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Evaluation of ecological and economic efficiency of investment in water management and land reclamation projects

Pyotr KOVALENKO[1] ✉, Anatoliy ROKOCHINSKIY[2], Pavlo VOLK[2], Vasyl TURCHENIUK[2], Nadia FROLENKOVA[2], Ruslan TYKHENKO[3]

[1] Institute of Water Problems and Land Reclamation of NAAS of Ukraine, Chapaeva Str., 14, fl. 6, 01030, Kyiv, Ukraine
[2] National University of Water and Environmental Engineering, Rivne, Ukraine
[3] National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine

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Abstract

The article is devoted to the actual scientific and practical problem of improving methodological and methodical approaches to the evaluation of design solutions in the water management and land reclamation industry based on the ecological and economic principles in conditions of uncertainty.

The current stage of the development of the water management sector in Ukraine is characterized by a combination of past negligence and the present energy, food and water crises, as well as global climate change. To solve these problems, it is necessary to reform organizational-economic relations in the industry, including new sources and forms of financing for water management and land reclamation projects, introduction of new environmentally advanced technologies, and the improvement of the existing ecological and economic evaluation of investments.

Based on scientific and methodological recommendations used for evaluating the effectiveness of investment in various spheres of economic activity, the authors developed and implemented an improved methodology for the evaluation of water management and land reclamation projects. It is based on methodological approaches that cover such elements as the variety of options, changes in the value of money over time, specific project implementation environment, including the impact of weather, climate and environmental factors on project performance, multilevel and gradual evaluation of a project against specific criteria and according to stages of the project cycle.

The method was tested during the reconstruction of a rice irrigation system in the steppe zone of about 3000 ha in Ukraine. Economic results, namely the deterministic payback period and investment return index confirm that the proposed mechanism, unlike the traditional one, increases the economic and environmental feasibility of water management and land reclamation projects. Therefore, it stimulates investment in the land reclamation sector.

Key words: *ecological and economic efficiency, evaluation, investments, land reclamation, risks, scientific and methodological principles, water management, weather and climatic conditions*

INTRODUCTION

The social and economic changes that have taken place in the country over the last decades are characterized by instability and the lack of a clear, effective economic development strategy in virtually all areas where natural resources are used. In particular, the current water management and land reclamation industry struggles against economic and environmental problems. These problems are primarily caused by improper funding due to the lack of interest on the part of the state and potential private investors.

The current stage of the development of the water management sector in Ukraine is characterized by a combination of past negligence and present energy, food and water crises, as well as global climate change. To solve these problems, it is necessary to reform organizational-economic relations in the industry, including new sources and forms of financing for water management and land reclamation projects, introduction of new environmentally advanced technologies, and the improvement of the existing mechanism of ecological and economic evaluation of water management projects. This will lead to an increased investment attractiveness of the sector and its development towards greener production. Indeed, the justification of economic feasibility and environmental reliability of such projects is a prerequisite and an incentive for their financing through both public and private investments in modern solutions.

If this problem is not addressed more carefully in other profitable sectors today, ecological and economic evaluation of economic decisions remain unsolved in water management and land reclamation as well. The existing system of economic and environmental evaluation is predominantly static and it is based on methodological approaches used in the past administrative and central planning economy. They were based on the concept of resource utilization cost, which included comparison and selection of economic decisions to minimize the total cost, as well as a static model of calculations without taking into account the life cycle of projects, changes in the cost of resources over time and risk factors. In addition, the existing methodology of economic calculations in the sector does not reflect the real impact of technological (parameters and structures of water management and reclamation systems) and environmental (in particular changing weather and climatic conditions) components on the economic project performance indicators.

MATERIAL AND METHODS

In the absence of domestic studies, it is advisable to focus on the foreign experience in and methodological approaches to economically and environmentally optimal business strategies, taking into account modern features of economic relations as well as the financial calculation practice in the water management and reclamation industry in Ukraine.

In the developed countries, project feasibility studies have been based on the methodology developed by United Nations Industrial Development Organization (UNIDO). The methodology was first published in 1978 and became fundamental for making project decisions. The methodology focuses on changes in the value of money over time, evaluation of project effectiveness throughout the its life cycle, investment decisions based mainly on the net present value, and risk evaluation and their impact on the project performance.

