JOURNAL OF WATER AND LAND DEVELOPMENT
e-ISSN 2083-4535

Polish Academy of Sciences (PAN)
Institute of Technology and Life Sciences (ITP)

JOURNAL OF WATER AND LAND DEVELOPMENT
2021, No. 48 (I–III): 48–54; https://doi.org/10.24425/jwld.2021.136145

Available (PDF): https://www.itp.edu.pl/JWLD; http://journals.pan.pl/jwld

Received 14.04.2020
Reviewed 03.06.2020
Accepted 14.08.2020

The variability of natural and climatic conditions in investment projects in the field of nature management

Anatoliy ROKOCHINSKIY[1], Nadia FROLENKOVA[1], Vasyl TURCHENIUK[1], Pavlo VOLK[1], Nataliia PRYKHODKO[1], Ruslan TYKHENKO[2], Ivan OPENKO[2] ✉

[1] National University of Water and Environmental Engineering, Str. Soborna, 11, 33000, Rivne, Ukraine
[2] National University of Life and Environmental Sciences of Ukraine, Str. Vasylkivska, 17, 03040, Kyiv, Ukraine

For citation: Rokochinskiy A., Frolenkova N., Turcheniuk V., Volk P., Prykhodko N., Tykhenko R., Openko I. 2021. The variability of natural and climatic conditions in investment projects in the field of nature management. Journal of Water and Land Development. No. 48 (I–III) p. 48–54. DOI 10.24425/jwld.2021.136145.

Abstract

The article focuses on the actual scientific and practical problem of accounting for the influence of meteorological and climatic factors in the technical and economic calculations in the field of environmental management.

It has been proven that the introduction of scientifically sound and effective methods of using meteorological and climatic information in economic calculations significantly reduces the loss caused by weather conditions and improves the implementation of an optimal strategy for agricultural production on reclaimed lands.

Such calculations are based on economic and statistical modelling of different variants that accounting for standard hydrometeorological information in the implementation of design, management and economic decisions. This increases the validity and reliability of calculations, as well as their compliance with the actual operating conditions of environmental and economic facilities. Consequently, this attracts increased interest of both public and private investors.

Not only under such conditions is a sustainable development of environmental management sectors possible but also the adaptation to global climate change and additional benefits from the efficient economic activity in the new environmental conditions.

Key words: *agricultural production, environmental management, forecasting and optimization models, investment projects, natural and climatic conditions, water management and land reclamation systems*

INTRODUCTION

The current development of Ukraine is characterized by significant imbalances in the development of various sectors of the economy. This is mainly due to the scarcity of financial resources, their different investment attractiveness and the presence of negative trends in sectors that actively use natural resources. At present, the situation is exacerbated by challenges of the present energy, food and water crises, and the climate change at both global and regional levels [BLANC, SCHLENKER 2017; DONG *et al.* 2016; GOHAR, CASHMAN 2016; KOVALENKO *et al.* 2019; MARTYN *et al.* 2019; MARTYN *et al.* 2020; MASSEY 2012; OPENKO *et al.* 2020; REZAEI ZAMAN *et al.* 2016; ROKOCHINSKIY 2010].

Such changes need special attention and investment in the highest sensitive and the least adaptable industries as most ecosystems are very sensitive to farming practices and resources demand. Therefore, an effective mechanism and toolkit for business planning is needed in such ecosystems to reduce the losses caused by adverse climate change.

That is why special attention should be paid to the development and functioning of the natural-engineering sectors, where the economic growth is limited by the rational use of natural resources and environmental protection.

Land reclamation is one of such sectors [KOVALENKO *et al.* 2019; ROKOCHYNSKIY *et al.* 2020].

The current state of the sector is characterized by a decrease in the efficient use of reclaimed land and its role in agricultural production. It is a consequence of a deep economic crisis that has hit all sectors of the economy. Today, the economic and environmental problems of land reclamation are of particular relevance.

In the last decade, the trends in the sector have been characterized by a complex of unresolved issues, such as underfunding due to the lack of interest from both state and private investors.

These problems in water management and land reclamation can be solved by the restructuring of the system of economic relations, introduction of effective market management methods, and the application of new methodology and methods to economic calculations.

