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Differentiation in the value of drained land in view of variable conditions of its use

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Abstract: The article is devoted to a topical scientific problem in modern conditions – valuation of land in Ukraine. The imperfection of the existing approaches requires further research on the changing conditions of land use and their impact on land pricing.

A methodology for determining the market value of reclaimed land based on a differentiated assessment of its productivity through crop yields is proposed, taking into account natural and climatic zones and other conditions of a particular region. The basis of the methodology is the application of long-term forecast and a set of forecast and simulation models, in particular the model of area climatic conditions and the model of water regime and water regulation technologies on reclaimed land. At that the crop yield model as a complex multiplicative type model takes into account all main factors influencing crop yield formation: weather, climatic and soil conditions, cultivation techniques, water regime of reclaimed land, etc.

The proposed approaches were tested by the method of large – scale machine experiment using a land plot in the zone of Western Polissya of Ukraine as the example. The obtained results indicate that there is a differentiation in land value, which is a proportional derivative of the yield of cultivated crops depending on the conditions of their cultivation. The variation range of the studied indicators in relative form by the ratio of maximum and minimum values to the weighted average value is for cultivated crops – 393%, and for the above soils – 44.6%. Thus, within one object, the estimated value of land in view of available soils and cultivated crops varies from USD2456$\cdot$ha^{-1} to USD4005$\cdot$ha^{-1}, averaging USD3522$\cdot$ha^{-1}.

Keywords: agricultural land, cost of land, drained lands, land resources, monetary valuation of land, soil assessment, rational use of land

INTRODUCTION

The introduction of the land market in Ukraine determines the relevance of determining the value of the land fund, taking into account all the most important aspects of its use. The imperfection of the existing approaches to the land value causes an active discussion among politicians and scientists, as well as among the owners of land shares, farmers, agricultural holdings, etc. [Martyn *et al.* 2020].

The value of agricultural land is currently influenced by both objective and subjective factors. Among the objective factors, it is worth noting one of the main indicators that forms a rental income, namely crop yields.

Subjective factors include the desire of landowners to exercise their full rights, namely to alienate their land. This will be possible after the lifting of the moratorium on the sale of agricultural land.

STUDY METHODS

The analysis conducted by various researchers confirms that the forecast price for Ukrainian chernozem is the lowest in Europe [Barvinsky, Tykhenko 2015; Martyn, Tykhenko 2015; Novakovsky 2015].

Thus, according to the calculations of the Ministry of Economy, a hectare of land in Ukraine after the opening of land market can cost about 2.2 thous. USD according to the common model (sale to residents and non-residents) and 1.5 thous. USD according to the limited model (sale to residents only). The value of agricultural land in Ukraine is influenced by yields, infrastructure and the owner's desire to sell shares quickly. As the area of the plot increases, the price per hectare almost does not decrease.

For comparison, the estimated price per hectare of land in other countries is: USA – USD7487, Canada – USD5667, the Netherlands – USD81,836, Luxembourg – USD42,700, Italy – USD40,200, Great Britain – USD28,140, Ireland – USD23,884, Denmark – USD20,794, Slovenia – USD20,000. You could buy a hectare of land at USD10,000–15,000 in Greece, Spain, Poland, Sweden, Finland two years ago. In Latvia, Croatia and Slovakia it is substantially cheaper – USD3600. Only the cost of a hectare in Romania (USD2500) is close to the projected price of land in Ukraine [slovoidilo.ua 2019].

Thus, Ukraine is currently in the transition from regulatory to mass land valuation and the use of the EU INSPIRE Directive on the use of market value for land valuation and taxation in view of Ukrainian legislation will provide a full basis for land taxation.

Agrarian reform has become an integral part of general economic transformations in the country and makes radical changes in relations between producers and the state, organisational and legal forms of management and types of ownership [Martyn *et al.* 2019; 2020; Tykhenko 2010b]. From the moment when land use in Ukraine became paid, the most important economic function of land – its value as an object of trade, investment and taxation became important [Zakon... 2004].

Due to the development of market relations, the results of land valuation in recent years do not quite correspond to the current state of the economy of agricultural production [Openko *et al.* 2020]. Until recently, the current methods of agricultural land valuation did not take into account the specifics of its direct use [Panas, Malanchuk 2013; Seryy 1986; Tykhenko 2016].