The methodology is subject to studies, improvements and adaptation to various industries. Studies have been presented in research papers, including TEICHROEW *et al.* [1965], KWAK *et al.* [2000], SUDONG *et al.* [2000], MOHAMED *et al.* [2001], NOWAK [2005], BIERMAN *et al.* [2006], CHEN [2006], HAKA [2006], ARMEANU *et al.* [2009], and WANG *et al.* [2019].

Currently, the authors focus on the evaluation based on investment efficiency indicators, their comparative analysis in different sectors, evaluation models of alternative investment under uncertainty, and determining of investment analysis criteria, etc.

When analyzing methodological approaches to the evaluation of water management and land reclamation projects regarding their ecological and economic effectiveness, their specific features and differences from investment projects in other sectors should be taken into account. This determines the choice of their evaluation method and calculation of economic indicators. Therefore, we have identified the following factors that are decisive for the improvement of traditional approaches to the evaluation of economic decisions in environmental management:

- dependence of ecological and economic effect and weather and climatic conditions, which is extremely relevant in the context of present and future changes [ROKOCHINSKIY *et al.* 2017];
- deep relationship between ecological and economic effect and weather and climatic conditions [MARTYN *et al.* 2020; OPENKO *et al.* 2020];
- use of natural resources (land, water, etc.) in addition to materials and labor [MARTYN *et al.* 2019; SHEVCHENKO *et al.* 2017];
- application of specific technology: water management technology on reclaimed land (engineering infrastructure, main reclamation funds, technological processes) and agrotechnics (system of basic agricultural funds, planting, fertilizing methods, etc.).

While taking into account these features in present conditions, land reclamation projects are proposed to be considered not as purely technical but as complex environmental, technical and economic systems.

It is suggested to consider the water management and land reclamation project as an ecological and economic system designed to deliver rational environmental management and optimal and efficient agricultural production on the reclaimed land. This can be achieved by minimizing the impact of adverse environmental conditions on the ecological and economic effects obtained over a certain period.

In the world's practice of economic calculations there are two main approaches to the evaluation of economic investment efficiency of any project, including those in the water sector. According to these approaches, methods of economic investment evaluation can be divided into two groups:

- simple (static) methods;
- discounting methods (dynamic).

The first group became popular in the domestic economic practice. However, they ignore the project life cycle, volatility of cash flows, and risk factor impact on project outcomes. Despite the use of progressive methods of investment analysis in other spheres, domestic design organizations, which develop and implement water-management and land reclamation projects, still use archaic and inefficient methodology for project documentation and feasibility studies. The approach used in substantiating the economic efficiency of water management projects does not take into account changes in the value of money over time, impact of changing climatic conditions on economic parameters, and environmental risks.

The second group includes analytical methods of investment project evaluation that encompass the notion of "time series" and require the application of a special mathematical apparatus and a more thorough preparation of background information. Indicators used are adequate to the main purpose of production under market conditions, and they address revenue and expenditure of a project throughout its implementation period, take into account change in the value of money over time, enable to evaluate risk of a project decision, and provide guidance while selecting a project which best facilitates the growth of the enterprise value.

Usually, indicators used to make investment decisions are the net profit value (*NPV*), profitability index (*PI*), discounted payback period (*DPP*) and internal rate of return (*IRR*), as well as their modifications. However, conventional methods need to be adapted to domestic economic conditions, especially to the calculation of economic indicators in different sectors.

Generalizing commonly accepted approaches and requirements for the evaluation of investment efficiency of technical projects and in view of characteristics of the land reclamation sector, methodological approaches to the evaluation of water management and land reclamation projects should be based on the following principles:

1. Various options (best design solution chosen from possible alternatives).
2. Change in the value of money over time (water management and land reclamation project dynamics and comprehensive study of effectiveness throughout the life cycle).
3. Specific features of the project implementation environment expressed in the impact of:
   – environmental factors,
   – weather and climate.
4. Multilevel and gradual evaluation of the project (selection of evaluation criteria and indicators according to project cycle stages).
5. Determination of decision making criteria for:
   – projects of national importance which focus less on the economic and more on the environmental and social effectiveness;
   – commercial projects designed to generate desired profits which compensate the uncertainty of their final result.
6. The use of indicators that meet:
   – main goals and objectives of the project,
   – interests of the main parties to the investment process, and
   – project implementation environment.
7. Full return on investment from proceeds generated by the project within the timeframe acceptable to the investor.
8. Where appropriate, qualitative indicators and expert opinions that enable to take into reflect intangible effects (social, environmental).

