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Article
Land Valuation Systems in Relation to Water Retention

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Abstract: This article uses a derived econometric model to estimate the impact of the physical properties of soil on its retention capacity and, subsequently, the impact of retention capacity on production potential. This is an important aspect considering climate change impacts, which are affecting food production across the world. An investigation of academic publications shows that very few studies address opportunities to price rainwater in relation to agricultural production. As such, the objective of the submitted article is to use soil physical property spatial data to create an econometric model. The econometric model itself determines the intensity and direction of action of the soil's physical properties on the ability of the soil to hold rainwater. The results demonstrate the positive effect of physical properties such as porosity and humus content. Important information for farming practice is the relatively pronounced influence of soil acidity (pH) on its retention capacity, which is mainly the result of its effect on soil biogeochemical processes. The most significant variable in terms of the extent of action is the depth of the soil profile, which is in line with general assumptions. The actual evaluation of soil retention capacity was undertaken using an option with the use of a sensitivity analysis. In order to include the non-production function of the soil (retention capacity), we conclude for individual enhanced quality soil ecological units an increased price of 1–12%. These conclusions are particularly valuable because some soils may have a low production potential while also being highly valuable for their particular location in terms of their non-production potential (typically desirable floodwater retention, etc.). Considering climate change, this is a particularly topical issue. The use of enhanced-quality soil ecological units is reflected in a wide range of fields through legislative processes—determining rural land protection class and, especially in the tax obligations of agricultural entities, farming agricultural land.

Keywords: soil; retention of soil; production potential; physical and chemical properties of soil; econometric modelling; climatic regions

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1. Introduction

Water and soil are natural resources that are essential for the existence and development of human civilisation [1,2]. In regions of the world afflicted by water shortages, economic activities can be limited by water availability, leading to competition both between sectors and between human uses and the needs of the environment [3,4]. To ensure economic efficiency, an equal relationship between the limit value of the product and the marginal value of water should be achieved for all uses and all users [5].

As such, water management, alongside issues of water policy, has become more important internationally in recent years, especially in the context of global warming. For this reason, it is essential to look at innovative proposals for water rights, the modularisation of water supplies, hydroeconomic models, etc. [6–8].

A lack of and degradation of water resources is an important environmental challenge in Europe which the Water Framework Directive, the Urban Waste-Water Treatment Directive, and the Nitrates Directive focus on [9]. Precipitation has fallen significantly in some regions (e.g., the Middle East), resulting in a reduction in the amount of groundwater for irrigation that can be used in agriculture [10]. Technical analysis can be used, for example, to determine the optimal amount of irrigation, and then implement a strategy of penalty prices [11].

Drought itself has a large number of secondary effects, which influence recreation and tourism, pastures, forests, and wood and may have significant indirect impacts on ecosystems and water-dependent species. Despite its significance, the effect of drought within the land management sector is a field that is less researched compared to other water-intensive branches [12].

Actual legislation concerning water in different countries is generally governed by a Water Act. Different countries have almost diametrically opposed approaches to the creation and content of this highly important tool, which defines the rights of different subjects. The 1967 "Greenbelt" law in Mexico, for example, does not correspond to the situation today and does not fulfil the purpose it was originally adopted for. The law completely overlooks a co-operative view on water extraction, including a system for monitoring current consumption, and this may result in unreliable water supply [13]. In contrast, Chile has become a leading global example of a free market approach to water and water resource management [14]. Implementing new approaches and systems for water management may represent a great challenge in large countries, especially in rural areas [15].

From the perspective of agriculture, the above relates to the monitoring of hydrological drought, which affects the reliability of irrigation water supply. From an agricultural perspective, for example, Spain monitors the willingness of agricultural subjects to pay for insurance against this phenomenon [16]. A similar study was made in Tunisia, and its results show that farmers would be willing to pay a higher price (by up to 63%) in order to get better services and stability in terms of water supplies [17]. In general, we can say that in areas affected by climate change, i.e., mainly in warmer and drier areas, there is a considerably higher willingness to pay for the accessibility of irrigation water [18]. Momeni et al. do not agree with increasing the price of irrigation water, stating that water for agricultural use should be free of charge, as it returns to the water cycle, and instead of increasing the cost of water, the objective should be reducing its consumption through the use of new technologies [19].

In terms of actual valuation, we need to differentiate between irrigation water and rainwater. Most studies look at irrigation water for valuation, which is water drawn from groundwater or distributed via irrigation systems from reservoirs or rivers.

In Iran, the sustainable management of water resources is dealt with in the context of preserving environmental needs. Here, a translogarithmic cost function was used to determine water pricing. The results were used to recommend setting an optimal price for inputs, including pesticides, manures, and fertilisers linked to the price of water in order to limit any consequential pollution of the environment [20].

A study was undertaken in China, specifically in the Yellow River basin, looking at the pricing of irrigation water and rainwater (since the pricing of rainwater is heavily overlooked). This information is extremely important for authorities involved in water allocation, and also for investors. The main reason for the study was an increase in total water consumption in the region by a factor of three [21]. Increased water consumption may be the result of population growth, improved socioeconomic conditions, and higher demand for various methods of water use, and as such, an effective charging method is required [22]. In these cases, the price of water can also be set dynamically, which results in a fair and reliable distribution of water amongst involved parties [23]. Areas with water shortages have an extremely inflexible response to water prices, leading to cost inefficiency in terms of water savings. Research shows it is appropriate to incorporate deficit irrigation in the model, making water demand much more flexible [24].

Agriculture is the largest consumer of freshwater resources, with roughly 70 per cent of all extracted freshwater used for food production [25]. For this reason, research into water pricing and valuation is extremely important since agriculture has the greatest potential for saving water [26]. Savings in water consumption can mainly be achieved through technical effectiveness, meaning improved technical efficiency and expanding water-saving irrigation techniques [27]. It is very important to ensure the correct water price rate, and this rate should incorporate the determined impacts on regional agriculture. The reason for this may be the influence of water pricing on sowing methods and commodities grown [28].

If water shortages limit agricultural production, it is also appropriate to invest in research in order to improve productivity. Here, co-operation through PPP projects is ideal, with the public sector investing in research into technologies for water supply and the private sector supplying other inputs [29]. The price of water for the end consumer, which may not reflect all the costs of the public sector on the irrigation infrastructure, may represent a problem. In regard to political interventions in water pricing, it is important to have a broad understanding of the issue [30].

The efficiency of water use directly within the agricultural sector is looked at, e.g., on the island of Lombok, where the objective is to analyse the accessibility and demand for irrigation water. In order to economically determine water pricing, an RIA (residual imputation approach) was used to set the price of irrigation water for various grown commodities (rice, corn, soya beans and peanuts) [31].

Other options for more efficient water management include using agricultural drainage water, which is recultivated using DHS technology. In Egypt, for example, this approach has led to a reduction in water volume used to grow tomatoes by up to 22%, while also achieving greater yield per hectare [32].

In some parts of the world, groundwater may be of poor quality, making it a limited value input for farmers [33]. Pesticides as the most efficient means for killing weeds, for example, may have negative impacts on groundwater and surface water [34]. The transfer of pesticides and herbicides to water is affected by the type of soil, hydrology (soil hydrologic group), river basin type, and the sowing methods of individual farmers [35].

Soil structure can be significantly changed by agricultural practices and procedures and also through the effects of its environment. There are growing concerns about interdependent environmental problems such as soil degradation, desertification, erosion, the greenhouse effect, and climate change [36]. Practices and procedures that increase productivity and reduce soil disturbance result in better soil aggregate stability [37]. Organic soil modifications may improve hydrophysical properties and potentially improve the resistance of agricultural systems to drought and flooding. The application of compost, organic residues, and manure, for example, leads to a reduction in volume weight, higher infiltration capacity, and a greater ability to hold water [38–41]. This has also been demonstrated in Sierra Nevada, USA, where adding organic matter to the soil has increased soil retention, giving plants an extra 35 days without water stress during a dry summer [42]. Another benefit of applying compost to clay soils is increased resistance of the soil to water erosion [43]. The effect of organic substances has also been investigated on the yield of wheat grain and husks, where it resulted in yield improvements of up to 22% [44]. Organic matter has a positive impact on total yield and water accessibility for plants, and it is an important element within sustainable agriculture [45].

In Ukraine, land valuation includes not just productivity measured via the yield of individual plants and climate zones but also water regimen models and water regulation technologies on recultivated land [46].

It is evident from the above overview that the issue of water is one that is looked at around the globe and from various perspectives. A common denominator is the pricing of water or approaches to pricing that aim to increase the efficiency of agricultural entities farming on the land. On the basis of an inventory of irrigation equipment in the Czech Republic (CR), we can state that only 190 thousand ha of arable land makes use of various irrigation systems out of a total of 3 million ha of arable land. Thus, most arable land relies on normal precipitation. For this reason, this article focuses on the opportunity of land valuation based on the ability of the soil to be infiltrated by and hold rainwater. The article aims to use an econometric model to determine the intensity and direction of action of soil hydrologic properties on the ability of the soil to hold rainwater and also determine its influence on production potential. Within the Czech Republic, the official land price is used for this purpose, and this is based on the Czech official agricultural land valuation code (BPEJ). The determination of BPEJ price is only based on production potential in terms of food production, and no other important roles of the soil that do not refer to production are incorporated into the price. For this reason, the article outlines the option of and pricing of soil retention capacity for the conditions in the Czech Republic.