In modern conditions, economic evaluation of agricultural land should be carried out primarily on the basis of differentiated assessment of its productivity through crop yields, taking into account the specifics of climatic zones and other conditions of a particular region [Openko *et al.* 2017; Shevchenko *et al.* 2017]. At the same time, the current and future changes in weather and climatic conditions determine the increase of the use of agricultural land in almost all regions of Ukraine both in drained and irrigated areas.

In addition, in modern conditions it is necessary to adhere to the major world trends in land valuation, among which the main one is the transition from the regulatory to the market valuation as a basis for land taxation. This will enable to develop a more universal method of land valuation.

In the United Kingdom, the process of land valuation is divided into two stages: the first stage is agro-climatic evaluation, and the second one – economic evaluation of the previously identified types of land, which is based on standard net output [Tykhenko 2010a].

Adamuscin *et al.* [2017] analysed the methodological basis of land ownership valuation in Poland and Slovakia. They note that in the Polish methodology of property valuation a comparative method is the most used while in the Slovak methodology the method of positional differentiation is used.

According to the Standard on Mass Appraisal of Real Property most regions value agricultural land applying a user value. That makes it inappropriate to use a comparative methodological approach for agricultural land, the market value of which exceeds a user value [IAAO 2017].

In Latvia valuating a monetary (cadastral) valuation of land is carried applying two main models:
- valuation of built-up land,
- valuation of agricultural land.

Cadastral valuation in the Baltic States is based on uniform international valuation principles, which involve the information about the real estate market and the objects registered in the National Information System of Real Estate Cadastre [Barvika 2020].

RESULTS AND DISCUSSION

When concluding civil law agreements on land plots and rights to them, an expert monetary valuation of land plots is used. The current legislation identifies three methodological approaches to land valuation (profit, cost, comparative) which, in turn, can be implemented through the use of certain methods.

The methodical approach of comparing the sale prices of similar land plots (comparative approach), which is based on the principle of substitution, is implemented in practice using the methods of pair-wise comparison and statistical analysis of the market.

According to the comparative (market) approach, the value of a land plot is calculated in view of the comparison results with analogues. Despite the advantages of the comparative approach (the possibility of determining the real market value of the property and ease of use), this method should be used only in developed market conditions. So until now, the agricultural land remains out of a full market circulation. Therefore, there is no base of the main elements of comparison, including the characteristics of such property by its location, physical and functional characteristics, sale conditions and so on.

The cost approach is used only to determine the cost of land improvements and has no independent significance for land valuation.

The profit approach is used in determining the value of plots, and shows the income from their use in future over a certain period. Such methods allow to obtain a valuation of land, based on the expected by the potential buyer income, and are applied only to land plots that bring profit.

The direct capitalisation method is based on the assumption of constant and unchanged cash flow from land use [Tykhenko 2010a].

Land value is defined as the ratio of net operating or rental income and capitalisation rate [KMU 2018; Ministerstvo APPU 2017]:

$$V_{dc} = \frac{I_o}{R_c} \tag{1}$$

where: V_{dc} = land value, determined by direct capitalisation (in monetary units); I_o = net operating or rental income (in monetary units); R_c = capitalisation rate (in the form of a decimal fraction).

Net operating or rental income is the difference between the projected annual income (I_p) and current expenses (C) for the production of outputs, which consist of agricultural and reclamation costs. In turn, the projected annual income by the types of crops depends on the yields of agricultural products and average prices for their sale. Then:

$$V_{dc} = \frac{I_p - C}{R_c} \tag{2}$$

That is, the distribution of annual rental income having the appropriate capitalisation rate converts the amount of expected income to the land value.

To determine the rental income from the land plots used in agricultural production, the methodology proposes to take into account the typical set of crops for the area, which ensures efficient use of the plot, crop rotation and preservation of soil fertility. To determine the normal (typical) yield, the data of long-term observations on the actual soil yields within the valuated land plot or field research data on crop yields on different soils can be used. In practice, farms usually do not have data of long-term studies on yields in the years with different climatic conditions and are not able to predict the expected yields.

The existing yield standardisation system used in the projects of construction, reconstruction and operation of reclamation systems, does not fully depict the state and does not take into account the characteristics of reclaimed land in specific conditions of their operation (climate, soils, crop yield, water regulation regimes and technologies etc.). Its standard values cannot be effectively used in the proposed approaches. In this regard, there is an urgent need to create appropriate scientific and methodological approaches that will allow taking into account all these multiple variables, which influence on the project development.

