., 2018). Ecosystem services, and the stock of natural capital that provides them, are critical to the functioning of the Earth's life support system. They contribute both directly and indirectly to human well-being and thus represent part of the total economic value of the planet (Costanza et al., 1997).

Ecosystem services (as mentioned above) are the benefits that people derive from ecosystems. They include provisioning services (water and food), regulating services (flood, drought and soil degradation control, etc.), supporting services (soil formation, nutrient cycling, photosynthesis, biodiversity) and cultural services (cultural and recreational, spiritual, religious and other intangible benefits) (Slizhe et al., 2023). Identifying the potential of ecosystems to provide ecosystem services (ES) is highly dependent on the level of detail and completeness of the baseline ecosystem map. Current instructions for the production of this type of map includes only a few basic types of ecosystems, which function only on a national or international scales and are insufficient for the identification of the full potential of ecosystem services at local or regional scales (Kruczkowska, Solon and Wolski, 2017). In the EU, mapping and assessment of ecosystems and their services, abbreviated as MAES, is considered a key activity for achieving biodiversity targets and informing the development and implementation of related policies in the water, climate, agriculture and forestry sectors (Maes et al., 2016).

Recent interest in the economics of biodiversity and broader ecosystem services has been expressed empirically as a focus on economic valuation. This emphasis has been stimulated by a growing recognition that the benefits and costs of opportunities associated with such services are often superficially reflected, or even ignored, in policy analyses. The valuation of biodiversity and ecosystem services is therefore increasingly seen as a key element of sound decision-making, as reflected in a growing amount of relevant research (Atkinson, Bateman and Mourato, 2012; Tinch et al., 2019).

Prices of marketed goods and services are readily available and are considered to be indicators of their value. However, determining the monetary value of non-marketed goods and services requires the application of specific valuation methods (Deniz and Ok, 2016). Traditionally, project benefits have been assessed using the reproduction cost method (RCM) or cost-benefit analysis (CBA). At present, however, environmental economics offers alternative methods, such as conditional valuation (CV) and others based on stated preferences, whose main advantage is their ability to capture non-utility and future utility values, which are essential for monetary valuation. Comparisons show that CV estimates of net environmental benefits are almost twice as high as estimates obtained using standard methods (Almansa, Calatrava and Martinez-Paz, 2012; Deniz and Ok, 2016; Damayanti, Bambang and Soeprobowati, 2018). Other methods include willingness to pay (WTP) and willingness to accept (WTA). These are the main tools of the conditional valuation (CV) method, and the willingness to pay method in particular is widely used in the valuation of public goods and ecosystem services in many parts of the world (Liu, 2020; Sourokou et al., 2023).

The modified WTS method was subsequently developed. WTS leads to the achievement of a reasonably balanced price through public valuation of the value of public goods or ecosystem services, rather than the cost of production of a provider (Chang and Yoshino, 2017). In particular, it points to the weakness of the main economic approaches to valuation, growth and development. It concludes that the substantial contributions of ecosystem services to the sustainable well-being of people and the rest of nature should be at the heart of a fundamental shift in both economic theory and practice that is needed if we are to achieve social transformation towards a sustainable and desirable future (Costanza et al., 2017).

Water retention in the landscape is a highly relevant issue in the context of climate change, and a number of research studies have looked at it from an ecosystem services perspective. Results from China, for example, show that soil surface moisture changes dramatically with the seasons. Forests, grasslands, croplands and pastures retain more than 80% of the total soil moisture, which plays an important role in water conservation and quality (Deng, Li and Feng, 2011). In the Azores, peat bogs, as water retention structures, promote landscape equilibrium and reduce the frequency of major events such as landslides. However, these ecosystems are facing increasing disturbance and changes in land use that challenge the future security of these critical ecosystem services. Higher elevations and pristine areas represent the largest hydrological reservoirs and natural sources of water management services (Pereira, Mendes and Dias, 2022). Studies have focused on mangrove ecosystems and their impact on the provision of ecosystem services, or the impact of mineral extraction on forest ecosystems (Sannigrahi et al., 2020; Dushin et al., 2020).

As one of the factors of production, soil is primarily associated with agricultural production, which provides food for the human population. Climate change caused by global warming will make this fundamental task increasingly difficult in the coming years, as it is an activity that is highly dependent on and sensitive to climate change. Population growth is another reason (Tesfaye et al., 2015). Therefore, it is imperative to understand the interactions between climate and agricultural production, especially in light of the increased likelihood of droughts, rainfall variability and rising average temperatures (Hui et al., 2013; Orlandi et al., 2020). The impacts of climate change on food production have been examined in numerous studies, which typically differ in their focus on specific crop types (Zhu et al., n.d.; Yang et al., 2021; Gamal, Samak and Shahba, 2021; Zhang et al., 2021). However, climate change also primarily affects ecosystem services, and can have both positive and negative impacts on adaptation (Lungarska and Chakir, 2024). Databases of soil surveys, soil analyses, soil data systems and enterprise soil systems provide tools and a wide range of quantitative and qualitative data and information for valuation. Assessment of soil resources based on pedological and non-pedological scientific databases is essential for decision-making to ensure more sustainable use of soil resources (Mikhailova et al., 2020).