2. Materials and Methods

Data from the Research Institute for Soil and Water Conservation (VÚMOP) were used to meet the defined objective: specifically, the data were the physical properties of the principal land units within the BPEJ classification. Public authorities make use of Annex No. 4 of Decree 441/2013 Coll. for determining tax payments and certain grants. The 2013 decree currently in force contains 2172 BPEJ codes as the basic mapping and valuation unit. Looking at this in more detail, the BPEJ code comprises a five-digit number (e.g., 12034). The first digit in the code specifies which climatic region the land belongs to (expressed as 0–9). The climatic region (KR) covers territories with similar climatic conditions for plant growth (average annual temperature, sum of temperatures, average precipitation, likelihood of growing season drought, and guaranteed water during the growing season—in more detail in Appendix A). The second and third digits indicate the main soil unit (HPJ) according to the classification system. The fourth digit indicates a combination of slope and exposure (expressed by a number between 0 and 9) and the fifth digit represents a combination of soil profile depth and skeletonisation (volumetric content of gravel and stone in soil) expressed by a number between 0 and 9. The monitoring of the properties of the CR's land and soils is a complex problem, and as such, the method describes the basic division of input variables in relation to soil retention capacity. Water retention capacity can be characterised as the amount of water that the soil is able to hold in its system of capillary pores and gradually release for the needs of plants. The applied method utilises the BPEJ database and its categorisation into hydrologic groups and data from data banks of physical, chemical, and morphological characteristics and properties of CR land, the results of our own measurements, and published sources. The resulting values of water retention capacity take into account the average profile depth and water content and therefore characterise the actual amount of water that the soil is able to hold when there is precipitation. Similar calculations were undertaken for very stony soils. Subsequently, soils were categorised into five groups with different retention levels, and this classification is given in Table 1. The retention values for HPJ 1–78 range from 15 to 340 L/m^2 (more details in Appendix B).

Table 1. Categorisation of soil water retention capacity according to VUMOP.

Range of Values (L/m^2)	Descriptor
Over 320	High
220–320	Medium–high
160–220	Medium
100–160	Medium–low
Below 100	Low

Source: VUMOP.

Main soil unit (HPJ)

The main soil unit is defined as a synthetic agronomised unit characterised by the purposeful (agronomic) grouping of genetic soil types, subtypes, soil-forming substrates, grain size, soil depth, type and level of hydromorphism, and land relief. The valuation classification system represents 78 HPJ, which from a genetic and agronomic perspective comprises 13 base groups. HPJ and its characteristics are based on Annex 2 of Decree no. 327/1998 Coll., as amended by Decree no. 546/2002 Coll. In future, the number of HPJs may be expanded to include soils affected or created by humans (cultivated and anthropic) and soils produced as a result of the action of water erosion (colluvium).

The following variables based on VUMOP specifications were selected to determine the influence on retention capacity. These are porosity, humus content, grain size, pH CKl, soil profile depth, and soil hydrologic group.

Porosity

Soil is not a compact mass, as there are spaces between the soil particles, which we call pores. These are how water and air penetrate the soil, and we call the overall volume of the pores the soil's porosity. Pores have various shapes and sizes: these include micropores and macropores and capillary or non-capillary pores. Capillary pores are important in terms of water transport within the soil. Non-capillary pores are mainly filled with air and allow the soil to soak up water and the saturation of groundwater sources. Non-structural soils with freely deposited particles (sandy soils) generally contain pores of larger sizes (non-capillary). For structural soils comprised of soil aggregates (connected by elementary particles), we differentiate pores not just between aggregates but also within these aggregates. In practice, we determine porosity based on the difference between the particle density (soil density without pores) and the bulk density (soil density including pores). It is given as a percentage, with quality agricultural land having soil with a porosity of at least 45%. The total porosity of agricultural land soils gives an indication of their looseness, cohesion, and any harmful soil compaction. Low porosity results in disruption to the water regime and the physical, chemical and biological properties of the soil. Porosity for different HPJs in the CR ranges from 40.5 to 51.5%.

Humus

Humus is a range of organic matter in the soil formed by dead plant, animal, and microbial matter mixed into the minerals of the soil at various levels of decomposition. A characteristic feature of humus is its heterogeneity and lability, resulting in significant activity in the dynamics of soil processes. As a result, it has a major impact on soil fertility. Without a balanced level of organic matter, the amount of humic substances and stable humus is reduced, with a wide range of soil properties made worse. Humus content for individual HPJs is expressed as a percentage, and the following Table 2 gives an assessment of the soil according to its content. Humus content for different HPJs ranges from 1.2 to 7.5 (more details in Appendix C).

Table 2. HPJ assessment by humus content.

Humus (%)	Assessment
<1	very low
1.0–2.0	low
2.0–3.0	medium
3.0–5.0	high
>5	very high

Source: VUMOP.

Grain size

Grain size is affected by the amount of different fractions in the soil. Fractions are a set of soil particles of various sizes that affect the soil's solid mineral composition. The most important soil fractions are sand, dust, and clay. Depending on the proportions of these fractions, we can classify soils into particular soil types. Soil types can also be determined according to the level of clay particles (with particle diameters of less than 0.01 mm), where, as the proportion of these particles increases, the soils are described as sand, loamy sand, sandy loam, loam, loamy clay, clayey, and clay. Grain sizes for different HPJs are divided in accordance with the following Table 3. Grain size for different HPJs ranges from 1 to 4.5 (more details in Appendix D).

Table 3. Categorisation of soil by grain size.

Category	Index	Category Description According to Triangle Diagram
1	L	light
2	Lst	medium heavy–light
3	St	medium heavy–typical
4	T	heavy
5	Vt	very heavy

Source: VUMOP.

pH CKl—soil acidity

Soil acidity (soil pH) can be expressed using the pH scale. The pH scale ranges from 0 to 14. The pH value shows whether the soil is acidic or alkaline. Neutral soil has a pH value of around 7. The lower the pH, the more acidic the soil, and the higher the pH, the more alkaline the soil. Soil acidity ranges for different HPJs from 4.5 to 6.9 (more details in Appendix E).

Soil profile depth

Soil depth is defined as the soil profile thickness, which is limited at a certain depth either by solid rock or broken rock, high stoniness (>50%), or permanent water table. For the purposes of the econometric model, different HPJs are divided according to values in the following Table 4. The soil profile depth for different HPJs is characterised in Appendix F).

Table 4. Soil profile depth quantification.

Soil Depth	Description
up to 30 cm	shallow
30–60 cm	medium deep
60–120 cm	deep
over 120 cm	very deep

Source: VUMOP.

Hydrologic soil group (HSP)

We divide soils according to their hydrologic properties into four groups, A, B, C, and D, on the basis of the minimum water infiltration rate into the soil. The soil infiltration capacity means the ability of the soil surface to absorb water. In general, a soil's infiltration capacity should be moderate to high in order to minimise surface water runoff and water erosion. For the purposes of the article, different hydrologic soil groups are defined as follows—see Table 5.

Table 5. Soil hydrologic groups and their division.

Group A: Soils with high infiltration rates (>0.20 mm/min) even when completely saturated mainly include deep, well to excessively drained sands and gravels.
Group B: Soils with moderate infiltration rates (0.10—0.20 mm/min) even when completely saturated mainly include moderately deep to deep, moderately to well-drained, sandy loam to loamy clay soils.
Group C: Soils with low infiltration rates (0.05–0.10 mm/min) even when completely saturated mainly include soils with a soil profile layer that impedes the downward movement of water and loamy clay to clayey soils.
Group D: Soils with very low infiltration rates (<0.05 mm/min) even when completely saturated mainly include clays with high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at the surface or just below it, and shallow soils over nearly impervious material.

Source: VUMOP.

To study the effects of soil characteristics on the retention capacity and at the same time the effect of retention on the production potential, we use a structural econometric model. The structural econometric model as opposed to the reduced form model provides better insights into the marginal effects of employed variables on both retention capacity and production potential. The conceived relationships are intentionally specified as a recursive system of equations, primarily for reasons of avoiding 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.