The transformation of economic relations of Ukraine, the emergence of new financing sources for investment projects, and the need for greening modern production require the revision and improvement of traditional approaches, particularly to ecologically and economically optimal design solutions in the areas of environmental management in general and water management and land reclamation in particular [ARMEANU, LACHE 2009; BIERMAN, SMIDT 2006; HAKA 2006; MOHAMED, MCCOWAN 2001; NOWAK 2005].

This, however, is complicated by the specific functioning of water management and reclamation facilities and the development of projects in the difficult and changing environmental conditions. The above must be taken into consideration when selecting the best option for project implementation [ROKOCHYNSKIY 2016; ROKOCHYNSKIY *et al.* 2019].

METHODS

The most important and distinctive feature of agricultural production, including one on the reclaimed land, is the influence of natural factors. In general, agricultural production in different climatic zones is determined by existing agro-climatic conditions [ROKOCHYNSKIY *et al.* 2010; 2016; ZHUKOVSKY 1981]. Agricultural productivity depends not only on biological capabilities of crops, machines and mechanisms, timely and high-quality tillage, fertilizers, crop rotations, etc., but also on a number of meteorological factors and their interaction. Agricultural production is extremely susceptible to weather conditions and changes in hydrometeorological parameters. Therefore, the output of the agricultural activity on the reclaimed land and, accordingly, the effectiveness of investment in land reclamation depend not only on the availability of material resources and their use, but also on the presence or absence of necessary natural and climatic resources.

Transition from the established practice of considering water management and reclamation facilities is needed, since it is not only a technical issue, but complex natural and technical, ecological and economic systems of nature management. Corresponding changes in the methodology, technical and technological strategy of their formation and functioning should follow. This requires direct consideration of volatile natural and climatic conditions. Along with land reclamation factors, they have a decisive influence on the overall natural and reclamation regime of reclaimed land and the corresponding ecological and economic effect.

Therefore, meteorological and climatic factors should be urgently taken into consideration in the technical and economic calculations. The introduction of scientifically sound and effective methods of using meteorological and climatic information in economic calculations will significantly reduce losses caused by weather conditions. In addition, the effect can be boosted by the implementation of an optimal strategy for the organization of agricultural production on reclaimed land.

Thus, according to scientific sources and practical approaches to the substantiation of optimal technical and technological solutions for water management of drained and irrigated lands on ecological and economic grounds, a climate-optimal strategy has been implemented at different intervals in the reclamation projects [ROKOCHYNSKIY 2016; ROKOCHYNSKIY *et al.* 2010; ZHUKOVSKY 1981].

Losses due to variable weather conditions and natural phenomena require special attention, since atmospheric processes are continuous in their nature [ROKOCHYNSKIY *et al.* 2010; 2012].

Although at the present stage of development it is possible to avoid some production losses, it is still impossible to stop or change the course of atmospheric processes. It is necessary to take into account these processes, anticipate their adverse impact, apply protection measures, and thus, partially or completely preserve material assets and successfully perform production tasks.

However, in view of the changing nature of climatic conditions, it should be noted that the methodological basis for calculating the economic and environmental effect is still very weak in different production sectors. Results of domestic and foreign studies in the second half of the last century created a theoretical basis for determining the economic effect of different strategies that use predictive and regime climate information [BLANC, SCHLENKER 2017; DONG *et al.* 2016; GOHAR, CASHMAN 2016; REZAEI ZAMAN *et al.* 2016].

With regard to water-reclamation measures as a component of agricultural production, in their technological aspect, we need to justify and evaluate different technologies of water management and their influence on reclaimed lands, proper types and designs of reclamation systems and consider their implementation in variable natural and reclamation conditions in the future.

The environmental effect is determined by projected and practical effects of land reclamation, whereas **the economic effect** is determined by the agricultural production and the investment in land reclamation.

As practice and experience show, the accuracy and objectivity of relevant calculations directly depend on the accuracy of relevant weather or meteorological forecast used at the appropriate level of decision making.

In fact, such calculations are based on economic and statistical modelling of different options with the use of standard hydrometeorological information when implementing design, management and economic decisions [FROLENKOVA *et al.* 2007; 2020; ROKOCHYNSKIY *et al.* 2010].

To build such models, it is necessary to obtain information about:

– laws of distribution of actual and estimated values of a forecast element;
– type and parameters of the user's loss (or profit) function that characterize losses (or profits) of different values and forecast errors (for alternative forecasts, so-called payoff matrix).

