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C – statistical analysis
D – data interpretation
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F – literature search

Forecasted estimation of the efficiency of agricultural drainage on drained lands

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Abstract

In the article we developed the design principles and implementation of a complex model and optimized the design parameters of drainage. The study was based on the implementation of interconnected structural and technological forecasting simulation and optimization model blocks, which in turn allowed to justify the optimal design parameters and drainage considering multiple natural and agronomic conditions and reclamation facilities. Example of evaluating the performance of drainage on drained lands was made for the conditions of a real project, implemented on lands of agricultural holding "May Day" located within of drainage system "Ikva" in the Rivne region. For the object conditions (average decade formation conditions of the drainage flow module for growing perennial grasses, winter cereals and potatoes) the estimated duration of the growing season was 214 days (100%), of which the total duration of drainage was 60% and included different levels of efficiency: 39% – ecological, 15.5% – technological and 5.5% – economic. The duration of its critical operations (forming module drainage flow exceeds the design of its value) does not exceed 5%. Thus, this approach enables the assessment of drainage with predetermined or specified parameters in the construction or renovation of drainage systems on different levels of effectiveness. It can be effectively used in the overall complex predictive and optimization calculations to substantiate the design and parameters of agricultural drainage, taking into account the variability of natural agrotechnical and reclamation conditions of a real object.

Key words: *agricultural drainage, complex model, effectiveness, parameters*

INTRODUCTION

Undeniable is the fact that at different levels of design productivity of crops on different soils requirements for drainage work should be different [MIODUSZEWSKI *et al.* 2010; ROKOCHINSKIY *et al.* 2017; VAN DER MOLEN *et al.* 2007].

Authors developed design principles and implementation of a complex model and optimize the design parameters of drainage [ROKOCHINSKIY 2010]. It is based on the implementation of interconnected structural and technological, forecasting simulation and optimization model blocks, which in turn allow you to justify the optimal design parameters and drainage considering multiple natural, agronomic conditions and reclamation facility.

MATERIALS AND METHODS

The research methodology uses an optimization approach, that consists of a comprehensive optimization model of drainage parameters. This model takes into account not only economic factors but also environmental aspects. As an economic factor, had accepted a minimum of reduced costs taking into account weather and climatic risk, and as an environmental factor, the deviation of the weighted average value of the drainage module [ROKOCHINSKIY *et al.* 2017].

Obtained parameters of the optimal variant drainage range from environmental to economic levels of its efficiency with respect to the corresponding values of the modules of the drainage flow, but it does not address all possible periods of drainage, including critical when a roll of intense rainfall (50 mm) module formed drainage flow exceeding estimated its value:

$$i_0 = \{b_0, d_0, \varphi_0, q_0, B_0\} \qquad (1)$$

Where: b_0 = type; d_0 = diameter; φ_0 = filter; q_0 = module drainage flow; B_0 = distance between drains.

Then exceedance of limit values waterlogging duration leads to a significant loss of productivity [LOUCKS *et al.* 2017; SHKINKIS 1981; SMEDEMA *et al.* 2004].

In this regard, at the level of the project there is a need to assess the effectiveness of drainage with respect to different levels of its effectiveness by appropriate levels of crops receptivity $\{r\}, r = \overline{1, n_r}$ (r = 1 = environment, r = 2 = technology (the work of drainage, which is determined through the calculated value of the drainage modulus, and meets the ecological and economic requirements), r = 3 = economics, r = 4 = critical).

Critical conditions of the drainage (r = 4) occur when taken in calculating ten-day rainfall immediately – per day. Then there can be a dramatic elevation of groundwater and formed drain plug flow that exceeds its estimated value. In this case, designed drainage could not cope with the challenge of excess moisture in the soil, is permissible or critical waterlogged soil, which leads to loss of yield.

Yield losses from short-term uplift to a depth of 0.5 m from the ground up for 2–3 days 10–20%, at a depth of 0.6 m – 8–14% and 0.7 m – 5–10%. Thus, the impact of flooding on the yield of winter wheat for 3 days reduces the yield by 20–40%, from 3 to 6 nights – 30–90% 7 days or more – 80–100%. The loss of crops of winter rye occurs within 8–10 days, barley – after 5–8 days, of oat – after 10–11 days. When flooding the root system of potato for 2 nights' yield is reduced by 20–50% off 3 nights or more at 90–100%. Flooding perennial grasses for 4 days reduces their productivity by 20–30%, respectively, 5–7 days – 40–70%, 8 days or more – up to 100%.

Drainage performance evaluation can be performed based on the so-called "length indicators" which characterize various aspects of its operation within the terms of the calculated moisture and heat of the vegetation period.

In turn, in the duration of drainage are determined by the corresponding values of the drainage flow modules together for each crop $\{q_{kgp\tau}\}$, soils $k = \overline{1, n_k}$, calculated under the terms of moisture and heat vegetation periods $g = \overline{1, n_g}$, calculated time intervals (decade), which are formed under the influence of multiple volatile natural $\tau = \overline{1, n_\tau}$, agronomic and reclamation conditions the real object, and comparing them with calculated.