In particular, we first explain the retention capacity using porosity, humus, grain size, pH CKl (soil acidity), and soil profile depth variables and then the predicted values of retention capacity enter the equation of production potential, which is further explained by porosity, grain size, and hydrologic soil group variables. Soil production capacity is absolutely fundamental, as soil is the source of plant, and therefore also animal, production. Soil production capacity is directly related to soil fertility, which is one of the main soil quality traits. This represents the ability of the soil to create the optimal conditions for plant growth and development during the growing season. Soil fertility depends on a number of properties—physical, chemical, mineralogical, and biological—which it acquires over the course of its formation and development. In practice, however, we need to assess fertility from a narrower perspective. In this case, we focus on production capacity. In order to support agricultural production, agricultural land has been divided into favoured areas (FA) and less-favoured areas (LFA). Single criteria are used to determine this division across all countries in Europe. Within the Czech Republic, areas have been divided up even further: favoured areas into areas with the highest productivity and areas with high productivity and less-favoured areas into mountain areas, other areas, and areas with special restrictions. This is undertaken based on a points score of production potential ranging from 6 to 100 points, within which a score of 91–100 defines the most valuable agricultural land in terms of production, a score of 81–90 defines above-average production capacity, a score of 71–80 defines average production capacity, a score of 35–70 defines below-average production capacity, and the final group is land with very low production capacity with a score of between 6 and 34.

Formally, we can write the model as:

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

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}—a dummy variable for the k-th hydrologic soil group. D_j is the j-th dummy variable. Then, i is the main soil unit and j is the climatic region. $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, γ, and $\boldsymbol{\sigma}$ 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 a least square estimator with:

$$\mathbf{X}_* = \mathbf{M}_\mathrm{d}\mathbf{X} \quad \text{and} \quad \mathbf{y}_* = \mathbf{M}_\mathrm{d}\mathbf{y} \tag{2}$$

where $\mathbf{M}_\mathrm{d} = \mathbf{I} - \mathbf{D}\left(\mathbf{D}^\mathrm{T}\mathbf{D}\right)^{-1} * \mathbf{D}^\mathrm{T}$ and $\mathbf{X}$ is a matrix of regressors, $\mathbf{y}$ is a vector of dependent variables, and $\mathbf{D}$ 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 results of the econometric models set out above are used to value the non-production function. The determination of prices is undertaken with the use of a sensitivity analysis, with the following options defined:

(1) The determination uses 100% of the BPEJ price in terms of the soil production function and 5% of the retention price within the non-production function of the soil.
(2) The determination uses 100% of the BPEJ price in terms of the soil production function and 10% of the retention price within the non-production function of the soil.
(3) The determination uses 100% of the BPEJ price in terms of the soil production function and 20% of the retention price within the non-production function of the soil.

Considering their size, the results are given only for the first 50 BPEJ codes out of a total number of 2172 codes.

3. Results and Discussion

The first section of the results is focused on the impact of soil's physical properties on the retention capacity within the conditions of the Czech Republic.

Table 6 presents the estimated parameters of the first equation of model (1), i.e., the effects of individual variables on soil retention capacity. Almost all variables have a positive effect on retention, with the exception of extreme humus values (the humus variable is expressed twice due to its non-linear course, with a concave dependence curve anticipated—once the limit amount has been achieved, the humus content in the soil is a negative determinant of retention). This assumption and the theoretical pedological aspects of the model were essentially proven to be true in all cases. The lowest influence level was detected for porosity, with an increase of one per cent increasing retention by 0.07 L/m^2 (c.p.). The second smallest intensity in the resulting model was seen in a relatively small increase in humus, with an increase of 1% resulting in retention increasing by approx. 2.6 L/m^2 (c.p.) evaluated on the sample mean. Unfortunately, the influence of both of these variables is not significant ($\alpha = 0.05$), which means they will be abstracted in the following evaluation. The other estimated parameters are highly statistically significant, and so they can be applied. The results achieved confirm the theory that a single increase in humus content has a negative impact, reducing water retention by more than six units (c.p.). In contrast, increasing the grain size by a unit has a positive impact, increasing retention by almost 19 L/m^2 (c.p.). The soil acidity variable also has a positive impact but to a greater extent. This variable is expressed on the pH scale, and increasing its value generally results in a shift away from acidic soils towards alkaline soils. From the estimated outcome, it is evident that increasing the alkalinity (by one degree) leads relatively quickly to an increase in water retention (by 44 L/m^2), which is again in line with pedological theory. The final variable included is soil profile depth (measured on a scale), which in the estimate achieved is the variable that acts most intensively, again in line with generally logical assumptions. If the soil depth increases by one degree on the registered scale (representing in reality an increase in depth by a number of tens of cm), there is an increase in retention of greater than 100 L/m^2 (c.p.). Making an overall agricultural and economic assessment, we can say that all our results correspond almost perfectly to assumptions on water retention in soil. The basic premise for practice is a desired increase in water retention. In order to achieve this objective, according to the results of the estimate it is a good idea to focus in particular on the soil thickness, although this is often fixed due to soil and geological aspects. In terms of common farming practice, it is therefore important to look at the other model outcomes, in terms of the relatively large impact of soil acidity, which is a factor that is relatively easy to modify in terms of agrotechnical principles—if soil acidity is systematically reduced, then soil water retention would be significantly higher. According to the literature, soil pH in a natural environment has a massive influence on soil biogeochemical processes, which is why soil pH is described as the "main soil variable", influencing myriads of soil biological, chemical, and physical properties and processes, which further impact plant growth and biomass yield [47]. Grain size is another specific property that has a positive impact on retention. Here, farming practice is unclear, since a certain form of agrotechnical interventions can have a positive impact on this property. According to the research undertaken, the size of pores can influence water retention in soil in the driest areas in particular [48], and although this would have a positive effect, it is a long-term process and the end result may be more negative for many crops, since clay soil is unsuitable for many food crops. Finally, in terms of significant influences, it is also a good idea to note the conflicting influence of humus in the soil. It is generally evident from the model outcomes that a slight increase in humus content is desirable for water retention, but only to a certain degree. According to agronomic principles, humus content in soil is a crucial factor impacting agricultural crop yields [49]. However, after a certain level of saturation, any further increase is contraindicated for water retention. Further research should be undertaken in this regard in order to determine this optimal proportion. Last but not least, it should also be noted that the estimates of fixed effects for different climate regions are also included in Table 6 for the completeness of results, although these are all statistically insignificant, i.e., the differentiation of climatic region is not statistically significant in terms of the influence of the analysed variables. For this reason, we shall not be focusing further on these estimated parameters.

Table 6. Results of the econometric model (influence of variables on soil retention capacity).

Number of Obs. = 486						
F (15,470) = 101.79						
Prob > F = 0.0000						
R-Squared = 0.7199						
Root MSE = 51.364						
Retention	**Coefficient**	**Std. Err.**	**t**	**P > |t|**	**[95% Conf. Interval]**	
x_1—Porosity	0.07076	0.247905	0.290	0.775	−0.41638	0.557904
x_2—Humus	2.64961	7.105467	0.370	0.709	−11.31281	16.612020
$(x_2)^2$ Humus 2	−6.89636	1.770308	−3.900	0.000	−10.37506	−3.417664
x_3—Granularity	18.92267	2.615131	7.240	0.000	13.78387	24.061470
x_4—pH kcl	44.09994	3.907938	11.280	0.000	36.42075	51.779130
x_5—Soil depth	103.31240	4.569918	23.920	0.000	100.33240	118.292400
KR						
1	0.53247	11.87166	0.000	0.996	−23.2749	23.38135
2	1.84024	11.34360	0.160	0.871	−20.4502	24.13069
3	2.81794	10.96730	0.260	0.797	−18.7331	24.36894
4	5.09292	11.21198	0.450	0.650	−16.9389	27.12473
5	3.38745	11.22553	0.300	0.763	−18.6710	25.44589
6	1.60468	11.78921	0.150	0.892	−21.5614	24.77076
7	2.16581	11.86096	0.180	0.855	−21.1413	25.47288
8	3.30591	14.34417	0.230	0.818	−24.8807	31.49255
9	11.52178	16.82349	0.380	0.494	−21.5368	44.58035
_cons	−422.83020	28.67424	−14.750	0.000	−479.1757	−366.48460

Source: own calculations according to data from VUMOP.

Table 7 gives the defined HPJs in Czech Republic conditions (1–78), while the second column gives the table value of soil retention (L/m^2). The third column gives a calculation of retention for the different HPJs using the above given model of the influence of different physical properties, based on these properties. For some HPJs (e.g., 11, 12, 20), the results show a clear significant difference in the estimated retention compared to the table value used. More significant differences would require further detailed investigation or measurement. These results can thus result in a more exact definition of individual retention capacities for HPJs within Czech Republic territory.

Table 7. Comparison of table retention values and model retention values (L/m^2).