But to date, such loss (or profit) functions and payoff matrices for the majority of users in various sectors of the economy (including agriculture and water management) have not been determined yet.

General approaches to the building and implementation of the models that optimize business decisions at different levels by using climate data and meteorological forecasts in the creation and operation of complex meteorological and economic systems are set out in the work of ZHUKOVSKY [1981]. He introduced the concept of the "meteorological and economic system" and the "climatological strategy". When using it, a specific business decision that takes into account data on the climatic conditions of an object has limited efficacy. A climatological strategy can be "climatologically optimal" if the economic decision determined by it ensures the achievement of the extreme of a selected quality criterion.

Climatic or weather conditions in many cases have a decisive influence on the formation of water and natural and reclamation regimes of agricultural lands and crop yields. It is necessary to collect data for a relevant object from a number of previous years. The number of parameters and the selection of specific years depend on the typical long-term interseasonal variability of meteorological conditions for the region.

The application of mathematical methods and technical and economic research into reclamation involves not only various calculations, but such methods and models should also be used as a tool for obtaining theoretical conclusions and practical results.

Once we have necessary information, indicators depending on variable meteorological conditions can be determined by means of generally accepted statistical methods which are the most reasonable when developing reclamation projects.

Given the complexity of such nature management projects, modern BIM-technologies should be used for their automation and optimization. For the effective implementation of such tasks, we have developed a set of optimization, forecasting and simulation models. The models help to assess the following: climatic conditions of the area, meteorological regimes, water regimes, technologies of water regulation on drained lands, and the productivity of drained lands. In Ukraine, the practical application of forecasting and simulation models is regulated by relevant state industry standards [OPENKO *et al.* 2017; ROKOCHYNSKIY 2016; 2019; SHEVCHENKO *et al.* 2017; ZHUKOVSKY 1981].

RESULTS AND DISCUSSION

The basis for calculating all technological, economic and environmental indicators is a crop yield, which, as noted above, directly depend on changing weather and climatic conditions. While traditional approaches do not take this feature into account, static values of productivity – design, forecast, expected or standard have been used to calculate ecological and economic efficiency of water management projects. Accordingly, economic and environmental results cannot be collated with different meteorological conditions in specific years.

The method we propose enables to avoid such a shortcoming and to bring the estimated forecast values closer to the real ones, while taking into account the effect of actual weather conditions for the operation of an object in a given year.

According to the analysis, the economic result of agricultural production on reclaimed land (E_i), current agricultural (C_a) and reclamation costs (C_M), water costs (C_W), and possible losses (R) may vary and depend on many factors, the main of which are natural and climatic conditions of the production facility.

General approaches to the development and implementation of economic decision optimization models at different levels using climate data and meteorological forecasts when creating and operating complex meteorological and economic systems, are presented in the work by ZHUKOVSKY [1981]. He introduced the concepts of the "meteorological and economic system" and the "climatological strategy". According to the approach, a specific one-off economic decision is made based on climatic conditions data pertaining to a specific production facility. In this case, a climatological strategy is "climatologically optimal" if the economic decision, determined by it, reaches an extreme value of a chosen quality criterion.

Due to the seasonality of agricultural production on reclaimed lands, there are different periods of vegetation with different temperatures and humidity. These can be classified in typical annual groups. The distribution of these groups within the project life cycle is uneven and can be made with the help of a corresponding coefficient in the form of a share (probability of detection) of the corresponding yearly group within the total project implementation period.

In addition, the expected yield and the annual operating cost are influenced by the type and design of the land reclamation system, which determine the technology of water regime control (water regulation) on the reclaimed land.

For this reason, the effect of agricultural production on reclaimed lands and operating costs throughout the life cycle of the reclamation facility will depend on three main factors.

1. Weather (meteorological) conditions in the corresponding period, the statistic population – $P = \{p\}$, $p = 1, m$.

2. The share or frequency (probability) of detection of the respective yearly group within the total project life cycle – $\{\alpha_p\}$, $p = 1, m$.

3. The type and design of the reclamation system (method, water regulation plan), the statistic population – $S = \{s\}, s = 1, n$.