In this context, the term "soil security" is used, which can only be achieved by conserving and improving global soil resources, which requires a reversal of current degradation processes (Bouma, 2015). In addition to climate change, food production is affected by the physical and chemical properties of soil, especially by its hydrological properties. The goal of agricultural production should be sustainable food production, which requires an understanding of the balance between productivity itself and ecological management (Thao et al., 2023).

Agriculture in areas with limited water availability is possible thanks to irrigation. Irrigated agricultural land is expanding and the demand for irrigation water is increasing. However, there is limited understanding of how much water is used for irrigation and how efficient irrigation increases crop productivity under different climatic conditions. Results indicate that soil hydraulic properties have a very strong influence on the assessment and efficiency of irrigation water (Soylu and Bras, 2024).

Food production and biodiversity are more sensitive to changes in arable land and water regulation, and soil retention is more sensitive to changes in vegetation composition (Sannigrahi et al., 2020). Ecosystem services can also influence the value of land in a cadastral area. Results show that if these ecosystem services are not included in the sale price of a plot of land, its value and price are underestimated, encouraging unorganised forms of urban expansion (Paris et al., 2023).

Soil is a very specific factor of production, as its characteristics do not allow it to be reproduced or relocated, and it is limited in extent. For these reasons, it is very important to protect this source of production for future generations (Pérez-Soba et al., 2001). A very sensitive aspect of soil is certainly the determination of an appropriate price for soil (especially agricultural soil). Worldwide, different methodological approaches and valuation systems are used for this purpose, which can differ significantly, especially depending on the definition of the qualitative parameters of the soil, but also on the mechanism for determining the final price of the land. In the European area, there are generally two basic trends in land valuation, which can be characterised as maximally simplifying mechanisms (usually based only on the market price determined by market supply and demand) and systems which, on the other hand, take into account a wide range of soil characteristics/effects. Scientific work thus provides a possible comparison, where the expansion of multi-criteria land valuation systems is likely, in view of the direction of future agricultural policy and the growing importance of agricultural land for food security; see e.g., Tezcan et al. (2020), Asiama et al. (2017), Cay et al. (2010), Choumert and Phélinas (2015), Niroula and Thapa (2005) and Jürgenson (2016).

The two valuation options, in terms of both market and official land prices, are primarily based on the production potential of the agricultural land or other factors (land shape, access to land, etc.). As a result, the resulting price does not include non-productive functions that are important for human society and the biosphere.

It is clear from the above review that ecosystem services are a very broad concept, ranging from water retention in the soil to religious or spiritual benefits. The aim of this paper is to model the change in the value of land plots in two different cadastral areas (selectively chosen to represent typical regions of the Czech Republic) when taking into account the retention capacity of soils, i.e. including the ecosystem service in the total price of the land, in three basic scenarios based on the main soil units (MSU) structure:

1) Inclusion of the effect of holding capacity on production potential at 5%.
2) Including the effect of retention capacity on production potential at 10%.
3) Including the effect of retention capacity on production potential at 20%.

The results of the article can serve as supporting material for the relevant state administration authorities (State Land Office, Ministry of Agriculture). Inclusion of soil retention capacity in ESEU prices would have an impact on the Valuation Decree No. 441/2013 Coll., which will subsequently be reflected in other laws.

Materials and methods

The basis for the valuation of agricultural soils is evaluated soil-ecological units (ESEU), which is recorded in numerical and cartographic documents. The evaluated soil-ecological unit expresses, by means of a five-digit numerical code, the main soil and climatic conditions affecting the productive capacity of agricultural land and its economic valuation. Data on evaluated soil ecological units are provided by the State Land Office in the national database of ESEU. The characteristics of the evaluated soil ecological units and the procedure for their maintenance and updating are determined by the Ministry of Agriculture by decree. In the conditions of the Czech Republic, the ESEU price is used for valuation, which is historically based only on the production function of the soil through the production potential of individual areas. The production potential and the resulting protection classes play an important role in landscape planning and regional development.

The main objective of the presented paper is to incorporate the non-productive function, in the form of soil retention capacity, into the price of individual ESEU and to estimate the increase in land value in two selected cadastral areas according to defined scenarios. The reason for including the non-productive function (retention capacity) is also that some soils may have a low productive potential but at the same time be very valuable for the site in terms of non-productive potential (typically desirable water retention during floods, etc.). In order to determine the prices of ESEU increased by the retention capacity, and thus the value of the land in the cadastral area, the econometric model previously estimated, specified below, was used to determine the effect of retention on the production potential.

A structural econometric model is used to study the effect of soil characteristics on retention capacity and the effect of retention on production potential. The structural econometric model, as opposed to the reduced form model, provides better insights into the marginal effects of the variables used on both retention capacity and production potential. The relationships are deliberately specified as a recursive system of equations, mainly to avoid the endogeneity problem. At the same time, in order to fulfil the objectives of the work, it is necessary to take into account the effect of other influences on the explained retention capacity, which leads to the construction of a recursive model.