We have developed these principles based on concept and methodological approaches to evaluate alternative options for water management and land reclamation projects.

Such investment options were tested by the authors when evaluating alternative technical solutions for different climatic zones, in particular, for the irrigated area in the Odessa region in Ukraine (latitude 47°0'0" N; longitude 30°0'0" E).

RESULTS AND DISCUSSIONS

The research helped to develop theoretical and methodological approaches and practical recommendations for the improvement of ecological and economic evaluation in water management and land reclamation projects, set forth by ROKOCHINSKIY *et al.* [2018].

The main components of the proposed methodology are as follows:

1) in general terms, it is two-tier system for evaluating alternative projects – **preliminary simplified** and **final investment** evaluation based on various criteria and methodologies to enhance decision-making;
2) weather and climatic conditions taken into account in economic calculations, since they have a decisive influence on the formation of economic and environmental effects of water management and land reclamation facilities;
3) quantifies weather and climate risk as a determining factor for comparing alternatives to design decisions [FROLENKOVA *et al.* 2015; 2020; ROKOCHINSKIY *et al.* 2020];
4) quantified ecological effects of water management and land reclamation facilities, which is necessary to compare design solutions.

Thus, a preliminary environmental and economic assessment of alternative project options is advisable at the stage of a concept design before precise information on basic technical and technological indicators and project parameters are defined. Instead of a detailed calculation of revenue and expenditure of each alternative project option, the primary objective to convert them into comparable forms according to selected efficiency criteria to facilitate a final decision in the future.

With that in mind, it is advisable to use simple and generally accepted methods of project effectiveness assessment that are suitable when a preliminary decision is necessary and there is a lack of relevant information. The first criterion is minimal discounted cost adjusted with regard to the level of weather and climate risk.

Thus the general model of preliminary environmental and economic assessment of project options $\{i\}$, $i = \overline{1, n_i}$, under minimal discounted costs *ZP* with regard to **climatologically optimal strategy** [FROLENKOVA *et al.* 2007; KOVALENKO *et al.* 2019; MAZHAYSKIY *et al.* (ed.) 2017; ROKOCHINSKIY *et al.* 2017] is as follows:

$$ZP_0 = \min_{\{i\}} \left[\frac{\sum_{j=1}^{m} \left(C_{ij}^{a} + C_{ij}^{o} + A_i + EK_i + \overline{R_{ij}} \right) \alpha_{p_j}}{\sum_{j=1}^{m} V_{ij} \alpha_{p_j}} \right] \quad i = \overline{1, n} \quad (1)$$

Subject to certain restrictions, the environmental credibility coefficient under *i*-option of a land reclamation project, which characterizes its environmental acceptability, falls within the following range:

$$0.5 < k_i \leq 1.0 \qquad (2)$$

Where: $C^a_{i_j}$ = agricultural inputs in growing crops for the *i*-th version of project decisions, totality $\{i\}$, $i = \overline{1, n_\iota}$, on the totality of estimated years$\{j\}$, $j = \overline{1, n_j}$, within the project time of the facility (USD·ha^{-1}); C^o_{ij}= operational production costs for alternative projects (USD·ha^{-1}); A_i = depreciation costs for alternative projects (USD·ha^{-1}); α_{p_j} = coefficient reflecting the impact of changeable weather and climate conditions in design years $\{j\}$, $j = \overline{1, n_j}$, within the project period $\sum_{j=1}^{m} \alpha_{p_j} = 1$; E = normative coefficient of economic efficiency of capital investment K_i (USD·ha^{-1}) for alternative projects; V_{i_j} = respective output value under *i*-project option, (USD·ha^{-1}); R_{i_j} = weather and climate risk (USD·ha^{-1}); k_i = environmental credibility coefficient under *i*-option of water and land reclamation project, which is calculated according to the following formula:

$$k_i = \sum_{j=1}^{m} k_{ji} \alpha_{p_j} \qquad (3)$$

Environmental reliability can be calculated based on the expert evaluation of physical technological and environmental performance indicators for facilities representative of the ecological and ameliorative status of the territory.