Having expressed a variable economic parameter as Y_{ps}, the following utility function can be constructed in a general form:

$$Y_{ps} = Y(p, s, \alpha_p), \quad p = 1, m; \quad s = 1, n \tag{1}$$

For better clarity, this function can be expressed as a payoff matrix (Tab. 1).

Table 1. Payoff matrix sample

$\{p\}, p = 1, m$	α_p	$\{s\}, s = 1, n$			
		s_1	s_2	…	s_n
p_1	α_{p1}	Y_{11}	Y_{12}	…	Y_{1n}
p_2	α_{p2}	Y_{21}	Y_{22}	…	Y_{2n}
…	…	…	…	…	…
p_m	α_{pm}	Y_{m1}	Y_{m2}	…	Y_{mn}

Source: own study.

Due to the uneven distribution of yearly groups differentiated by weather conditions throughout the project life cycle, the weighted average but not arithmetic average value by the yearly groups should be used as an annual average variable economic parameter. According to [KOVALENKO *et al.* 2019; ROKOCHYNSKIY *et al.* 2010], the weighted average value by the yearly groups is given by the formula of mathematical expectation, since it is the most important characteristic of a random variable that serves as the center of its probability distribution. This variable shows the most plausible value of the estimated or predicted factor.

Therefore, following the Bayesian approach [FROLENKOVA *et al.* 2012; ROKOCHYNSKIY *et al.* 2010; 2012], it can be argued that average (in statistical sense) values of economic variables for each alternative reclamation project in view of the climatological strategy of managing the reclamation facility over its life cycle, is given by the formula:

$$Y_i = \sum_{j=1}^{m} Y_{ij}\, \alpha_{pj}, \quad i = 1, n \tag{2}$$

Obviously, the determining of the share coefficients α_{pj} for the respective estimated yearly group within the project life cycle (probability values corresponding to given economic parameter by estimated yearly group) is very important for the future result.

The determination of the α_p indicator results from the need to assess the total heat and water supply of the estimated year by all major meteorological factors. These factors determine weather conditions in general (precipitation, temperature, saturation deficit and relative air humidity, etc.). Therefore, such assessment can accurately be carried out for any facility, subject to the statistical analysis of the observation years by the relevant meteorological factors.

According to the long-term (50–70 years) retrospective observations at meteorological stations and posts located near (up to 50 km) the investigated facility, the appropriate model of meteorological support for forecasting and optimization calculations [KOVALENKO *et al.* 2019; ROKOCHYNSKIY *et al.* 2010] is based on the investigation of weather factors variability, including:

– computer-aided multivariate statistical analysis;
– schematization of meteorological regimes by a comprehensive assessment of meteorological factors and complexes built on their basis;
– identification and formalization of the mechanism of meteorological regimes formation for both long-term and vegetation periods.

Such a model, unlike already available ones, enables to obtain a typical distribution of major meteorological factors (precipitation; average temperature, moisture deficit and relative air humidity); the statistic population is $\{f\}$, $f = \overline{1, n_f}$ for a basic ten-day period in typical (estimated) vegetation periods as regards heat and humidity; the statistic population is $\{p\}$, $p = \overline{1, n_p}$ $(n_p = 5)$: 1 – very wet, p = 10%; 2 – wet, p = 30%; 3 – average, p = 50%; 4 – dry, p = 70%; 5 – very dry, p = 90%.

Such a number of typical meteorological regime models is sufficient for the engineering and economic practice to provide forecast and optimize calculations on a long-term basis. The real values of the shares α_p, $p = \overline{1, n_p}$ are also determined for the implementation of a climatologically optimal strategy for the managing of the facility at the design stage.

In the general model implementation structure, after dividing the statistical sequence into typical groups, the shares of different vegetation periods regarding water supply are determined $\{\alpha_p\}$, $p = \overline{1, n_p}$ within the analysed period $\{j\}$, $j = \overline{1, n_j}$

$$\alpha_p = n_{jp}/n_j, \; p = \overline{1, n_p}, \tag{3}$$

where n_{jp} the number of elements of the observation yearly group, the statistic population is $\{j\}$, $j = \overline{1, n_j}$, which were included in the p^{th} yearly group by the water supply, the statistic population is $\{p\}$, $p = \overline{1, n_p}$, of the treated statistical series, the statistic population is n_j.