To achieve the main objective of the paper, an econometric approach will be used, using a previously published model that will allow for the estimation of changes in production potential when specific soil influences are included. The model has been presented in detail in the publication Land Valuation Systems in Relation to Water Retention (Slaboch and Malý, 2023), however, the model can be simplified as follows:

$$\begin{aligned} y_{1ij} = {} & \sigma_1 + \beta_{11} * x_{1ij} + \beta_{12} * x_{2ij} + \beta_{12}^{*} * x_{2ij}^{2} + \\ & + \beta_{13} * x_{3ij} + \beta_{14} * x_{4ij} + \beta_{15} * x_{5ij} + \\ & + \textstyle\sum_j \alpha_{1j} * D_j + \varepsilon_{1ij} \\ y_{2ij} = {} & \sigma_2 + \gamma_{21} * \hat{y}_{1ij} + \beta_{21} * x_{1ij} + \beta_{23} * x_{3ij} + \\ & + \textstyle\sum_k \beta_{26k} * x_{6kij} + \sum_j \alpha_{2j} * D_j + \varepsilon_{2ij} \qquad (1) \end{aligned}$$

where y_{1i} stands for retention capacity, y_{2i} is production potential and the regressors are: x_{1i} – porosity; x_{2i} – humus; x_{3i} - grain size; x_{4i} – pH CKl; x_{5i} – soil profile depth; and x_{6ki} – is dummy variable for k-th hydrologic soil group. D_j is j-th dummy variable. Then, *i* indexes main soil unite and j climatic region. *α, β, γ* and *σ* are parameters to be estimated.

Each equation of model (1) can be viewed as a least square dummy variable (LSDV) model and is estimated using least square estimator with:

$$X_* = M_d X \quad \text{and} \quad y_* = M_d y \qquad (2)$$

where $M_d = I - D(D^TD)^{-1} * D^T$

and X is a matrix of regressors, y is a vector of dependent variable and D is a matrix of dummy variables.

Moreover, we assume the strict exogeneity of regressors in model (1). To avoid potential heteroscedasticity problems related to the biased estimate of the covariance matrix, robust standard errors of the parameters are calculated.

The resulting estimate of the model determining the production potential of the area depending on soil properties was determined as follows (Slaboch and Malý, 2023) (Table 1).

On the basis of the estimate obtained, we quantified the effect of retention on production potential under the assumed scenarios and then precisely quantified the resulting official price of land in the study regions. For this purpose, data from the Research Institute for Soil and Water Conservation (RISWC) are used, which define the ESEU codes for the given cadastral area, including the land area; the results are then compared for both sites and the effect of the price increase for each ESEU on the value of the cadastral area is evaluated.

The aim is therefore to show the influence of the non-productive function (retention capacity) on the selected sites, which in the conditions of the Czech Republic is not included in the valuation, but may have a significant impact on the price in case of inclusion. For the purpose of this article, three alternative scenarios are presented, which may serve as supporting material for the authorities concerned. Inclusion of soil retention capacity in ESEU prices would have an impact on the Valuation Decree No. 441/2013 Coll., which is subsequently reflected in other laws.

For a relevant comparison, we selected sites whose structure and soil properties make them typical regions in the Czech production zones, i.e. key regions for agricultural production.

Site 1 (Ivančice):

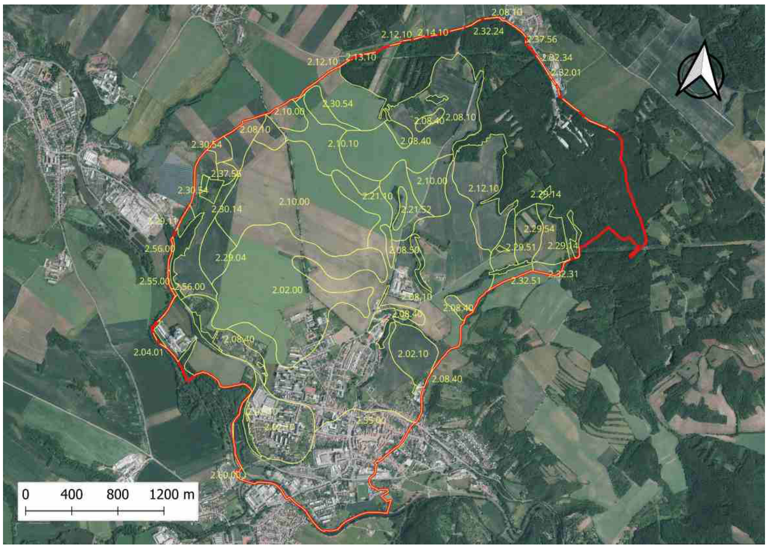
The selected site is detailed in Figure 1, which clearly shows the soil blocks according to the ESEU classification. The entire cadastral area falls within climate region 2.

The total area of the second study site is 1531.26 ha. Figure 2 below shows its detailed structure. The structure of the MSUs affects the overall value of the selected site, so the structure, including the categorisation into protection classes, is described below. It is clear that the largest share of the cadastral area is occupied by MSU 55,

Number of obs. = 486						
F(15,470) = 239.55						
Prob > F = 0.0000						
R-squared = 0.7254						
Root MSE = 11.377						
Prodpot	Coefficient Coefficient	Std. err.	t	P>|t|	[95% conf. interval]	
Retention_predicted_0	0.11231	0.005626	19.970	0.000	0.10126	0.123368
Granularity	0.53909	0.709976	0.760	0.448	-0.85603	1.934211
Porosity	0.38512	0.066809	5.760	0.000	0.25384	0.516399
HSP_A	18.31641	3.062413	5.980	0.000	12.29869	24.334120
HSP_B	16.00687	1.885650	8.490	0.000	12.30152	19.712210
HSP_C	12.85021	2.047846	6.270	0.000	8.82614	16.874280
KR						
1	-6.45611	1.73492	-3.720	0.000	-9.8653	-3.04695
2	1.43243	3.62493	0.400	0.693	-5.6906	8.55551
3	1.11994	1.62536	0.690	0.491	-2.0739	4.31380
4	-8.34180	1.60658	-5.210	0.000	-11.4864	-5.19722
5	-8.08002	1.67247	-5.030	0.000	-11.2370	4.92306
6	-6.56621	1.67247	-3.930	0.000	-9.8527	-3.27976
7	-12.24967	1.63649	-7.490	0.000	-15.4654	-9.03393
8	-16.83460	1.82562	-9.220	0.000	-20.4220	-13.24720
9	-24.41644	2.12075	-10.100	0.000	-25.5838	-17.24912
_cons	21.99123	5.21171	4.220	0.000	11.7501	32.23237