HPJ	Table v.	Model v.	Difference	HPJ	Table v.	Model v.	Difference
1	340	294	−46	40	100	88	−12
2	340	294	−46	41	120	119	−1
3	340	294	−46	42	300	282	−18
4	90	120	30	43	250	253	3
5	160	239	79	44	250	215	−35
6	340	387	47	45	250	262	12
7	340	387	47	46	220	252	32
8	340	259	−81	47	180	220	40
9	340	318	−22	48	110	123	13
10	340	353	13	49	130	162	32
11	340	316	−24	50	120	122	2
12	340	262	−78	51	145	158	13
13	160	159	−1	52	195	183	−12
14	340	283	−57	53	210	212	2
15	340	284	−56	54	225	216	−9
16	220	207	−13	55	95	149	54
17	130	194	64	56	340	289	−51
18	130	128	−2	57	340	306	−34
19	140	190	50	58	170	180	10
20	140	235	95	59	170	206	36
21	80	150	70	60	340	295	−45
22	120	177	57	61	340	333	−7
23	220	172	−48	62	310	273	−37
24	175	145	−30	63	255	256	1
25	175	172	−3	64	140	126	−14
26	180	204	24	65	60	15	−45
27	130	121	−9	66	60	15	−45
28	260	196	−64	67	60	125	65
29	140	141	1	68	60	143	83
30	165	167	2	69	40	143	103
31	80	138	58	70	70	126	56
32	100	109	9	71	70	82	12
33	225	303	78	72	25	x	x
34	130	92	−38	73	20	x	x
35	225	122	−103	74	20	x	x
36	190	102	−88	75	135	110	−25
37	20	x	x	76	135	92	−43
38	25	x	x	77	200	100	−100
39	15	x	x	78	200	68	−132

Source: own calculations according to data from VUMOP (for "x", not all required physical characteristics of a specific HPJ are defined).

The following Table 8 gives the estimate of the specified model for the calculation of production potential as a core factor for soil economic valuation. The model's concept is based on a recursive relationship between equations (see Table 6), i.e., the explanatory variables included fitted retention, grain size, porosity, and soil hydrologic group, all while respecting the variability of climatic regions. It is evident from the estimate made that all the variables included influence the production potential positively. The intensity of influence differs, and we need to further clarify the basic interpretation by using broader contexts on the character of the chosen variables. According to the size of parameters, the soil hydrologic category is dominant, generally representing its water infiltration capacity. For the presented model, all three hydrologic soil groups are conceived as opposed to the worst group, D, and we can thus state that our resulting estimate is in full accordance with pedological theory. Hydrologic group C as opposed to D has a higher production potential of almost 13 points, while for category B as compared to category D, the implied increase in production potential is approx. 16 points, with the greatest change in production potential (of approx. 18 points) achieved by moving from group D to group A. All the soil hydrologic group variables are also highly statistically significant. Another significant variable is porosity, with a unit increase resulting in an increase in production potential of 0.38 units (c.p.). This can be perceived as a confirmation of standard theory, with a general increase in space within soil generating a greater ability of the soil to absorb desired substances (including water), leading to greater soil production potential. The final significant variable is soil retention, with a unit increase resulting in an increase in production potential of around 0.11 units (c.p.). Since the retention unit is litres per square metre and according to the results of the previous model (and real data), retention ranges in the order of hundreds of litres per m^2, the theoretical capacity to increase production potential is enormous in this regard. The data confirm the initial assumption that retention capacity is significantly undervalued in the current economic land valuation system, and it would be appropriate to consider including this aspect in further evaluations as one of the main price determinants. At the same time, it is a good idea to produce recommendations for farming practices that can support water retention capacity in the soil; see the results of the previous model. The last variable included in the model was granularity, with a unit increase potentially leading to an increase in production potential of around 0.54 units (c.p), although statistical significance was not proven for this variable.

In terms of the model produced, it is finally important to look at slight differences between climatic regions. The estimated effects (see Table 8), with the exception of KR 2 and 3, are confirmed at the level of significance (α = 0.05), while all other climatic regions see a reduction in the production potential basis values as opposed to KR 0 purely through the influence of regional specificities. An exact expression of the influence of climatic region on production potential is given in Figure 1, see below.

The econometric model was used to calculate the production potential of individual HPJs in CR climatic regions (see Table 9). It is evident from the table that some HPJs occur only in some climatic regions (KR). According to the table values, production potential ranges between 6 and 100 points (the higher the production potential, the greater the agricultural production and potential profit for agricultural subjects. The following table gives the results for production potential estimated by the model. Within the Czech Republic, production potential has also been used to define less suitable growing areas (so-called LFAs/less favoured areas). The EU's single methodology resulted in a redefinition of LFAs, which are now described as Areas with Natural Constraints, or ANCs. Inclusion is based on biophysical criteria, which are laid out in Annex III of Regulation (EU) no. 1305/2013 of the European Parliament and of the Council. These criteria are binding for all EU member states, in particular with regard to the payment of grant titles. It is evident here that the lowest production potential is for HPJs 73 and 74 in climate region 9 with an estimated production potential of 4.8 points. In terms of agricultural use, these are very poorly fertile areas, and so are unsuitable for food production. In terms of the results, other poorly fertile soils are HPJs 39, 66, 68, 69, 70, 71, 72, and 76, with their potential generally given as less than 40 points. The highest production potential, and therefore the land most suitable for growing food, are HPJs 1, 2, 3, 6, 8, 9, 10, 15, 42, 56, and 60. For these cases, the production potential is above 85 points in most climatic regions.

Table 8. Econometric model for calculating the production potential of individual HPJs in climatic regions.

Number of Obs. = 486						
F(15,470) = 239.55						
Prob > F = 0.0000						
R-Squared = 0.7254						
Root MSE = 11.377						
Prodpot	**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 calculations according to data from VUMOP.

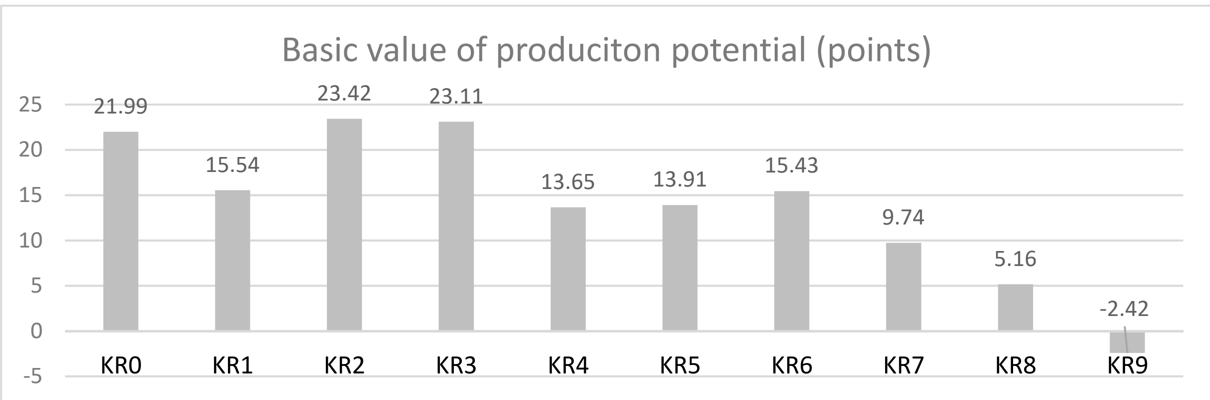

Figure 1. Influence of climatic region on production potential. Source: own calculations (all climatic regions are taken into account in the graph, regardless of the robustness of the estimate of the regional constant).

Table 9. Model values of production potential for individual HPJs and KRs (point scale 0–100 points).

HPJ	KR 0	KR 1	KR 2	KR 3	KR 4	KR 5	KR 6	KR 7	KR 8	KR 9
1	95.3	88.9	96.8	96.4	87.0					
2	96.1	89.6	97.5	97.2	87.8					
3	92.6	86.1	94	93.7	84.2					
4	67.4	60.9	68.8	68.5						
5	74.3	67.8	75.7	75.4						
6	95.1	88.6	96.5	96.2						
7	82.4	76	83.9	83.6						
8	96	89.6	97.5	97.1	87.7	87.9				
9			97.1	96.8	87.4	87.6				
10	96.5	90	97.9	97.6	88.1	88.4				
11			97.5	97.2	87.8	88	89.5			
12			97.9	97.6	88.1	88.4	89.9	84.2		
13		68.2	76.1	75.8	66.3	66.6	68.1	62.4		
14		89.1	96.9	96.6	87.2	87.4	89	83.3		
15		89.6	97.5	97.2	87.8	88		83.8		
16			82.7	82.4	73	73.2	74.7	69.1		
17			73.1	72.7		63.5	65.1			
18	69.2	62.7	70.6	70.3	60.8	61.1		56.9	52.3	47.7
19	74.1	67.6	75.5	75.2	65.8	66				
20	59.8	53.3	61.2	60.9	51.4	51.7	53.2	47.5	42.9	
21	65.4	59	66.9	66.5	57.1	57.3	58.9	53.2	48.6	
22	68.8	62.3	70.2	69.9	60.5	60.7	62.2	56.6	52	
23	77.3	70.9	78.8	78.5	69	69.3	70.8	65.1		
24	74.7			75.8			68.1	62.4		
25		71.5	79.4	79.1	69.6	69.9		65.7		
26		70.7	78.6	78.3	68.8	69.1	70.6	64.9		
27				71.1	61.6	61.9	63.4	57.7		
28		79.9	87.8	87.5	78	78.3	79.8	74.1		
29	72.9	66.4	74.3	74	64.5	64.8	66.3	60.6		
30		68.9	76.8	76.5	67.1	67.3		63.2		
31	65.8	59.4	67.2	66.9	57.5	57.7	59.2	53.6		
32	68.1	61.6	69.5	69.2	59.7	60	61.5	55.8		
33		77.6	85.5	85.1	75.7	75.9		71.8		
34									55.1	
35									65.8	
36										55.4
37	59.5	53.1	61	60.6	51.2	51.5	52.9	47.3	42.7	38.1
38	61.6			62.7	53.2	53.5	55	49.3	44.7	
39	37	30.6	38.5	38.2	28.7	29	30.5	24.8	20.2	15.6
40	66.2	59.8	67.6	67.3	57.9	58.1	59.6	54	49.4	44.8
41	72.3	65.9	73.7	73.4	64	62.2	65.7	60.1	55.5	50.9
42			93.4	93.1	83.6	83.9	85.4			
43				87.5	78	78.3	79.8	74.1		