Otherwise, when long-term observation data is unavailable, values of the indicator α_p can be assumed based on hydrological simplified calculations or appropriate recommendations.

Provided the empirical probability of any hydrological or meteorological characteristic is known, one can calculate its probable frequency over years. The frequency of a hydrological value means a number of years N during which this value occurs on average once.

Probability p (%) and frequency N are related as follows:

$$N = \frac{100}{p} \qquad \text{when } p < 50\% \tag{4}$$

$$N = \frac{100}{100-p} \qquad \text{when } p < 50\% \tag{5}$$

Firstly, values α_p, calculated using Equations (4) and (5), take the same values for different facilities regardless of their location. Secondly, they do not take into account the complex influence of meteorological factors on the environment of meteorological regimes in the estimated years.

Therefore, based on the generalization of results from our own studies, data from other authors and reference data (e.g. ROKOCHYNSKIY *et al.* [2010; 2013; 2019; 2020]; SHALAY *et al.* [2004], etc.), the normalized values of the indicator α_p by natural zones for drained lands have been determined and shown in Table 2.

Table 2. Recommended normalized values αp for estimated vegetation periods on drained lands by natural zones in Ukraine

Natural zone	Normalized values α_p at probability p				
	10%	30%	50%	70%	90%
Forest steppe	0.10	0.20	0.20	0.30	0.20
Polissya (forest area)	0.15	0.20	0.25	0.25	0.15
Subcarpathia	0.15	0.25	0.30	0.20	0.10
Transcarpathia	0.10	0.20	0.30	0.25	0.15

Source: own study.

These values are well suited for approximate calculations when substantiating design technical and technological solutions for water management on drained lands on a long-term basis based on optimization models, taking into account the climatological strategy for the facility management and estimation of the overall economic efficiency of irrigation implementation. If necessary, the recommended values of α_p can be adjusted for a specific object, taking into account changes in weather and climatic conditions in the future.

Based on this approach, forecasting and optimization models for selecting technically, economically and environmentally optimal variants of design solutions were developed and implemented when reconstructing existing hydro-reclamation systems in various natural and climatic zones in Ukraine. More specifically, it was done during the optimization of agricultural drainage parameters, technology of water management and design of hydro-reclamation systems on drained lands, technological and design solutions for the operation of rice irrigation systems, etc. (e.g. BIERMAN and SMIDT [2006], NOWAK [2005], HAKA [2006], ROKOCHYNSKIY *et al.* [2019], etc.).

Table 3 shows the economic result of agricultural production on reclaimed lands in changing climatic and reclamation conditions when cultivating potatoes. This crop is one of the most profitable in the project crop rotation on drained mineral soils in the Ukrainian forest-steppe zone. Data on yields and technical and economic indicators are necessary for the project to provide forecasting and optimization calculations to substantiate the optimal technology of water regulation in conditions studied.

This assessment was performed as a computer-based experiment using an appropriate set of predictive and simulation models [ROKOCHYNSKIY *et al.* 2010] for different water management technologies (1 – drainage; 2 – preventive locking as periodic watering by partial accumulation of drainage runoff and ponding of ground water table

Table 3. Yields and main technical and economic indicators of potato cultivation in variable natural, agricultural and ameliorative conditions in the forest-steppe zone in Ukraine