Source: own estimation according to data from RISWC (Slaboch and Malý, 2023)

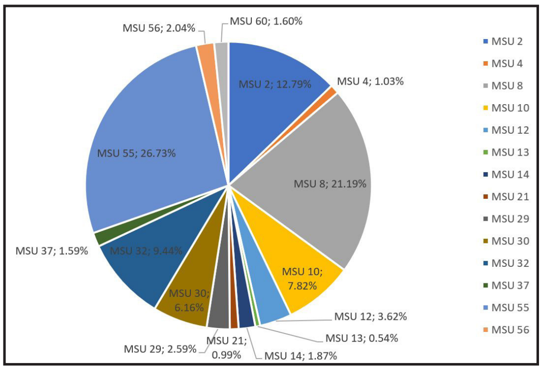
Table 1: Econometric model for calculating the production potential of individual MSU in climatic regions.



Source: own processing, RISWC

Figure 1: Cadastral area - Invančice.

which occupies 26.73%, or 409.24 ha in absolute terms. The genetic soil representatives of MSU 55 are psephitic fluvisol, arenic fluvisol, stratified fluvisol, gleyed fluvisol, arenic phaeozem and arenic colluvisol. These are soils with average to slightly above-average production potential, but classified within KR0-KR4, among soils at risk of wind erosion with lower retention capacity. MSU 8 occupies a significant share (21.19%), with an absolute area of 324.48 ha. Its genetic soil representatives are modal chernozem, modal brown earth, luvic brown earth and modal luvisol. These are soils with average to slightly above average production potential and high retention capacity. MSU 2 has the third highest share, namely 12.79%, covering 195.88 ha in absolute terms. The genetic soil representatives of MSU 2 are luvic chernozems and weakly gleyed luvic chernozems. These are soils with very high production potential and high retention capacity. The MSU 10 and 32 are noteworthy in terms of their proportions. The share of MSU 32 is 9.44%, covering 144.58 ha in absolute terms. Its genetic representatives are modal to mesobasic cambisols and arenic cambisols, including weakly gleyed variants. These soils have average to slightly above average production potential with low retention capacity. MSU 10 occupies 7.82% of the area, which is 119.71 ha in absolute terms. The genetic soil representatives are modal brown earth and modal weakly gleyed brown earth. These are soils with high to very high production potential and high retention capacity. The proportion of other MSU on the selected site is very low, ranging from 1.03 to 6.16%. MSU 30 occupies 6.16% of the cadastral area, or 94.3 ha in absolute terms. The genetic representatives are modal to mesobasic cambisol, pararendzina modal and pararendzina cambic. These are soils with average production potential and average retention capacity. MSU 12 occupies 3.62% of the cadastral area, or 55.4 ha in absolute terms. The genetic representatives are brown earth modal, cambisol modal and luvic cambisol. These are soils with average to slightly above average production potential and high retention capacity. MSU 29 occupies 2.59% of the cadastral area and 39.7 ha in absolute terms. The genetic representatives are the cambisol modal and the cambisol mesobasic. These are soils with average to slightly above average production potential and higher retention capacity. MSU 56 occupies 2.04% of the cadastral area and 31.2 ha in absolute terms. The genetic representatives are modal and mesobasic fluvisol, cambrian fluvisol and colluvisol modal. These are soils with slightly above average to high production potential and high retention capacity. MSU 14 occupies 1.87% of the cadastral area, or 28.6 ha in absolute terms. The genetic representatives are luvisol modal and brown earth luvic. These are soils with slightly above average to high production potential and high retention capacity. MSU 60 represents 1.60% of the cadastral area and 24.4 ha in absolute terms. The genetic representatives are modal chernitzas, chernitzas arnica and chernitzas fluvic. These are soils with very high production potential and high retention capacity. MSU 37 occupies 1.59% of the cadastral area and 24.3 ha in absolute terms. The genetic representatives are cambisol lithic, ranker modal and parendzina lithic. These are soils with low to average production potential and very low retention capacity. MSU 4 occupies 1.03% of the cadastral area, or 15.7 ha in absolute terms. The genetic representative is black earth arenaceous. These are soils with average to slightly above average production potential and low retention capacity. MSU 21 has a share of 0.99% of the cadastral territory, in absolute terms it is 15.1 ha. The genetic representatives are cambisol arenic, pararendzina arenic and fluvisol arenic. These are soils with slightly below average to average production potential and very low retention capacity. MSU 13 has a share of 0.54 % of the cadastral area, in absolute terms it is 8.3 ha. The genetic representatives are brown earth modal, luvisol modal, fluvisol modal and fluvisol stratified. These are soils with slightly above average to high production potential and medium retention capacity. See Figure 2 for more detail.