Table 9. *Cont*

HPJ	KR 0	KR 1	KR 2	KR 3	KR 4	KR 5	KR 6	KR 7	KR 8	KR 9
44				83.8	74.3	74.6	76.1	70.4	65.8	
45				84.3	74.9	75.1	76.6			
46			80.3	80	70.5	70.8	72.3	66.6		
47				75.5	66	66.3	67.8	62.1		
48			66.2	65.8	56.4	56.6	58.2	52.5	47.9	
49				59.4	49.9	50.2	51.7	46	41.4	
50		60.3	68.3	67.8	58.4	58.6	60.2	54.5	49.9	45.3
51		61.7	69.5	69.2	59.8	60	61.5	55.9		
52			76	75.7		66.5		62.3	57.7	
53			67.6	67.3	57.8	58.1		53.9	49.3	
54		62.7	70.6	70.3	60.8	61.1	62.6	56.9	52.3	
55	67.7	61.2	69.1	68.8	59.3	59.6	61.1	55.4	50.9	46.3
56	94.9	88.4	96.3	96	86.5	86.8	88.3	82.6	78	73.4
57	82.1	75.6	83.5	83.2	73.7	74	75.5	69.8		
58	71.6	65.1	73	72.7	63.2	63.5	65	59.3	54.7	50.2
59	63.2	56.7	64.6	64.3	54.8	55.1	56.6	50.9		
60	94.9	88.4	96.3	96	86.5	86.8	88.3			
61	82.2	75.8	83.7	83.4	73.9	74.2	75.7			
62	88.5	82.1	90	89.6	80.2	80.4	82			
63	72.3	65.9	73.7	73.4	64	64.2	65.7			
64	71.3	64.9	72.8	72.4	63	63.2	64.8	59.1	54.5	49.9
65	62.5		63.9	63.6	54.1	54.4		50.2	45.6	41
66			50.8	50.5		41.3		37.2	32.6	28
67	49.9	43.4	51.3	51	41.5	41.8	43.3	37.6	33	28.5
68		24.2	32	31.7	22.3	22.5	24.1	18.4	13.8	9.2
69	28.4	24.9	29.8	29.5	20	20.3	21.8	16.1	11.5	7
70	31.7	25.3	33.2	32.9	23.4	23.7	25.2	19.5	14.9	10.3
71		25.3	33.2	32.9	23.4	23.7	25.5	19.5	14.9	10.3
72	26.8	20.2	28.1	27.8	18.3	18.6	20.1	14.4	9.8	5.3
73			27.5		17.8	18.1	19.6	13.9	9.3	4.8
74				27.2		18.1	19.6	13.9	9.3	4.8
75		51.8		59.4	50	50.2	51.7	46	41.5	36.9
76		32.6		40.2		31	32.5	26.8	22.2	17.6
77	58.9	52.5	60.4	60	50.6	50.8	52.4	46.7	42.1	37.5
78	58.9	52.5	60.4	60.0	50.6	50.8	52.4	46.7	42.1	37.5

Source: own calculations.

The next section of the article focuses on the opportunity for valuing soil retention as a non-production function, which is not included in the BPEJ price. For these purposes, we have set up options for adding a retention capacity price for different HPJs to the original BPEJ price (see Methods chapter). The subsequent Table 10 gives the results of a monetary valuation for the first 50 BPEJ codes. The results show an evident increase in BPEJ price for all the different options. If we add 5% of the retention capacity influence to the price of individual BPEJs, the resulting increase ranges from 0.01 CZK/m^2 to 0.42 CZK/m^2 in absolute terms. The highest price increase is seen for the code BPEJ 30300, which represents chernozem soil on loess in climatic region 3, flat, with deep soil profile and low skeletonisation. In contrast, the lowest increase for this option is seen for BPEJ codes with a very low production potential as seen in HPJs 39, 68, 71, 72, 73, and 74 in all climatic regions, this mainly being the result of these soils having very low retention capacities. The second defined option is to add a 10% influence of the non-production function to the BPEJ price. The increase in individual prices here ranges from 0.01 CZK/m^2 to 0.83 CZK/m^2. For the final defined option, the increase in BPEJ prices ranges from 0.01 CZK/m^2 to 1.67 CZK/m^2 in absolute terms. This increase is derived from the proportion of soil retention capacity to production potential. If we look at the increase in BPEJ prices in relative terms, the results range from 1 to 12% for the option of adding 20% for non-production soil function.

Table 10. Increase in the price of BPEJ by non-production function (retention) of individual HPJs (CZK/m^2).

BPEJ	CZK/m^2	100PP/5R	100PP/10R	100PP/20R	BPEJ	CZK/m^2	100PP/5R	100PP/10R	100PP/20R
00100	16.77	17.05	17.34	17.90	01904	7.40	7.46	7.52	7.64
00110	14.94	15.19	15.44	15.95	01911	9.95	10.03	10.11	10.27
00112	12.88	13.10	13.32	13.75	01914	6.50	6.55	6.60	6.71
00300	18.10	18.41	18.72	19.34	01941	6.96	7.01	7.07	7.18
00401	7.32	7.36	7.41	7.49	01944	3.99	4.02	4.05	4.12
00411	6.44	6.48	6.52	6.59	01951	8.47	8.54	8.60	8.74
00501	9.18	9.26	9.34	9.50	01954	5.06	5.10	5.14	5.22
00511	7.50	7.57	7.63	7.76	02001	8.17	8.24	8.32	8.46
00600	12.79	13.04	13.28	13.78	02004	5.76	5.81	5.86	5.97
00602	11.38	11.60	11.82	12.26	02011	7.34	7.41	7.47	7.60
00610	11.73	11.96	12.18	12.64	02014	4.74	4.78	4.82	4.91
00612	9.68	9.87	10.05	10.43	02041	5.47	5.52	5.57	5.67
00640	8.90	9.07	9.24	9.59	02044	2.86	2.89	2.91	2.96
00650	9.83	10.02	10.21	10.59	02051	6.26	6.32	6.37	6.48
00700	14.10	14.38	14.66	15.21	02054	3.65	3.68	3.72	3.78
00710	12.55	12.80	13.05	13.54	02110	5.41	5.44	5.47	5.54
00740	9.46	9.65	9.83	10.21	02112	4.73	4.76	4.79	4.84
00750	10.37	10.57	10.78	11.19	02113	4.26	4.29	4.31	4.36
00800	13.59	13.86	14.14	14.68	02142	3.25	3.27	3.29	3.33
00810	11.80	12.04	12.27	12.75	02143	2.68	2.70	2.71	2.74
00840	8.42	8.59	8.76	9.10	02152	3.95	3.97	4.00	4.04
00850	10.08	10.28	10.49	10.89	02153	3.48	3.50	3.52	3.56
01811	8.61	8.68	8.75	8.89	02210	6.53	6.58	6.63	6.73
01901	10.92	11.01	11.10	11.27	02212	5.82	5.87	5.91	6.00

Source: own calculations (note: only for the first 50 BPEJ codes out of a total of 2172 codes, the current rate is 24.68 CZK/EUR −25 October 2023).

The article's first objective was to use an econometric model to identify the main determinants of soil resistance and determine the direction and intensity of their influence on the soil's ability to hold rainwater. In this regard, through gradual restriction, a specific econometric model was designed, which on the basis of the achieved outputs confirmed a significant influence on soil retention. Some of the significant determinants include humus content, particle size, soil acidity, and soil profile depth. Contrary to the theoretical assumption, porosity was not shown to have an influence. Thus, internal validation can demonstrate the fundamental influence of at least four core physical properties that may have a significant positive impact on soil retention capability. This is in line with the expectations laid out in the theoretical section of the article. The article's second objective was to verify the influence of water retention on production potential, which was achieved through the second conceived model. The outcomes substantially confirm the significant influence of both retention itself and the porosity and soil hydrologic group, and this is in line with the modern findings of economic pedology and demonstrates both the appropriateness of including these parameters in the system of land valuation and the importance of these properties during the current changes in climate.