An important component of the proposed approaches is weather and climate risk taken into account in calculations. The risk factor reflects deviation of the actual yield from its potential value in favorable meteorological conditions. Such risk can be identified using statistical analysis of a long-term research data set [FROLENKOVA *et al.* 2015].

In the end, weather and climatic conditions as well as the determination of all necessary indicators of technological, economic and ecological efficiency of a particular water management and land reclamation facility under variable natural and ameliorative conditions have been taken into account in proposed complex of interrelated forecast and simulation models. They are implemented on the basis of a computer-aided machine experiment. It allows to develop a long-term forecast and evaluate climatic conditions and meteorological regimes, including water regime, water regulation technologies and productivity of reclaimed lands [ROKOCHINSKIY *et al.* 2017]. Their practical application is regulated by relevant sector standards set by the Ukrainian State Agency of Water Resources (Ukr. Derzhavne ahentstvo vodnykh resursiv Ukrayiny).

Therefore, according to ROKOCHINSKIY *et al.* [2018], based on the results of the preliminary simplified evaluation at the stage of a concept design, one or more options are selected from the considered set (economically optimal and environmentally acceptable). Then technical designs are developed to determine final values of all project resource indicators and evaluate their investment attractiveness at the final stage.

The final evaluation of selected pre-optimal design solutions is performed according to the UNIDO recommendations based on the indicators listed above and taking into account the impact of meteorological conditions defined according to the following model:

$$PI_0 = \max_{\{i\}} \sum_{j=1}^{m} PI_i \alpha_{p_{ij}} \quad i = \overline{1, n} \qquad (4)$$

Provided that

$$\begin{cases} NPV_i \geq 0 \\ IRR_i \geq d_i \\ DPP_i \geq DPP \end{cases} \qquad (5)$$

Where: d_i = discount rate under project option; *DPP* = discounted payback period acceptable for the investor.

Each indicator in the general model is calculated while taking into consideration volatile weather and climate conditions and their impact on basic economic parameters.
For instance,

$$PI_i = \left[\frac{\sum_{t=0}^{T} \frac{E_{ai}}{\left(1+d_{i_t}\right)^t}}{\sum_{t=0}^{T} \frac{I_{i_t}}{\left(1+d_{i_t}\right)^t}} \right] + 1 \quad i = \overline{1, n} \qquad (6)$$

Where: E_{ai} = annual economic benefit under each option of water management and land reclamation project, which is calculated according to the following formula:

$$E_{ai} = \sum_{j=1}^{m} \Delta NI_{ij} \alpha_{p_j} + \Delta A_i - I_i, \quad i = \overline{1, n} \qquad (7)$$

Where: I = annual investment (USD·ha^{-1}); ΔNI = increase in annual anticipated net income as a result of investment project (USD·ha^{-1}); ΔA = increase in annual depreciation related to the introduction of new fixed capital (USD·ha^{-1}).

Other components of the model are calculated in a similar manner.

The proposed methodological approaches were tested while developing optimal parameters for technological and construction decisions under water management and land reclamation projects in different climatic zones [MAZHAYSKIY *et al.* (ed.) 2017; OPENKO *et al.* 2017; ROKOCHINSKIY *et al.* 2019; SHEVCHENKO *et al.* 2017].

As an example, let us consider the evaluation of economic and environmental efficiency of the reconstruction of the Danubian rice irrigation systems in Odessa, Ukraine (about 3000 thous. ha). The goal is to enhance general efficiency of operation based on engineering and land reclamation measures.

According to the analysis and consolidation of research and production data pertaining to the operation of the Danubian rice irrigation system in 1966–2016, a complex regime of technological and technical measures was developed to examine the need and feasibility of the following:

- transfer from the traditional resource-intensive to rational and resource-efficient use of water and energy;
- reuse of drainage and wastewater;
- application of deep loosening using appropriate low energy consumption aggregates;
- periodic leaching of saline soils together with their deep loosening;
- additional equipment added to the existing open drainage network, including subsoil drains;

– construction of additional drainage in addition to existing drainage canals to protect against deformation of the canal bed.