The most important feature and difference of agricultural production from other branches of social production is that it is influenced by natural factors, and the productivity of agriculture, including on reclaimed land. Land profitability is formed not only due to the biological capabilities of crop varieties, the existing set of machines and mechanisms, timely and high-quality tillage, fertilisers, crop rotations, etc., but also due to meteorological factors. Natural phenomena are uncertain and variable and difficult to predict. That is why agricultural production is very sensitive to weather conditions and changes in hydrometeorological factors. The formation of yields of cultivated crops occurs under cyclicality and variability of weather conditions both for multi-year and vegetation periods.

Weather conditions of each year and multi-year climatic characteristics, specific to a particular area, cause significant fluctuations in yields, which depending on weather (climatic) conditions can change 6–9 times.

We have developed theoretical and practical approaches and models for forecasting on a long-term basis the changes in weather and climatic conditions, soil water regime, water regulation technologies, land productivity and, accordingly, crop yields on reclaimed land [Gadzalo *et al.* 2017; Mazhayskiy *at al.* (eds.) 2017]. These models are implemented in the process of optimisation of technological (water regulation methods) and relevant design solutions for their provision (type, design, parameters of the reclamation system) based on a set of forecasting and optimisation models using modern BIM-technologies for construction and reconstruction projects for such facilities [Kovalenko *at al.* 2019; Kovalenko *at al.* 2021; Rokochinskiy *at al.* 2019; Rokochinskiy *at al.* 2021; Frolenkova *at al.* 2020]. Their practical application is regulated by the relevant sectoral standards of the State Agency of Water Resources of Ukraine.

This enables to move from using the methods of yield standardisation to determining the actual possible income depending on the type, design of the reclamation system, as well as the changes in weather conditions. Based on that, the value of land, which is based not on unreasonable regulations, but on more objective forecasts can be calculated [Pavlov *et al.* 2006].

The provision of a particular crop with external factors is determined primarily by the natural and climatic conditions of the facility location and the vegetation period of the crop.

Therefore, we have proposed an improved classification of yield categories in view of the factors influencing the crop development for reclaimed land in the form of an appropriate structural scheme (Fig. 1).

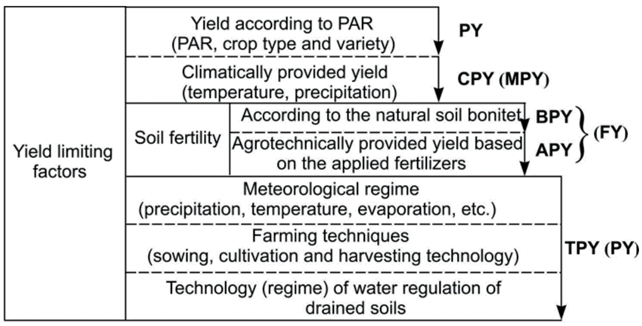

Fig. 1. Improved classification of yield categories on reclaimed land; PY = potential yield, CPY = climatically provided yield, MPY = meteorologically possible yield, BPY = yield, provided by the natural soil bonitet, APY = agro-technically provided yield, FY = feasible

It is the basis for making a general yield model (estimated analogue of the actual yield in the field conditions).

Based on the generalisation of the results of theoretical and experimental research, a model of crop yield on drained land has been developed and proposed in the form of a complex model of the multiplicative type. This model is expressed through the product of climatically provided yield and the functions of the factors impact on the formation of real yield. This impact is estimated by the corresponding multiple coefficients:

$$Y_{k\omega gsp} = Y^F_{\omega kp} \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot K_6 \tag{3}$$

where: = climatically provided yield of the k^{th} crop over the vegetation period of p^{th} its heat and moisture (depends on solar radiation inflow in a particular place and the degree of its use by the plant according to the efficiency factor of photosynthetic active radiation-PAR); K_1 = influence coefficient of soil bonitet on the yield ($0 \leq K_1 \leq 1$); K_2 = influence coefficient of applied mineral and organic fertilisers on the yield ($K_2 > 1$, but $0 < K_1 \cdot K_2 \leq 1$); K_3 = influence coefficient of the shifting of crop sowing term from the optimal one ($0 \leq K_3 \leq 1$) on the k^{th} crop yield under water regulation; K_4 = influent coefficient of current natural and reclamation conditions in the vegetation period (climate and water regulation technologies) on the crop yield ($0 \leq K_4 \leq 1$); K_5 = influence coefficient of the shifting of crop harvesting term from the optimal one ($0 \leq K_5 \leq 1$) on the crop yield; K_6 = yield reduction coefficient due to the losses during harvesting and transportation (net yield of grown products) ($0 \leq K_6 \leq 1$).