Source: own processing

Figure 2: Relative structure of main soil units (MSU) – cadastral area Ivančice.

The current legislation (Decree No. 48/2011 Coll.) establishes protection classes for individual blocks of soil, precisely in relation to the level of production potential. These protection classes have a significant impact on spatial planning within municipalities and urban areas, while soils with high production potential can hardly be used for non-agricultural purposes, typically in the context of conversion to building land, etc. There are five classes of protection for agricultural land:

I. Class I: The most valuable soils in individual climatic regions, mainly in flat or slightly sloping areas, which can only be withdrawn from the agricultural land fund in exceptional cases, mainly for projects related to restoring the ecological stability of the landscape or for linear constructions of fundamental importance.

II. Class II: Agricultural soils with above-average productive capacity within individual climatic regions. With regard to the protection of agricultural land, these soils are highly protected, only conditionally withdrawable and with regard to landscape planning only conditionally developable.

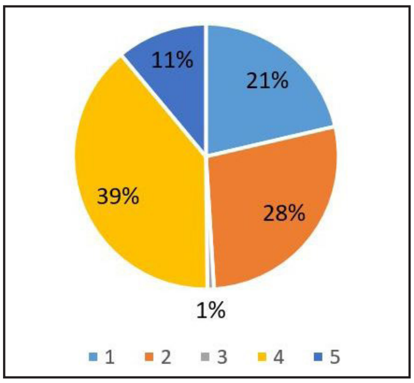
III. Class III: Soils with average productive capacity and medium level of protection, which can be used for development in landscape planning.

IV. Class IV: Soils with predominantly below average productivity within the relevant climatic region and with limited protection, suitable for development.

V. Class V: Soils with very low productive capacity, including shallow, very sloping, hydromorphic, gravelly to stony soils and soils highly susceptible to erosion. These are mostly agricultural soils that are not suitable for agricultural use. More efficient non-agricultural uses can be expected for these soils.

It is clear from the above that the determination of the production potential and the protection class derived from it play a crucial role in spatial planning and regional development. Production potential affects the price itself: the higher the production potential, the higher the price of the ESEU. Current practice has been to use the official values of production potential, but these are seriously outdated (often more than 20 years old) and do not correspond to changes in the landscape and geoclimatic development. Another relatively common problem is the lack of production potential values for newly created soil blocks or re-evaluated soil units.

The detailed structure for the cadastral area of Ivančice is shown in Figure 3. The figure shows that 49% of the cadastral area falls into protection classes I and II, i.e. soils with high to very high production potential, which in absolute numbers amounts to 750.69 ha. Only 1% of the cadastral area is in protection class III. The remaining 50% of the cadastral area is occupied by soils with below average to very low production potential (protection classes IV, V), typically without agricultural use.



Source: own processing

Figure 3: Structure of protection classes – cadastral area Ivančice.

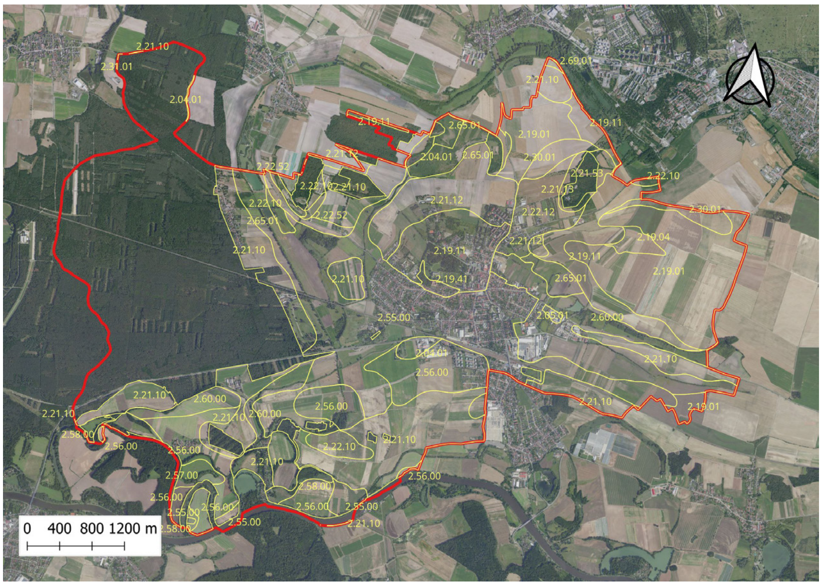
Site 2 (Lysá nad Labem):

The selected site is detailed in Figure 4, which clearly shows the soil blocks according to the ESEU classification. The entire cadastral area falls within climate region 2.

The total area of the cadastral territory of Lysá nad Labem is 5090.02 ha. Figure 5 shows that it contains 15 different main soil units (MSU). The structure of the MSU affects the total value of the selected area, therefore the structure, including the categorisation into protection classes, is described below. MSU 21 has the largest share (38.03%), covering 1936 ha in absolute terms. The genetic soil representatives of MSU 21 are arenic cambisol, arenic regosol, arenic pararendzina and arenic fluvisol. These are soils with average production potential, but they are classified within KR0-KR4, among the soils at risk of wind erosion with lower retention capacity.