The above-stated measures are IP protected and designed to enhance the overall efficiency of rice irrigation systems in line with current economic and environmental requirements. Parameter substantiation methods were improved.

Thus, the following alternative options have been considered:

– option 1 – is a benchmark for operating conditions in rice irrigation systems during designing, which provides for a rice share in a crop rotation within 70–90% including companion crops (perennial grasses, other grain crops) in largely unfavorable water and salt regimes of irrigated lands; regimes result from progressing waterlogging due to excessive irrigation (up to 25 thous. $m^3 \cdot ha^{-1}$) and insufficient drainage conditions;
– option 2 – shows operating conditions in rice irrigation systems when introducing measures aimed at enhancing drainage conditions of rice bays by providing additional equipment in the open drainage network with subsoil collecting drains that maintain the optimal vertical filtration in a rice bay at 8–10 $mm \cdot day^{-1}$ and provide the optimal rice share of 50–60% in a crop rotation. That shows improved regime and technological aspects of water regulation in rice irrigation systems;
– option 3 – measures under option 2, plus deep loosening of top low permeable soil layers of 0.6 m;
– option 4 – measures under option 2, plus reused drainage water diluted 1:1;
– option 5 – measures under option 2, plus reused drainage water diluted 1:2;
– option 6 – measures under option 3, plus reused drainage water diluted 1:1;
– option 7 – measures under option 3, plus reused drainage water diluted 1:2;
– option 8 – operation of rice irrigation systems in a design mode (option 1) plus deep loosening of soil to the depth of 0.6 m.

Source data for the determining of project decision effectiveness in attracting investment is given in Table 1.

Table 2 contains comparative characteristics and rationale for an optimal project decision based on consolidated economic and environmental effectiveness indices under respective methods.

The data (see Tab. 2) prove that the implementation of the complex of agrotechnical, engineering and land reclamation measures is economically feasible and environmentally acceptable under the existing operating conditions in the Danubian rice irrigation systems.

As regards environmental and economic terms, options 2–7 are acceptable, of which the best is option 3 with the environmental credibility criterion of 0.63.

Generally, results of the alternative project investment valuation are given in Table 3. The results have been used to determine the best possible option.

The calculations (see Tab. 3) prove both general economic and relatively high commercial effectiveness of options 3, 4, and 6.

Table 1. Source data for calculating investment decisions under the options of project decisions

Indicator	Value depended on project option							
	1	2	3	4	5	6	7	8
Annual net income	296.9	1 285.6	1 705.0	1 371.8	1 367.7	1 371.8	1 364.7	454.8
Depreciation cost.	114.6	127.1	127.1	127.1	127.1	127.1	127.1	114.6
Investments in PD	2 291.7	2 542.6	2 542.6	2 542.6	2 542.6	2 542.6	2 542.6	2 291.7

[1)] Measurement unit for all indicators is $USD \cdot ha^{-1}$.
Explanation: options are described above.
Source: own study.

Table 2. Optimal choice of project based on aggregate indicators of economic and environmental efficiency

Indicator	Value dependent on project option							
	1	2	3	4	5	6	7	8
Economic efficiency ZP_i	2.88	0.74	0.63	0.78	0.79	0.75	0.76	2.06
Ecological efficiency and reliability index k_j	0.41	0.87	0.63	0.75	0.78	0.81	0.83	0.53

Explanation as in the Table 1.
Source: own study.

Table 3. Valuation of project decisions to enhance efficiency of Danubian rice irrigation systems

Indicator	Value dependent on project option							
	1	2	3	4	5	6	7	8
Investment return index	0.50	1.91	2.47	1.62	2.11	1.30	1.29	1.08
Net current value since the beginning of the project ($USD \cdot ha^{-1}$)	918.0	3160.0	3735.0	3229.0	3194.0	3439.0	3380.0	648.0
Internal rate of return (%)	2.05	3.28	8.19	5.02	9.37	6.66	6.62	5.16
Deterministic payback period (year)	8.65	3.47	2.75	3.28	3.55	3.16	3.19	7.71

Source: own study.