Due to the natural seasonal cyclicity of agricultural production, according to heat and moisture provision there are different vegetation periods, which can be grouped into estimated (typical) groups of years. The distribution of these groups of years within the life cycle of the project is uneven and can be done using a share coefficient (detection probability) of the corresponding group of years within the total project implementation period (α_p).

This yield model (3) is implemented according to the long-term forecast in combination with the corresponding model of weather and climatic conditions relative to the typical heat and moisture conditions of the estimated years. However, this model does not directly take into account the weather conditions of a particular year and their impact on soil quality and other characteristics.

But according to the structure of construction, this model can take into account the possible risks and reduction of potential soil fertility due to the changes in weather and climatic conditions or using imperfect technology of agricultural production. In addition, the correction factors K_1, K_2, K_3, K_4 in this model in each case of its application are specified in view of the conditions of a real individual object.

Thus, the general yield model is the basis for determining the projected yield on reclaimed land, which can be represented as a weighted average in time and space:

$$\overline{Y}_k = \sum_{\omega=1}^{n_\omega} \sum_{g=1}^{n_g} (\sum_{p=1}^{n_p} Y_{k\omega gsp} \cdot \alpha_p) \cdot f_\omega \cdot f_g \tag{4}$$

where: $\overline{Y}_k$ = projected yield of the k^{th} crop according to the defined technology of water regulation in the required conditions; $Y_{k\omega gsp}$ = effective (really possible) yield of the k^{th} crop in the corresponding variable conditions of the population: climatic $\{\omega\}$, $\omega = \overline{1, n_\omega}$, soil $\{g\}$, $g = \overline{1, n_g}$, ameliorative (water regulation technologies) $\{s\}$, $s = \overline{1, n_s}$ conditions in different (calculated) in terms of heat and moisture provision vegetation periods $\{p\}$, $p = \overline{1, n_p}$; f, f_g = fractional shares of natural-climatic and soil differences within the object, respectively; α_p = known (determined or given) values of repeatability or shares of the population $\{p\}$, $p = \overline{1, n_p}$ of possible meteorological regimes in the estimated vegetation periods within the design period of object operation, $\sum_{p=1}^{n_p} \alpha_p = 1$.

In addition to yield, which has a decisive influence on the income and current agricultural costs, a capitalisation rate – the coefficient, which converts rent or net operating income into the current value of land, has an important influence on the final value of the land.

Traditionally, any interest rate on the market (R_m) is the sum of risk-free or safe interest rate (d) and risk premium (r):

$$R_m = d + r \tag{5}$$

In Ukraine, where the financial market is under development, the basis for the formation of market interest rates for today is refinancing rates and the bank rate of the National Bank of Ukraine.

As for the risks in agriculture, this is a separate big topic that still needs further research. Modern authors propose to include an insurance rate in the risk-free rate in the field of agriculture, which is a value approved by the relevant state authorities in the regions of Ukraine [Bagdonavicius, Ramanauskas 2004; Barvika *et al.* 2013; Pavlov *et al.* 2006] or calculated by insurance companies for each object individually.

A large-scale machine experiment using a computer to determine the forecasted cost of drained land using the average over the past 5 years cost data was performed by us on the example of a land plot of 430 ha, located in Rivne region (Western Polissya zone of Ukraine). Within the plot, the following multiple variable conditions can be specified:

- by the soils $\{g\}$, $g = \overline{1, n_g}$ (n_g = 3), which are characterised by different degree of potential fertility according to bonitet and the share of their distribution f_g within the object: 1 – sod-podzolic silt cohesive-sandy soil (B = 28), f_g = 0.1; 2 – soddy slightly podzolic sandy soil (B = 20), f_g = 0.3; 3 – peat medium-deep low-ash soil (B = 38), f_g = 0,6;
- by typical for the given zone cultivated crops of the population $\{k\}$, $k = \overline{1, n_k}$ (n_k = 3) and the corresponding share of their sown areas f_k: 1 – winter wheat, f_k = 0.3; 2 – potato f_k = 0.2, 3 – perennial grasses f_k = 0.5;
- by the typical (estimated) in terms of heat and moisture provision vegetation periods of the population $\{p\}$, $p = \overline{1, n_p}$ (n_p = 5): 1 – very wet, p = 10%; 2 – wet, p = 30%; 3 – average, p = 50%; 4 – dry, p = 70%; 5 – very dry, p = 90%.