Estimated heat and water supply for vegetation periods (%)	Yield t·ha^{-1}	Agricultural cost	Operational cost	Total running cost	Gross production	Net income
		USD·ha^{-1}				
Drainage						
p = 10	28.16	497.96	56.48	554.46	750.14	195.68
p = 30	32.61	538.52	48.54	587.05	948.20	361.15
p = 50	29.77	530.30	47.92	578.22	911.80	333.58
p = 70	28.58	507.62	47.92	555.55	797.90	242.36
p =90	23.86	468.97	47.92	516.89	610.16	93.27
Weighted average	28.64	**509.64**	**48.89**	**558.54**	**808.42**	**249.88**
Preventive locking						
p = 10	28.16	520.00	89.49	609.49	750.14	140.65
p = 30	33.33	563.82	71.51	635.35	964.22	328.87
p = 50	31.03	564.20	70.14	634.34	970.42	336.08
p = 70	30.89	551.78	73.47	625.25	906.12	280.87
p = 90	31.04	551.41	84.28	635.68	905.72	270.04
Weighted average	31.16	**553.43**	**76.18**	**629.60**	**914.91**	**285.31**
Watering locking						
p = 10	28.16	531.37	138.64	670.00	750.14	80.14
p = 30	33.33	575.19	117.47	692.65	964.22	271.56
p = 50	32.03	581.68	115.84	697.53	1 000.18	302.65
p = 70	31.78	573.84	119.76	693.60	959.72	266.12
p = 90	34.41	585.33	132.52	717.84	1 013.37	295.53
Weighted average	32.30	**573.72**	**122.95**	**696.67**	**958.48**	**261.80**
Sprinkling irrigation on drained lands						
p = 10	28.16	576.32	323.92	900.24	750.14	–150.10
p = 30	33.33	620.14	258.48	878.61	964.22	85.60
p = 50	36.94	650.83	253.47	904.30	1 115.35	211.05
p = 70	37.77	661.11	265.58	926.69	1 167.19	240.50
p = 90	42.18	697.17	304.97	1 002.14	1 343.60	341.47
Weighted average	36.64	**649.58**	**275.45**	**925.05**	**1 109.80**	**184.75**

Source: own study.

(GWT) in spring; 3 – locking as regular watering during the growing season by supplying water, rise and ponding of GWT on the system; 4 – sprinkling irrigation of drained lands and estimated as to the heat and water supply vegetation periods (p = 10% – very wet, p = 30% – wet, p = 50% – average wet; p = 70% – dry, p = 90% – very dry).

Results in Table 3 clearly demonstrate the necessity and usefulness of taking into account the impact of variable weather and climatic conditions in the economic analysis of agricultural production on reclaimed lands in the projects involving construction, reconstruction and operation of water and reclamation facilities.

Results in Table 3 convincingly show the significant impact of weather and climatic conditions on forecast yields by estimated years and their deviation from weighted average values obtained from Equation (2). This indicates the necessity of taking into account the effect of changing weather and climatic conditions in the economic analysis of agricultural production on reclaimed land in projects involving construction, reconstruction and operation of water management and reclamation facilities.

CONCLUSIONS

1. The integration of the long-term variability of natural and climatic conditions in environmental and economic calculations enables to:
- include them in the economic analysis of agricultural production on reclaimed lands;
- build and successfully implement forecasting and optimization models to substantiate both optimal technical and technological solutions for water regulation, and the development of investment projects for the construction and reconstruction of water management and reclamation systems;
- increase the validity and reliability of the calculations, as well as their compliance with real conditions for the operation of natural facilities. This should attract both public and private investments.

2. Such conditions enable to:
- maintain a steady development of nature management sectors and their adaptation to global climate change;
- prevent and reduce losses from uncontrolled environmental factors; and
- generate additional benefits from more rational economic activity in new environmental conditions.

REFERENCES

ARMEANU D., LACHE L. 2009. The NPV criterion for valuing investments under uncertainty. Economic computation and economic cybernetics studies and research. Academy of Economic Studies. No. 4 p. 133–143.

BIERMAN H. JR., SMIDT S. 2006. The capital budgeting decision: Economic analysis of investment projects. 9th ed. Abingdon-on-Thames. Routledge. ISBN 9780415400046 pp. 424.

BLANC E., SCHLENKER W. 2017. The use of panel models in assessments of climate impacts on agriculture. Review of Environmental Economics and Policy. Vol. 11. Iss. 2. Summer p. 258–279. DOI 10.1093/reep/rex016.

DONG Z., PAN Z., WANG S., AN P., ZHANG J., ZHANG J., PAN Y., HUANG L., ZHAO H., HAN G., WU D., WANG J., FAN D., GAO L., PAN X. 2016. Effective crop structure adjustment under climate change. Ecological Indicators. Vol. 69. October p. 571–577. DOI 10.1016/j.ecolind.2016.04.010.

FROLENKOVA N., KOZHUSHKO L., ROKOCHINSKIY A. 2007. Ekoloho-ekonomichne otsinyuvannya v upravlinni melioratyvnymy proektamy: Monografiya [Ecological and economic assessment in the management of reclamation projects: Monograph]. Rivne. NUVGP. ISBN 966-327-049-7 pp. 258.