CONCLUSIONS

1. Unlike traditional ones, the discussed and proposed approaches to assessing water management and land reclamation projects focus on project options with balanced costs and losses due to negative impact of environmental factors. These options support improved technology of water regulation.

2. Since the efficacy of the improved technology for soil water and air regime regulation less depends on unfavorable environmental conditions, the technology provides more stable income. Besides, such technology secures environmental sustainability and rational use of natural resources.

3. Considering volatile and uncertain climatic conditions, the mechanism of a two-tier evaluation of alternative projects while using different methodological approaches enables to enhance economic and environmental feasibility of technical and technological solutions. Consequently, this encourages investment in the industry.

4. Option 3 provides the highest investment return index of 2.47 and the total project cost of 3735 USD·ha^{-1}. The deterministic payback period under this option is 2.75 years, which is quite promising and ensures a rapid return on investment.

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. Iss. 4 p. 133–143.

BIERMAN H. Jr., SMIDT S. 2006. The capital budgeting decision, ninth edition: economic analysis of investment projects. 9th ed. New York. Routledge. ISBN 9780415400046 pp. 424.

CHEN J. 2006. An analytical theory of project investment: A comparison with real option theory. International Journal of Managerial Finance. Vol. 2. No. 4 p. 354–363. DOI 10.1108/ 17439130610705535.

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 F. 2015. The evaluation of environmental risks in the sphere of water and land reclamation [online]. Oxford Journal of Scientific Research. No. 1(9). Vol. III p. 155–160. [Access 15.06.2019]. Available at: https://core.ac.uk/download/pdf/33693269.pdf#page=155

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.

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.

KWAK Y.H., WILLIAM I.C. 2000. Calculating project management's return on investment. Project Management Journal. Vol. 31. Iss. 2 p. 38–47. DOI 10.1177/87569728000 3100205.

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. Proceedings of the 18th International Scientific Conference on 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.

MAZHAYSKIY Y., ROKOCHINSKIY A., VOLCHEK A., MESHYK O., JEZNACH J. (ed.) 2017. Pryrodoobustroistvo Polesia [Environmental management of Polissya]. Kn. 2. Vyp. 1. Ryazan. VNIIGiM of A. Kostiakov. ISBN 978-5-00077654-4 pp. 902.

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., 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.

OPENKO I., KOSTYUCHENKO Y., 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.

ROKOCHINSKIY A. 2010. Naukovi ta praktichni aspekti optimizacії 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., BILOKON W., 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., JEZNACH J., VOLK P., TURCHENIUK V., FROLENKOVA N., KOPTIUK R. 2018. 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 p. 432–443. DOI 10.22630/PNIKS.2019. 28.3.40.

ROKOCHINSKIY A., VOLK P., PINCHUK O., MENDUS S., KOPTYUK R. 2017. Comparative evaluation of various approaches to the foundation of parameters of agricultural drainage. Journal of Water and Land Development. No. 34 p. 215–220. DOI 10.1515/jwld-2017-0056.

ROKOCHINSKIY A., VOLK P., PINCHUK O., TURCHENIUK V., FROLENKOVA N., GERASIMOV IE. 2019. Forecasted estimation of the efficiency of agricultural drainage on drained lands. Journal of Water and Land Development. No. 40 (I–III) p. 149–153. DOI 10.2478/jwld-2019-0016.

TEICHROEW D., ROBICHEK A., MONTALBANO M. 1965. An analysis of criteria for investment and financing decisions under certaint. Management Science. Vol. 12. Iss. 3. DOI 10.1287/mnsc.12.3.151.

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 15.06.2019]. Available at: https://serialsjournals.com/abstract/34405_ch_11_f_-_ivan_openko.pdf

SUDONG YE., TIONG R.L.K. 2000. NPV-at-Risk method in infrastructure project investment evaluation. Journal of Construction Engineering and Management. Vol. 126. Iss. 3. DOI 10.1061/(ASCE)0733-9364(2000)126:3(227).

WANG L., XU N., XU N., SONG Y., WANG Y., SONG S. 2019. Research on investment decision of substation project based on life cycle cost. IOP Conference Series: Earth and Environmental Science. Vol. 242. Iss. 2. DOI 10.1088/1755-1315/242/2/022016.