The second highest share is held by MSU 19, namely 30.43%, covering 1549 ha in absolute terms. Thus, these two dominant MSUs account for almost 70% of the size of the cadastral area under study. The genetic soil representatives of MSU 19 are modal pararendzina, cambic pararendzina and bleached pararendzina. These are soils with average to slightly above average production potential. These soils are not threatened by wind erosion and have an average retention capacity.

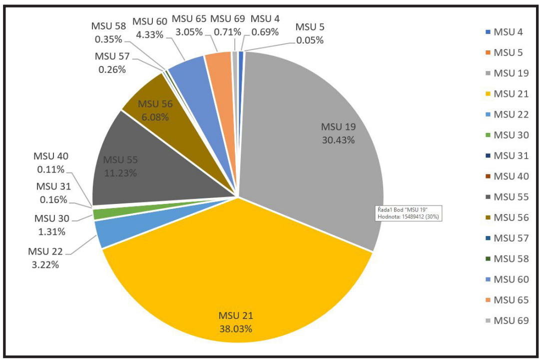
MSU 55 has the third highest share, namely 11.23%, with an absolute area of 571 ha. The genetic soil representatives of MSU 55 are psephitic fluvisol, arenic fluvisol, stratified fluvisol, gleyed fluvisol, arenic phaeozem and arenic colluvisol. These are soils with average to slightly above-average production potential, but within KR0-KR4, soils at risk of wind erosion with lower retention capacity. The proportion of other MSU on the selected site is very low, ranging from 0.05 to 6.08%. MSU 56 occupies 6.08% of the cadastral area, or 309.5 ha in absolute terms. The genetic representatives are fluvisol modal to mesobasic, fluvisol cambic to mesobasic and colluvisol modal. These are soils with medium to high production potential and high retention capacity. MSU 60 accounts for 4.33% of the cadastral area and 220.3 ha in absolute terms. The genetic representatives are modal chernitzas, chernitzas arnica and chernitzas fluvic. These are soils with very high production potential and high retention capacity. MSU 22 occupies 3.22% of the cadastral area, or 163.8 ha in absolute terms. The genetic representatives are cambisol modal, cambisol psephitica, leptosol modal and leptosol psephitica. These are soils with below average to average production potential and lower retention capacity. The MSU 65 occupies 3.05% of the cadastral area and 155.2 ha in absolute terms. The genetic representatives are modal to aquic gley, peaty gley, histic gley and organosol. These are soils with low to below average production potential and low retention capacity. MSU 30 occupies 1.31% of the cadastral area, or 66.4 ha in absolute terms. The genetic representatives are cambyseol modal to mesobasic, pararendzina modal and pararendzina cambic. These are soils with average production potential and average retention capacity. MSU 69 occupies 0.71% of the cadastral area, or 35.9 ha in absolute terms. The genetic representatives



Source: own processing, RISWC

Figure 4: Cadastral area – Lysá nad Labem.

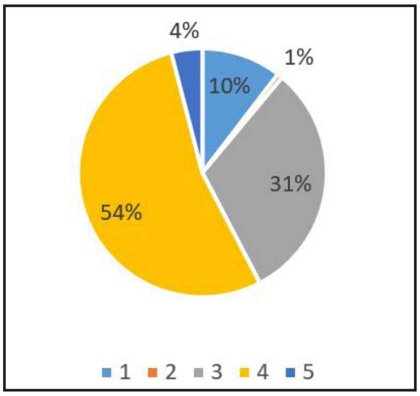
are the aquic gley, histic gley and the organosol. These are soils with very low production potential and very low retention capacity. The MSU 4 occupies 0.69% of the cadastral area, or 34.8 ha in absolute terms. The genetic representative is black earth arenaceous. These are soils with average to slightly above average production potential and low retention capacity. MSU 58 occupies 0.35% of the cadastral area, or 18.07 ha in absolute terms. The genetic representatives are gleyed fluvisol and weakly gleyed fluvisol. These are soils with average to above average production potential and medium retention capacity. MSU 57 occupies 0.26% of the cadastral area, or 13.4 ha in absolute terms. The genetic representatives are eubasic to mesobasic fluvisol and clayic colluvisol. These are soils with medium to high production potential and high retention capacity. MSU 31 occupies 0.16% of the cadastral area, or 8 ha in absolute terms. The genetic representatives are cambisol arenic to mesobasic, pararendzina arenic and pararendzina cambic. These are soils with average production potential and low retention capacity. MSU 40 occupies 0.11% of the cadastral area, or 5.3 ha in absolute terms. The genetic representatives are all soils with a slope of more than 12 degrees. These are soils with very low to below average production potential and low retention capacity. MSU 5 occupies 0.05% of the cadastral area, or 2.7 ha in absolute terms. The genetic representatives are modal chernozem, luvic chernozem and modal fluvisol. These are soils with above average production potential and medium retention capacity. See Figure 5 for more details.



Source: own processing

Figure 5: Structure of main soil units – cadastral area Lysá nad Labem

Figure 6 below shows the structure of protection classes in the selected cadastral area. It can be seen that only 11% of the cadastral area consists of the most valuable soils with above-average productive capacity (protection classes I, II). Conversely, 58% of the area is made up of soils with below-average or very low productivity (protection classes IV, V). Soils of average production capacity (protection class III) cover 31% of the area.



Source: own processing

Figure 6: Structure of protection classes – cadastral area Lysá nad Labem.