FROLENKOVA N., ROKOCHINSKIY A., VOLK P., SHATKOVSKYI A., PRYKHODKO N., TYKHENKO R., OPENKO I. 2020. Cost-effectiveness of investments in drip irrigation projects in Ukraine. International Journal of Green Economics (IJGE). Vol. 14. No. 4 p. 315–326. DOI 10.1504/IJGE.2020.112570.

GOHAR A., CASHMAN A. 2016. A methodology to assess the impact of climate variability and change on water resources, food security and economic welfare. Agricultural Systems. Vol. 147. September p. 51–64. DOI 10.1016/j.agsy.2016.05.008.

HAKA S. F. 2006. A review of the literature on capital budgeting and investment appraisal: Past, present, and future musings. Handbooks of Management Accounting Research. Vol. 2 p. 697–728. DOI 10.1016/S1751-3243(06)02010-4.

KOVALENKO P., ROKOCHINSKIY A., JEZNACH J., KOPTYUK R., VOLK P., PRYKHODKO N., TYKHENKO R. 2019. Evaluation of climate change in Ukrainian part of Polissia region and ways of adaptation to it. Journal of Water and Land Development. No. 41 (IV–VI) p. 77–82. DOI 10.2478/jwld-2019-0030.

MARTYN A., OPENKO I., IEVSIUKOV T., SHEVCHENKO O., RIPENKO A. 2019. Accuracy of geodetic surveys in cadastral registration of real estate: Value of land as determining factor. 18th International Scientific Conference. Engineering for Rural Development. 22–24.05.2019 Jelgava, Latvia p. 1818–1825. DOI 10.22616/ERDev2019.18.N236.

MARTYN A., SHEVCHENKO O., TYKHENKO R., OPENKO I., ZHUK O., KRASNOLUTSKY O. 2020. Indirect corporate agricultural land use in Ukraine: Distribution, causes, consequences. International Journal of Business and Globalisation. Vol. 25. No. 3 p. 378–395. DOI 10.1504/IJBG.2020.109029.

MASSEY E.E. 2012. Experience of the European Union in adaptation to climate change and its application to Ukraine [online]. Office of the Co-ordinator of OSCE Economic and Environmental Activities pp. 36. [Access 20.03.2020]. Available at: https://www.osce.org/ukraine/104019?download=true

MOHAMED S., MCCOWAN A.K. 2001. Modelling project investment decisions under uncertainty using possibility theory. International Journal of Project Management. Vol. 19. Iss. 4 p. 231–241. DOI 10.1016/S0263-7863(99)00077-0.

NOWAK M. 2005. Investment projects evaluation by simulation and multiple criteria decision aiding procedure. Journal of Civil Engineering and Management. Vol. 11. Iss. 3 p. 193–202. DOI 10.1080/13923730.2005.9636350.

OPENKO I., KOSTYUCHENKO Y. V., TYKHENKO R., SHEVCHENKO O., TSVYAKH O., IEVSIUKOV T., DEINEHA M. 2020. Mathematical modelling of postindustrial land use value in the big cities in Ukraine. International Journal of Mathematical, Engineering and Management Sciences. Vol. 5. No. 2. p. 260–271. DOI 10.33889/IJMEMS.2020.5.2.021.

OPENKO I., SHEVCHENKO O., ZHUK O., KRYVOVIAZ Y., TYKHENKO R. 2017. Geoinformation modelling of forest shelterbelts effect on pecuniary valuation of adjacent farmlands. International Journal of Green Economics (IJGE). Vol. 11. No. 2 p. 139–153. DOI 10.1504/IJGE.2017.089015.

REZAEI ZAMAN M., MORID S., DELAVAR M. 2016. Evaluating climate adaptation strategies on agricultural production in the Siminehrud catchment and inflow into Lake Urmia, Iran using SWAT within an OECD framework. Agricultural Systems. Vol. 147. September p. 98–110. DOI 10.1016/j.agsy.2016.06.001.

ROKOCHINSKIY A. 2010. Naukovi ta praktichni aspekti optimizacii vodoregulyuvannya osushuvanikh zemel' na ekologoekonomichnikh zasadakh: Monografiya [The scientific and practical aspects optimization of water regulation drained lands on environmental and economic grounds. Monograph]. Rivne. NUVGP. ISBN 978-966327-141-5 pp. 352.