The generalised results on the differentiation of the forecast values of cultivated crops yields and net rental income as a basis for determining the value of drained land in variable conditions of their use at the object under study are presented in Table 1.

Comparative characteristics in qualitative and quantitative values of the forecast value of drained land under the soil suitability conditions of its use at the object under study, determined using the data presented in Table 1, are presented in Figure 2 and Figure 3.

These data convincingly show that there is a differentiation in the value of land, which is a proportional derivative of the differentiation in crops yields depending on the conditions of their cultivation. The variation of the ratio of the difference between the maximum and minimum values to the weighted average value for the studied object is: for the cultivated crops – 393%, and for the given soils – 44.6%.

Thus, within one object alone, the forecast value of land in view of available soils and cultivated crops varies from USD2456·ha^{-1} to USD4005·ha^{-1}, averaging USD3522·ha^{-1}.

It is clear that it is impossible not to take this aspect into account when doing land valuation.

In addition, our previous studies have shown that the influence share of climatic factors on the productivity of reclaimed drained land reaches 80–90%, but the influence share

Table 1. Generalised comparative characteristics of forecast values of cultivated crops yields and net rental income on drained land under the soil suitability conditions of its use

Soils	Probability by heat and moisture supply	Winter wheat (grain) $f_k = 0.3$		Potato $f_k = 0.2$		Perennial grasses (hay) $f_k = 0.5$	
		Y_k centner·ha^{-1}	I_o USD·ha^{-1}	Y_k centner·ha^{-1}	I_o USD·ha^{-1}	Y_k centner·ha^{-1}	I_o USD·ha^{-1}
Soil $g = 1$, $f_g = 0.1$; $B = 28$	$p = 10\%$	20.50	304.39	245.30	2808.3	11.70	50.21
	$p = 30\%$	34.90	536.29	305.40	3577.16	18.90	97.00
	$p = 50\%$	43.20	676.39	282.40	3509.88	22.10	120.99
	$p = 70\%$	42.40	677.47	262.00	3021.08	22.00	127.66
	$p = 90\%$	37.10	595.21	222.90	2484.22	17.70	100.21
	weighted average	**37.25**	**583.45**	**266.35**	**3160.8**	**19.17**	**87.80**
Soil $g = 2$, $f_g = 0.3$; $B = 20$	$p = 10\%$	12.0	163.46	150.86	1666.49	21.00	105.94
	$p = 30\%$	20.40	297.70	156.99	1732.22	34.80	194.74
	$p = 50\%$	23.00	341.34	128.77	1407.67	42.70	251.52
	$p = 70\%$	24.20	372.98	110.28	1195.03	36.30	225.92
	$p = 90\%$	20.20	309.66	101.70	1096.38	29.30	181.28
	weighted average	**20.52**	**304.94**	**129.05**	**1411.6**	**34.94**	**204.56**
Soil $g = 3$, $f_g = 0.6$; $B = 38$	$p = 10\%$	35.20	529.74	163.80	1846.08	35.90	209.13
	$p = 30\%$	64.10	991.92	195.70	2259.69	50.90	306.01
	$p = 50\%$	86.40	1361.58	193.90	2382.94	67.20	422.27
	$p = 70\%$	81.80	1324.42	153.90	1934.58	57.80	378.43
	$p = 90\%$	71.10	1157.72	141.10	1841.22	45.00	295.48
	weighted average	**71.86**	**1136.95**	**175.10**	**2229.28**	**54.68**	**343.11**

Explanations: g = is a function that characterizes the different potential fertility by quality in the corresponding indices (example, 1 = sod-podzolic silt cohesive-sandy soil), f_g = a distribution rate of a particular soil within the object, B = soil quality index, which characterizes the potential fertility.
Source: own study.