One generally accepted assumption is that humus content in soil increases its infiltration and retention capacity. This assumption has been confirmed by a large number of studies [38–42] and the results of this study also confirm it. Tillage method and saowing system can also influence retention capacity or soil moisture [50]. In this study, porosity has a positive influence on retention capacity, but its increase has a small effect. This may be a result of the fact that the number of macropores increases with soil depth, while the number of micropores decreases [51]. Pore size and volume determine the soil bulk density and particle size of any soil [52]. Soil pH affects the soil's biological, physical, and chemical properties and thus also agricultural crop yield [47]. Crop yield is mainly affected because pH has a direct impact on the nutrient intake of plants being grown [53]. In this regard, acidic soils, or soils with a low pH, display lower productivity [54]. Soil pH level is also affected by what fertilisers are used on the agricultural land. The application, for example, of mineral fertilisers—nitrogen, potassium, and phosphorus—results in soil acidification. Contrastingly, the use of farmyard manure stabilises the pH value across the entire soil profile [55]. It is evident from the above that soil pH is important, and our results also confirm pH's influence on retention capacity itself and therefore on production potential. Reserves of usable water in the soil represent one of the crucial factors determining the yield of crops being grown, which has been included in the production potential of individual main soil units (HPJ) and subsequently reflected in increasing the price of individual BPEJ codes. For the purposes of the article, the physical and chemical properties of different HPJ soils within the territory of the Czech Republic were used. Thus, this study did not take into account the influence of, e.g., cover crops, which may be used by farm entities. In general, cover crops are considered crops that improve soil health by controlling erosion, adding organic matter, and improving water retention capacity [56].

The benefits of the outcomes achieved can be found both in methodological and application design terms. The scientific approach and overall method used demonstrate that designing econometric models also allows us to validate theoretical knowledge in the field of pedological research. The proposed method achieves very good results and can be used in further research studies, which will certainly have to be undertaken as climate change progresses, as it will be essential to undertake further evaluations of the relationship between soil and water in the landscape. Benefit application can be built on theoretical potential, the results confirming the necessity of changes in the soil valuation system. In this regard, crucial properties such as water retention and its determinants are currently perceived only as secondary parameters of non-productive soil function, even though the results demonstrate their significant impact on production potential, which is the basis for economic valuation algorithms. At the same time, the outcomes demonstrate the possibility of applying the proposed approaches for the actual revaluation of land. This would incorporate important mechanisms taking into account the growing significance of water retention in the landscape into the applied economic system.

It would be a good idea to carry out research on determining the optimal proportion/level of humus in soil not just in terms of retention capacity but also in terms of production capacity. It is well known that humus content is a key factor of soil fertility [49,57]. Another appropriate opportunity in terms of agricultural practice is the use of currently supported precision agriculture. This is an integral system of agrotechnology measures implementing technical and technological potential in practice in order to achieve the best environmental, energy, and economic results while preserving the cultural landscape and long-term sustainability of the countryside. Soil pH, as one of the core aspects of precision agriculture, helps in deciding on the type of crop to be grown on a field and also determines crop productivity. Soil pH analysis is extremely important because it plays a crucial role in crop yield control [58]. As precision agriculture has developed, tools have become available for measuring core physical and chemical soil properties in real time—these include remote sensors and the use of robots or drones with attachments, etc. [59,60]. These technologies can be used to monitor soil properties and to undertake the correct interventions to maintain the required soil quality for ensuring high crop yields while minimising negative environmental impacts.

4. Conclusions

This study provides a number of important conclusions for applied research as well as for practice. The construction and estimation of the soil retention capacity model demonstrated the positive influence of selected pedological factors. In terms of farming practice, the most important is the soil acidity indicator, as this factor is relatively easily influenced through agrotechnical interventions in soil preparation and the model also shows its relatively strong influence on the desired retention increase. We can also see the grain size factor in a similar manner, as increasing this is a relatively effective way to achieve greater water retention, although we need to take into account the selection of productive crops, with the positive effect of increasing soil water retention possibly eliminated by a grain size that is too large, as this is unsuitable for many crops.

This model can also impact the practice of valuing land units in use, with the estimate made providing significantly different retention values for some HPJs compared to the table values used. Greater differences should undergo more detailed investigation or requalification by a research institute. Thus, these results will ultimately likely lead to a more exact definition of different HPJ retention capacities within the territory of the Czech Republic.

Another important outcome is the valuation of retention capacity in the category of soil non-production function and its eventual inclusion in the system of valuing land via BPEJ, which currently does not incorporate these factors. The specified production potential model, however, demonstrated a significantly significant influence for a wide group of factors (including retention), which are also significant in terms of differences between climatic regions. In this regard, non-production soil function is of greater importance, further increasing the impact of climate change. Some soils in this regard may have low production potential, but they may also be highly valuable for their location in terms of non-production potential (typically desirable floodwater retention capacity, etc.). Considering climate change, this is a very topical and desirable aspect, and using the results achieved gives us the opportunity to give a more exact valuation of the influence of factors that have previously been considered as being outside of the agricultural sector. Including the proposed procedures in the system of valuing through modified BPEJ prices secures more exact resulting values, plus changes within the system that allow us to reflect properties not originally included. Putting this into practice via the legislative process would also impact a number of other areas—in particular, the tax obligations of agricultural subjects farming on agricultural land. The article's outcomes are thus suitable for farming practice, giving clear evidence of the appropriateness of treating the land carefully and the necessity of using smart water management for the soil and also for the use of public authorities, which can utilise these results to give a more accurate price for different BPEJs and therefore ensure a better determination of tax obligations for agricultural subjects farming within Czech Republic territory. Finally, the conclusions made suggest it is also probably a good idea to open up another area of research: specifically, comparing precipitation with the defined extent of different climatic regions and the related retention capacities of different HPJs—currently, precipitation is rather uneven and there is often heavy precipitation over a short time period. Climate change can be expected to lead to a further increase in differences seen both across time and across regions.

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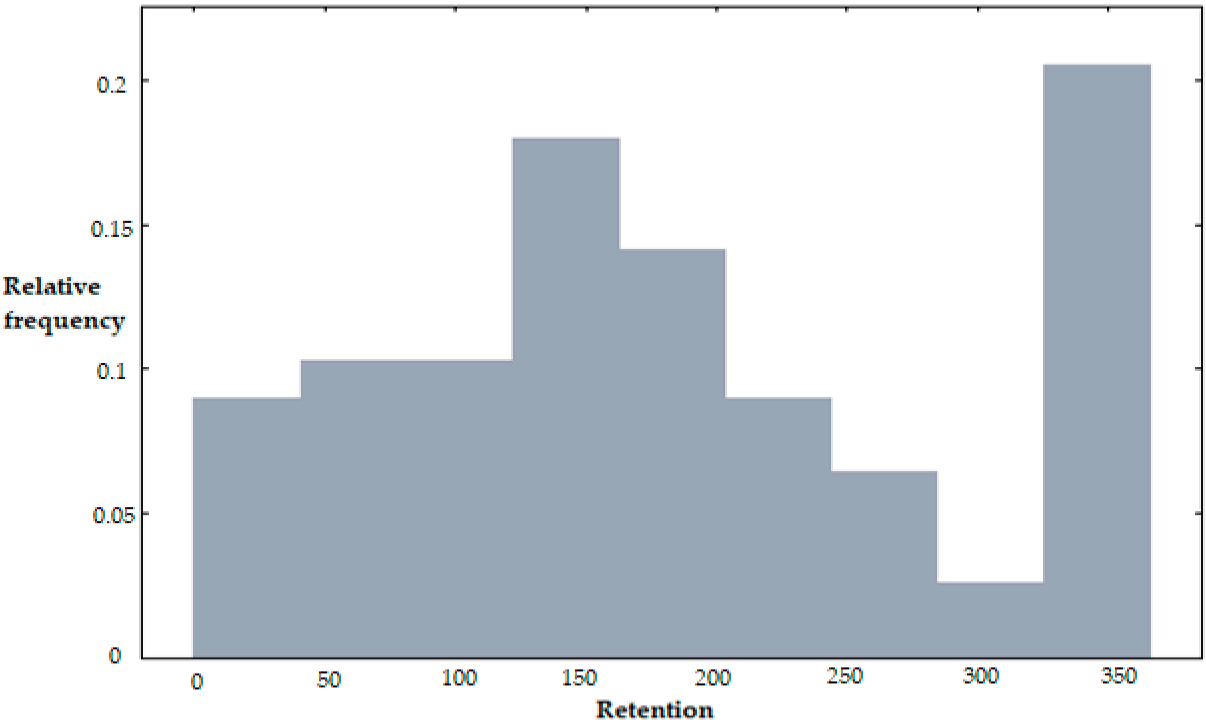
Appendix A. Definition of Climatic Regions in the Czech Republic

Climatic Region	Sum of Temperature above 10 °C (°C)	Average Temperature (°C)	Average Rainfall (mm)	Probability of Dry Growing Seasons (%)	Moisture Security
KR0	2800–3100	9–10	500–600	30–50	0–3
KR1	2600–2800	8–9	under 500	40–60	0–2
KR2	2600–2800	8–9	500–600	20–30	2–4
KR3	2500–2800	7–9	550–650	10–20	4–7
KR4	2400–2600	7–8.5	450–550	30–40	0–4
KR5	2200–2500	7–8	550–650	15–30	4–10
KR6	2500–2700	7.5–8.5	700–900	0–10	over 10
KR7	2200–2400	6–7	650–750	5–15	over 10
KR8	2000–2200	5–6	700–800	0–15	over 10
KR9	under 2000	under 5	over 800	0	over 10

Source: VUMOP.