ROKOCHINSKIY A. 2016. Systemna optymizatsiya vodorehulyuvannya yak neobkhidna umova stvorennya ta funktsionuvannya vodohospodars′ko-melioratyvnykh ob″yektiv na ekoloho-ekonomichnykh zasadakh [System optimization of water regulation as a prerequisite for the creation and operation of water management and reclamation facilities on ecological and economic grounds]. Vodne hospodarstvo Ukrayiny. No 104 p. 67–71.

ROKOCHINSKIY A., BILOKON V., FROLENKOVA N., PRYKHODKO N., VOLK P., TYKHENKO R., OPENKO I. 2020. Implementation of modern approaches to evaluating the effectiveness of innovation for water treatment in irrigation. Journal of Water and Land Development. No. 45 (IV–VI) p. 119–125. DOI 10.24425/jwld.2020.133053.

ROKOCHINSKIY A., FROLENKOVA N., KOPTIUK R. 2012. Investitsiyna otsinka proektiv optimizatsiï vodoregulyuvannya osushuvanih land of urahuvannyam mainly chinnikiv vplivu [Investment assessment project for optimizing water management of drained lands from the main bureaucrats]. Tavriys′kyy naukovyy visnyk. Vol. 83 p. 216–220.

ROKOCHINSKIY A., JEZNACH J., VOLK, P., TURCHENIUK V., FROLENKOVA N., KOPTIUK R. 2019. Reclamation projects development improvement technology considering optimization of drained lands water regulation based on BIM. Scientific Review Engineering and Environmental Sciences. Vol. 28. Iss. 3(85) p. 193–202. DOI 10.22630/PNIKS.2019.28.3.40.

ROKOCHINSKIY A., STACHUK V., FROLENKOVA N., SHALAY S., KOPTYUK R., VOLK P.. 2010. Tymchasovi rekomendatsiyi z optymizatsiyi vodorehulyuvannya osushuvanykh zemel′ u proektakh budivnytstva y rekonstruktsiyi vodohospodars′ko-melioratyvnykh ob″yektiv [Temporary recommendations for optimization of water management of drained lands in projects of construction and reconstruction of water management and reclamation facilities]. Rivne. NUVGP pp. 52.

ROKOCHYNSKIY A., TURCHENIUK V., PRYKHODKO N., VOLK P., GERASIMOV I., KOÇ C. 2020. Evaluation of climate change in the rice-growing zone of Ukraine and ways of adaptation to the predicted changes. Agricultural Research. DOI 10.1007/s40003-020-00473-4.

ROKOCHINSKIY A., VOLK P., FROLENKOVA N., SHALAY S., KOPTYUK R., ZAYETS V. PRYKHODKO N. 2013. Naukovometodychni rekomendatsiyi do obgruntuvannya optymal′nykh parametriv sil′s′kohospodars′koho drenazhu na osushuvanykh zemlyakh za ekonomichnymy ta ekolohichnymy vymohamy [Scientific and methodological recommendations for substantiation of optimal parameters of agricultural drainage on drained lands according to economic and environmental requirements]. Rivne. NUVGP pp. 34.

SHALAY S., ROKOCHINSKIY A., STASHUK V., BEZHUK V. 2004. Tymchasovi rekomendatsiyi z obhruntuvannya efektyvnoyi proektnoyi vrozhaynosti na osushuvanykh zemlyakh pry budivnytstvi y rekonstruktsiyi melioratyvnykh system [Temporary recommendations for substantiation of effective project yield on drained lands during construction and reconstruction of reclamation systems]. Rivne. NUVGP pp. 44.

SHEVCHENKO O., OPENKO I., ZHUK O., KRYVOVIAZ Y., TYKHENKO R. 2017. Economic assessment of land degradation and its impact on the value of land resources in Ukraine [online]. International Journal of Economic Research (IJER). Vol. 14. No. 15. P. 4. p. 93–100. [Access 18.06.2020] Available at: https://serialsjournals.com/abstract/34405_ch_11_f_-_ivan_openko.pdf

ZHUKOVSKY E. 1981. Meteorologicheskaya informatsiya i ekonomicheskiye resheniya [Meteorological information and economic decisions]. Leningrad. Gidrometeoizdat pp. 304.