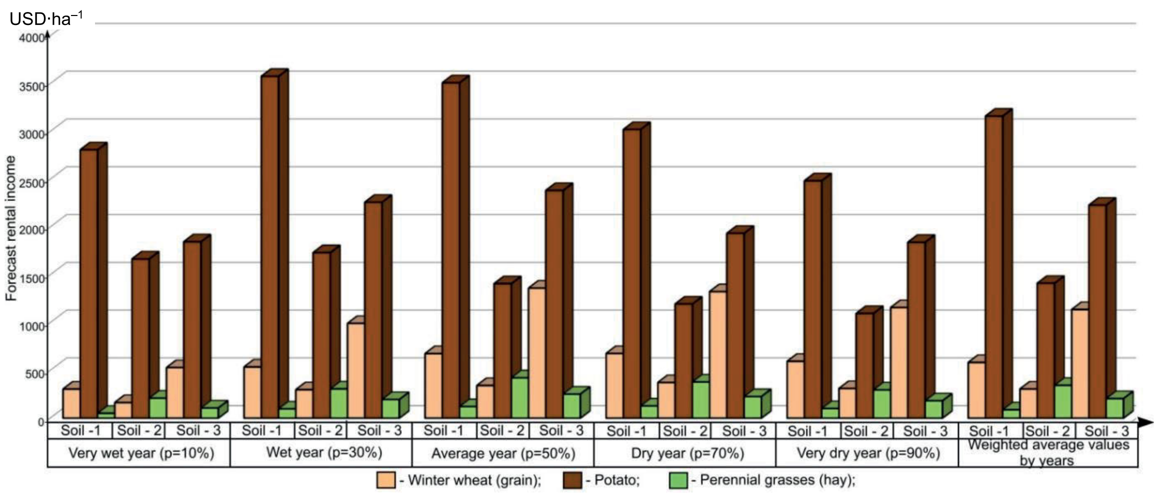

Fig. 2. Comparative characteristics of the forecast value of drained land under the soil suitability conditions of its use at the object under study; soil 1 = soddy, slightly podzolic, sandy, soil 2 = sod-podzolic silt cohesive-sandy, soil 3 = peat medium-deep low-ash; source: own study

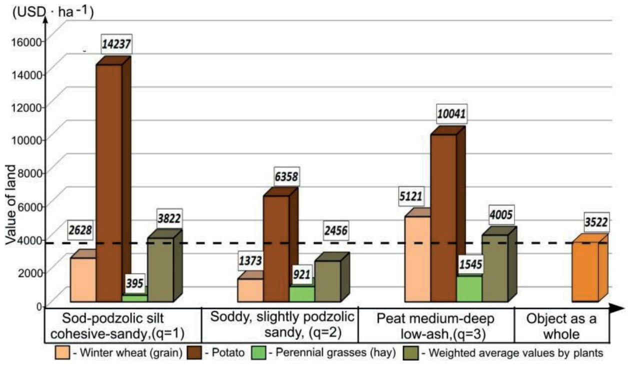

Fig. 3. Generalised comparative characteristics of the forecast value of drained land under the soil suitability conditions of its use at the object under study; source: own study.

of ameliorative factors depending on water regulation technologies and conditions of heat and moisture provision in the vegetation period is 5–10% when draining and up to 30–40% when irrigating drained land in dry periods [GADZALO *et al.* 2017; MAZHAYSKIY *at al.* (eds.) 2017].

Climate change that we are facing today and is expected to increase in the future, namely an increase in temperature by 5–25% and a decrease in water supply by 15–18% in Polissya region of Ukraine [ROKOCHINSKIY *at al.* 2019; 2020] will significantly affect the market value of drained land. It can decrease by 10–20% without providing irrigation, and increase by 40–60% and even more when replacing traditional crops with more productive and profitable (vegetables, berries, fruits, etc.) ones and providing regular irrigation during the vegetation period.

CONCLUSIONS

1. Introduction of a full-fledged land market in Ukraine and existing climate change determine the urgency of improving existing scientific and methodological approaches to determining the value of land, including for agricultural land with regulated water regime, in particular in the Polissya region of Ukraine.

2. It was experimentally determined that the determining factors in the formation of market value of land are their current or perspective productivity, which is determined by multiple variable conditions of its use: soil type, its effective and potential fertility; weather and climatic conditions of the location; type and variety of cultivated crops and agricultural machinery; carrying out the necessary agro-ameliorative and hydro-technical measures to regulate water, salt and other soil regimes, etc.

3. The results obtained on determining the differentiation in the value of drained land in view of the variable conditions of its use convincingly demonstrates the need to revise existing standards in order to increase the objectivity of such a valuation that within one object alone, the forecast value of land in view of available soils and cultivated crops varies from USD2456$\cdot$ha^{-1} to USD4005$\cdot$ha^{-1}, averaging 3522 USD$\cdot$ha^{-1}.

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