Results and discussion

This section characterises the results of the effect of soil retention on the determined price for the cadastral areas defined above using the specified production potential model. Including the ecosystem service of soil retention capacity generally changes the prices of individual ESEUs in the area, which has a positive impact on the resulting soil value quantified on two study sites.

Site 1 - Ivančice

Table 2 works with the quantified land price increase due to the defined scenarios of including the ecosystem component for Site 1. The first column divides the selected area into protection classes, the second column indicates the size of the area (m2), the third column indicates the value of the cadastral area according to the currently valid valuation decree, and the last columns calculate the value including the soil retention capacity according to the defined scenarios.

Plaas et al. 2019 found that soil biodiversity in Europe is deteriorating as a result of continued agricultural intensification and climate change. Healthy soils help prevent erosion, retain water in the landscape and stabilise crop yields. As noted by Zhao et al. (2022), considering only the production function when managing soil is not advisable in the long run, as it may lead to gradual soil degradation and weakening of other ecological functions. Precisely for this reason, our results focus on increasing the cadastral land value in the light of the soil's retention capacity.

In protection class I, the value of the land is set at CZK 53.284 million by the valuation decree (i.e. the average price is CZK 16.29/m^2). If the valuation includes an increase for retention capacity in the maximum assumed amount of 20%, the price of this protection class would increase to CZK 57.899 million, which is a relative increase of 8.66%, with a new average price of CZK 17.70/m^2.

For protection class II, the quantified value is CZK 52.541 million, with an average price of CZK 12.40 per m^2. Again, from Table 2 it can be seen that a 20% increase in the price of MSU due to retention would result in a value of CZK 58.023 million, which is a relative increase of 10.43%, with a new average price of CZK 13.70 per m^2. The higher price increase compared to protection class I is due to the higher retention capacity of MSU in protection class II.

For protection class III, the base land price is set at 1.269 million CZK, with an average price of 10.33 CZK/m^2; the relatively low value is mainly due to the fact that this protection class covers only 1% of the cadastral area. Taking into account the retention capacity in scenario 3, the value increases to CZK 1,340 million, which is a relative increase of 5.56%, with a new average price of CZK 10.91 per m^2.

As already mentioned, the largest share of the total area of the cadastral area under investigation is occupied by protection class IV (39%). In this case, the base price is CZK 49.755 million, with an average price of CZK 8.31 per m^2. In the last scenario, the value would increase to CZK 51.554 million, which is a relative increase of 3.61%, with a new average price of CZK 8.61/m^2.

Finally, protection class V includes mainly soils with very low production potential, with a base price of CZK 7.590 million (average price of CZK 4.48/m^2). Again, the application of the maximum scenario leads to an increase in value to CZK 7.971 million, which is a relative increase of 5.02%, with a new average price of CZK 4.71 per m^2. In summary, for Site 1 it can be concluded that the inclusion of ecosystem services at the 20% level would increase the total value of the cadastral area from CZK 164.441 million to CZK 176.788 million, which is a non-negligible relative increase of 7.51%.

Site 2 – Lysá nad Labem

Table 3 works with the quantified soil price increase due to the defined scenarios of including the ecosystem component for Site 2. The first column divides the selected area into protection classes, the second column indicates the size of the area (m^2), the third column indicates the cadastral value of the area according to the current valuation decree, and the last columns calculate the value including the soil retention capacity according to the defined scenarios.

In protection class I, the current land value is set at CZK 80.921 million (i.e. the average price is CZK 15.27/m^2) by the valuation decree. Taking into account a 20% increase for retention capacity, the value rises to CZK 88.185 million, i.e. a relative increase of 8.97%, with a new average price of CZK 16.64/m^2. For protection class II, the calculated value is CZK 3.703 million; in this case, the average price in this class is CZK 10.81/m^2. Again, from Table 1 it can be seen that a 20% increase in the ESEU price due to retention would result in a value of 3.973 million CZK, which is a relative increase of 7.28%, with a new average price of 11.60 CZK/m^2.

For protection class III, the calculated value is CZK 174.165 million, with an average price of CZK 10.94/m^2. The high value is due to the fact that this protection class accounts for 31% of the assessed cadastral area. Taking into account the retention capacity under Scenario 3, the value increases to CZK 181.825 million, which is a relative increase of 4.39%, with a new average price of CZK 11.42/m^2. As already mentioned, the largest share of the total area of the cadastral territory is occupied by protection class IV

Protection class	Area (m^2)	Cadastral area value	Cadastral area value - 5R	Cadastral area value - 10R	Cadastral area value - 20R
1	3271166	53 284 415	54 438 122	55 591 829	57 899 243
2	4235727	52 541 838	53 912 224	55 282 611	58 023 384
3	122869	1 269 570	1 287 218	1 304 866	1 340 161
4	5988848	49 755 174	50 204 912	50 654 651	51 554 128
5	1693985	7 590 384	7 685 780	7 781 176	7 971 967
Sum	15312595	**164 441 383**	**167 528 258**	**170 615 134**	**176 788 885**

Source: own processing

Table 2: Cadastral area value – Ivančice (CZK).