Appendix B. Basic Statistics for the "Retention" Variable



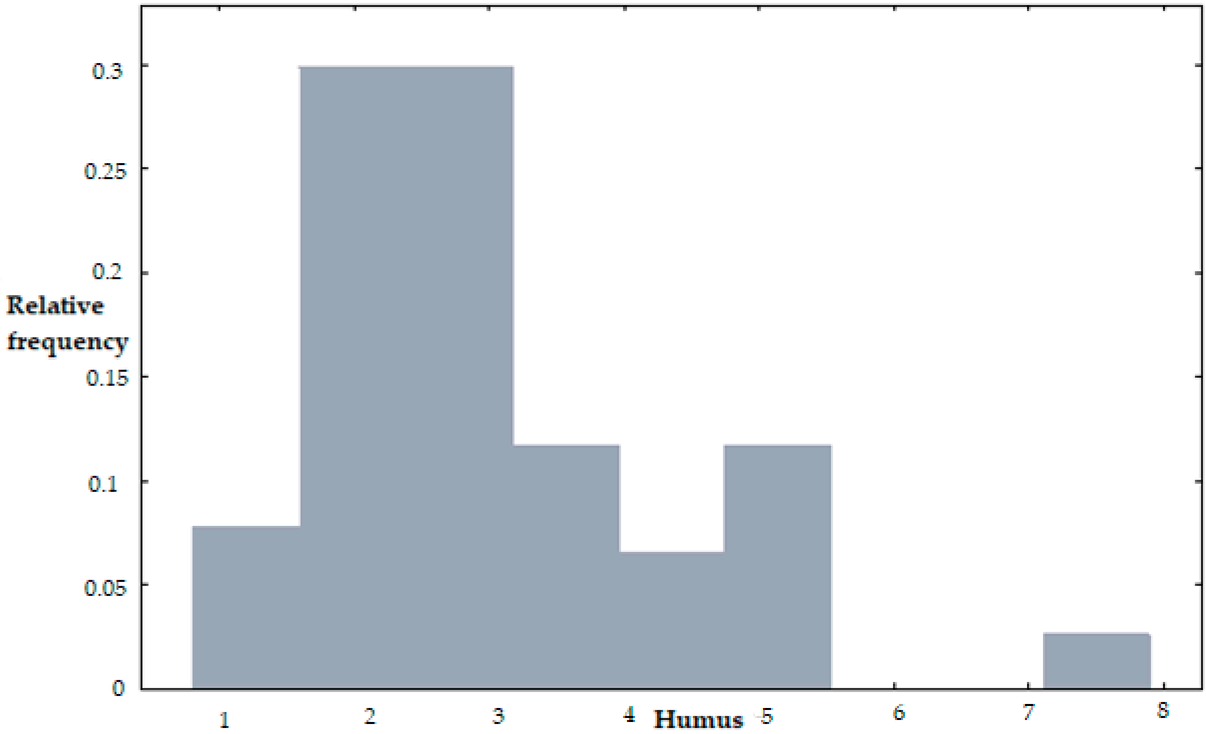

```
Frequency distribution for retention, 1–78
Number of classes = 9, (number of * means frequency in individual groups)

      interval        middle    frequency    rel.     cum.

           < 40.625    20.313        7      8.97%    8.97% ***
    40.625 – 81.250    60.938        8     10.26%   19.23% ***
    81.250 – 121.88    101.56        8     10.26%   29.49% ***
    121.88 – 162.50    142.19       14     17.95%   47.44% ******
    162.50 – 203.13    182.81       11     14.10%   61.54% *****
    203.13 – 243.75    223.44        7      8.97%   70.51% ***
    243.75 – 284.38    264.06        5      6.41%   76.92% **
    284.38 – 325.00    304.69        2      2.56%   79.49%
          >= 325.00    345.31       16     20.51%  100.00% *******
```

Mean value	Median	Minimum	Maximum
184.17	170.00	15.000	340.00
Standard deviation	Coefficient of variation	Skewness	Kurtosis
103.32	0.56099	0.22075	−1.0798
5% Percentile	95% Percentile	IQ range	Missing obs.
20.000	340.00	148.75	0

Appendix C. Basic Statistics for the "Humus" Variable



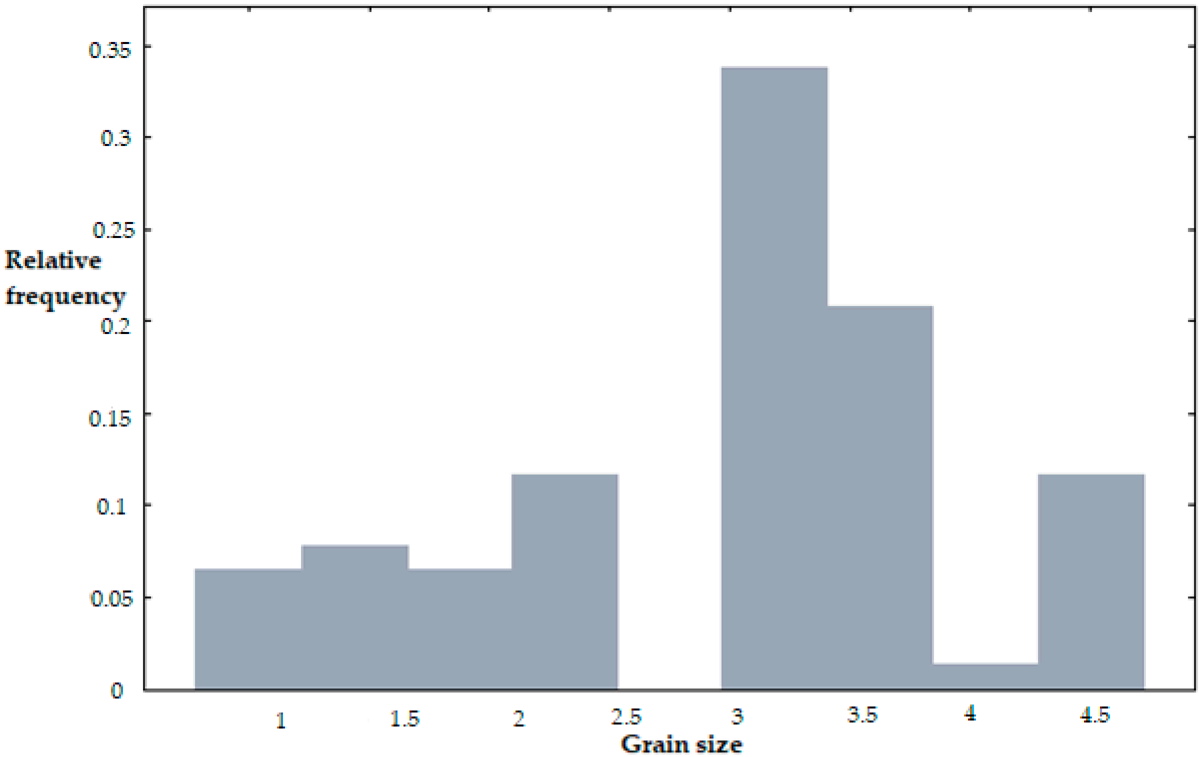

```
Frequency distribution for humus, 1–78
Number of classes = 9, (number of * means frequency in individual groups)

   interval          middle    frequency    rel.      cum.

          < 1.5938    1.2000        6      7.79%    7.79% **
    1.5938 – 2.3813    1.9875       23     29.87%   37.66% **********
    2.3813 – 3.1688    2.7750       23     29.87%   67.53% **********
    3.1688 – 3.9563    3.5625        9     11.69%   79.22% ****
    3.9563 – 4.7438    4.3500        5      6.49%   85.71% **
    4.7438 – 5.5313    5.1375        9     11.69%   97.40% ****
    5.5313 – 6.3187    5.9250        0      0.00%   97.40%
    6.3187 – 7.1062    6.7125        0      0.00%   97.40%
         >= 7.1062    7.5000        2      2.60%  100.00%
```

Mean value	Median	Minimum	Maximum
2.9922	2.5000	1.2000	7.5000
Standard deviation	Coefficient of variation	Skewness	Kurtosis
1.3404	0.44798	1.2917	1.6238
5% Percentile	95% Percentile	IQ range	Missing obs.
1.5000	5.5000	1.50000	1