Protection class	Area (m²)	Cadastral area value	Cadastral area value - 5R	Cadastral area value - 10R	Cadastral area value - 20R
1	5298723	80 921 311	82 737 476	84 553 641	88 185 972
2	342490	3 703 284	3 770 761	3 838 238	3 973 191
3	15918500	174 165 949	176 080 714	177 995 479	181 825 008
4	27285397	156 164 040	157 449 928	158 735 817	161 307 594
5	2057183	6 984 961	7 047 435	7 109 909	7 234 857
Sum	50902293	**421 939 548**	**427 086 317**	**432 233 085**	**442 526 622**

Source: own processing

Table 3: Cadastral area value – Lysá nad Labem (CZK).

(54%). In this case, the calculated value is CZK 156.164 million, with an average price of CZK 5.72/m^2. In the last scenario, the value would increase to CZK 161.307 million, which is a relative increase of 3.29%, with a new average price of CZK 5.91/m^2.

Finally, protection class V, which is intended for soils with very low production potential, is worth CZK 6.984 million and the average price is CZK 3.40 per m^2. Again, the application of the last scenario leads to an increase in value to CZK 7.234 million, which is a relative increase of 3.57%, with a new average price of CZK 3.52/m^2. Looking at the total value of the cadastral area, it increases from CZK 421.939 million to CZK 442.526 million, which is a relative increase of 4.87%.

An overall comparison of the two selected sites clearly shows that the main effect of including ecosystem services is to significantly change (increase) the value of the land in the area, which applies equally to both sites. The difference between the sites lies in the dynamics of the increase, which is mainly influenced by the different structure/representation of the different protection classes; nevertheless, two main effects can be observed from the results of Tables 2 and 3. At the same time, the relative increase in the proportion of water retention is not directly proportional to the relative increase in price, which ultimately leads to a faster rate of price increase for site 1, although the differences between the assumed scenarios are greater in absolute terms.

An assessment of the hydrological cycle and water retention in wetland soils has been carried out in Mexico and found different retention capacities for different soil types (Cejudo et al. 2024). However, the study did not quantify the monetary value of these ecosystem services.

Ecosystem service valuation has also been carried out in China, specifically in the Guangdong-Hong Kong-Macau Greater Bay Area. In this case, several ecosystem services were valued, in particular habitat quality, carbon storage and soil retention. The results show that the total value of ecosystem services for the area was 4.2 billion yuan, and the results are applicable to ecological compensation in urban agglomerations (Wu, Huang and Jiang, 2022). It is clear that ecosystem services can have a very significant value for a given area.

Therefore, many studies have addressed ecosystem services (including soil retention capacity) from the perspective of urban agglomeration development (Zhang et al., 2022) or disproportionate development of forest or arable land (Yan and Li, 2023).

In the EU, mapping and assessment of ecosystems and their services, abbreviated as MAES, is considered a key activity to achieve biodiversity targets and to inform the development and implementation of related water, climate, agriculture and forestry policies (Maes et al., 2016).

Soil retention capacity is also influenced by climate change, landscape composition and land use. From this perspective, it is important to identify the drivers of ecosystem services in a global context, thus providing a practical tool for soil management (Bai, Ochuodho and Yang, 2019).

Conclusion

The main objective of the paper was to demonstrate the importance of including soil retention capacity in the land pricing mechanism, especially with regard to the ever-increasing demands of soil water management in agricultural production, but also from the perspective of environmental protection in the context of current climate change. The current system of official land prices, based on normative methods with fixed evaluation criteria, obviously has many advantages, including the relative simplicity and clarity of expressing the value of a selected block of soil. However, the current changing natural conditions are leading to radical changes, both geoclimatic and ultimately economic, and it is probably highly desirable to analyse and respond to these changes. One of the primary and vital aspects is the issue of water availability and management, which is closely linked to soil management, as agricultural land is a crucial factor in water retention in the landscape and its continued agricultural productive use.

In the context of these changes, the current system of soil evaluation appears to be at least inflexible, or even outdated and inappropriate, because parameters related to water absorption and retention capacity of soils are minimally or not at all reflected in the existing system. Therefore, the main objective of this paper was to determine the influence of the non-productive function of soil in the form of retention on the value of land in a case study of two production significant areas of the Czech Republic. The results show that even a small increase in the share of the water retention indicator in the soil price quantification methodology has a significant impact on its value. We analysed three alternative scenarios (5%, 10% and 20%); all options increased the original quantified prices by millions of crowns per site. The difference between the original price and the shadow price with the highest share of water retention at the 20% level was approximately CZK 12.3 million for the Ivančice site and approximately CZK 20.6 million for the Lysá nad Labem site, indicating the importance of changing the current government methodology, as the water retention capacity of soils is and will be increasingly supported as a qualitative indicator. With regard to the production function of soil, the results obtained support the idea of including ecosystem service elements in the land price calculation mechanism. At the same time, it can be implicitly concluded that the importance of soil water retention will be strongly reflected in the non-production function of soil in the near future, as a highly valued means of protecting the landscape and people in the face of increasingly urgent climate variability.

The present results also point to the suitability or interrelationship of other study parameters, as can be seen from the comparison of the two sites, which showed a noticeable difference in the increase of the cadastral area value. The higher increase for the Ivančice site is caused by the higher proportion of more productive ESEU and, at the same time, the higher retention capacity of the MSU, which is absolutely essential for the valuation of agricultural land in the main production areas of the Czech Republic. The results confirm that in these most valuable areas the increased share of ecosystem components would lead to the greatest increase in the price of agricultural land, which can be considered an adequate and meaningful result, if only in the context of the comparison of agricultural land prices (still relatively low in the Czech Republic) among EU Member States.

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