Appendix D. Basic Statistics for the "Grain Size" Variable



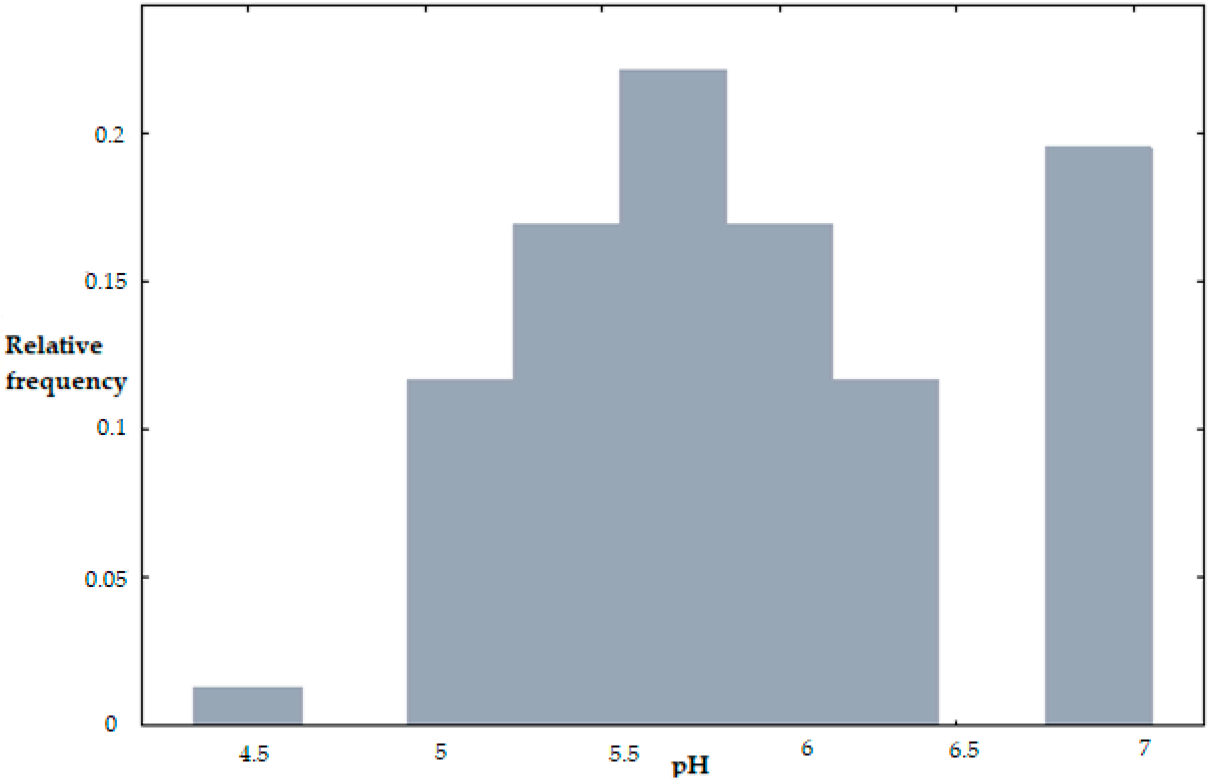

```
Frequency distribution for grain size, 1–78
Number of classes = 9, (number of * means frequency in individual groups)

       interval        middle    frequency    rel.     cum.

              < 1.2188    1.0000        5      6.49%    6.49% **
    1.2188 – 1.6563    1.4375        6      7.79%   14.29% **
    1.6563 – 2.0938    1.8750        5      6.49%   20.78% **
    2.0938 – 2.5313    2.3125        9     11.69%   32.47% ****
    2.5313 – 2.9688    2.7500        0      0.00%   32.47%
    2.9688 – 3.4063    3.1875       26     33.77%   66.23% ************
    3.4063 – 3.8438    3.6250       16     20.78%   87.01% *******
    3.8438 – 4.2813    4.0625        1      1.30%   88.31%
             >= 4.2813    4.5000        9     11.69%  100.00% ****
```

Mean value	Median	Minimum	Maximum
2.9182	3.0000	1.0000	4.5000
Standard deviation	Coefficient of variation	Skewness	Kurtosis
0.93101	0.31904	−0.28189	−0.23942
5% Percentile	95% Percentile	IQ range	Missing obs.
1.0000	4.5000	1.0000	1

Appendix E. Basic Statistics for the "pH" Variable



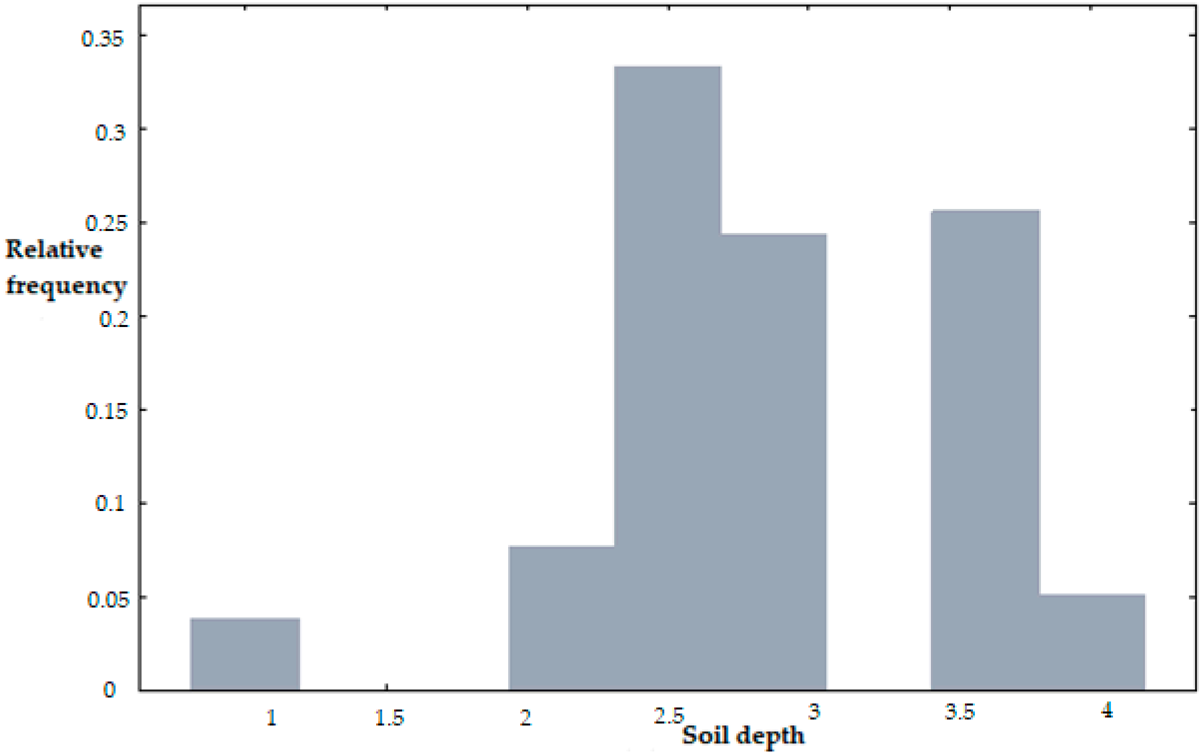

```
Frequency distribution for pH, 1–78
Number of classes = 9, (number of * means frequency in individual groups)

      interval        middle    frequency    rel.     cum.

            < 4.6500    4.5000        1      1.30%    1.30%
   4.6500 – 4.9500    4.8000        0      0.00%    1.30%
   4.9500 – 5.2500    5.1000        9     11.69%   12.99% ****
   5.2500 – 5.5500    5.4000       13     16.88%   29.87% ******
   5.5500 – 5.8500    5.7000       17     22.08%   51.95% *******
   5.8500 – 6.1500    6.0000       13     16.88%   68.83% ******
   6.1500 – 6.4500    6.3000        9     11.69%   80.52% ****
   6.4500 – 6.7500    6.6000        0      0.00%   80.52%
           >= 6.7500    6.9000       15     19.48%  100.00% *******
```

Mean value	Median	Minimum	Maximum
5.9039	5.6000	4.5000	6.9000
Standard deviation	Coefficient of variation	Skewness	Kurtosis
0.62754	0.10629	0.25361	−0.87374
5% Percentile	95% Percentile	IQ range	Missing obs.
5.0000	6.9000	0.90000	1

Appendix F. Basic Statistics for the "Soil Depth" Variable




```
Frequency distribution for soil depth, 1–78
Number of classes = 9, (number of * means frequency in individual groups)

     interval        middle    frequency    rel.     cum.

         < 1.1875     1.0000         3      3.85%    3.85% *
   1.1875 – 1.5625    1.3750         0      0.00%    3.85%
   1.5625 – 1.9375    1.7500         0      0.00%    3.85%
   1.9375 – 2.3125    2.1250         6      7.69%   11.54% **
   2.3125 – 2.6875    2.5000        26     33.33%   44.87% ************
   2.6875 – 3.0625    2.8750        19     24.36%   69.23% ********
   3.0625 – 3.4375    3.2500         0      0.00%   69.23%
   3.4375 – 3.8125    3.6250        20     25.64%   94.87% *********
        >= 3.8125     4.0000         4      5.13%  100.00% *
```

Mean value	Median	Minimum	Maximum
2.8628	3.0000	1.0000	4.0000
Standard deviation	Coefficient of variation	Skewness	Kurtosis
0.63983	0.22350	−0.64469	0.88093
5% Percentile	95% Percentile	IQ range	Missing obs.
1.9500	4.0000	1.0000	0

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