Modules to determine the drainage flow across the spectrum of multiple volatile natural, agronomic conditions and reclamation real object must use complex simulation models for predictive evaluation of long-term climatic conditions of the area, as well as water treatment and working conditions of drainage on drained lands [MARTYNIUK *et al.* 2018; ROKOCHINSKIY *et al.* 2013].

Index total duration of drainage within the settlement period of vegetation grown culture is defined as

$$\theta_p^q = \frac{t_{p\tau}^q}{t_{p\tau}}, p = \overline{1, n_p}, \tau = \overline{1, n_\tau} \qquad (2)$$

Index of drainage duration on the different levels of efficiency within the period of the drainage is determined as

$$\theta_{rkgp}^q = \frac{t_{rkgp\tau}^q}{t_{kgp\tau}}, r = \overline{1, n_r}, k = \overline{1, n_k}, g = \overline{1, n_g}, \\ p = \overline{1, n_p}, \tau = \overline{1, n_\tau} \qquad (3)$$

Where: $t^q kgp\tau$ = duration of drainage to changing conditions on the investigated object $k = \overline{1, n_k}$, $g = \overline{1, n_g}$, $p = \overline{1, n_p}$, $\tau = \overline{1, n_\tau}$, (days); $t_{kgp\tau}$ = the estimated duration of the growing season crops grown (days); $t_{rkgp\tau}^q$ = duration of drainage on the different levels of efficiency r to changing conditions on the investigated object $k = \overline{1, n_k}$, $g = \overline{1, n_g}$, $p = \overline{1, n_p}$, $\tau = \overline{1, n_\tau}$ (days).

The corresponding values of the drainage effective operation within the project period is defined as:

– on the overall lifetime of the drainage

$$\theta^q = \sum_{p=1}^{n_p} \theta_p^q \cdot \alpha_p \qquad (4)$$

where: α_p = the value of shares of common patterns of meteorological regimes in the during period of vegetation within the project term exploitation of drainage systems;

– on different levels of effectiveness of the drainage

$$\theta_r^q = \sum_{p=1}^{n_p} \theta_{pr}^q \cdot \alpha_p, r = \overline{1, n_r} \qquad (5)$$

Similar values of effective drainage work within the system are defined as:

– on the overall lifetime of the drainage

$$\theta_s^q = \sum_{p=1}^{n_p} \theta_p^q \cdot \alpha_p \cdot f_k \qquad (6)$$

– on different levels of effectiveness of the drainage

$$\theta_{sr}^q = \sum_{p=1}^{n_p} \theta_{pr}^q \cdot \alpha_p \cdot f_k, r = \overline{1, n_r} \qquad (7)$$

Where: f_k = share holdings of design culture within the system.

Evaluation of the efficiency of drainage in critical conditions (r = 4) is performed by the method similar to the previously outlined. Thus, instead of values average decade modules drainage flow, defined in terms of the formation of the total for the decade values precipitation should be considered similar to the average daily value of a roll of ten-day precipitation amount per day. Here expectancy permissible and critical periods of drainage work as designed drainage could not cope with the work and there permissible or critical waterlogged soil for cultivated crops are defined similarly considered indicators duration of drainage.

RESULTS AND DISCUSSION

Example of evaluating the performance of drainage on drained lands made for the conditions of a real project, implemented on lands of agricultural holding "May Day" located within of drainage system "Ikva" Rivne region in the area of the Iqua drainage system on an area of 125 hectares (Fig. 1).

Common soils on this territory are turf weakly podzolic sand on the sands, turf-podzolye gleyous fixed-sandy soil and on the peaty mean accumulation with low ash content (Tab. 1).

Table 1. Soil and hydrogeological conditions

Types of soil g_m	f_{gm}	k_f	T	m_D	μ
The turf weakly podzolic sand on the sands	0.1	1.0	5.4	5.0	0.10
The turf-podzolye gleyous fixed-sandy soil	0.3	0.7	2.9	4.5	0.08
The peaty mean accumulation with low ash content	0.6	0.4	2.1	4.0	0.03

Explanations: f_{gm} = share; k_f = coefficient of filtration (m·day^{-1}); T = soil permeability (m^2·day^{-1}); m_D = distance from the axis of the drain to the waterright stratum (m); μ = specific yield (m·day^{-1}).
Source: own study.

Initial data for calculation are the set design and optimization calculations drainage parameters (plastic tube with sand and gravel package, 63 mm in diameter, the distance between drains 12 m value calculation module drainage flow 0.65 dm^3·s^{-1}·ha^{-1}), the crops yield with a given project (perennial grasses – 3.5 t·ha^{-1}, winter cereals – 4.7 t·ha^{-1}, potatoes – 25 t·ha^{-1}), soil types (sandy turf weakly podzolic, podzolic gley – connected sandy loam, peat moderately low ash content) and principle of water regulation (drainage) – Figure 2.

For the object conditions found that average decade formation conditions of the drainage flow module for growing perennial grasses, winter cereals and potatoes estimated duration of the growing season is 214 days (100%), of which the total duration of drainage was 60%, and including on different levels of efficiency: 39% – ecological, technological – 15.5%, – 5.5% economic. The duration of its critical operations (forming module drainage flow exceeds the design of its value) does not exceed 5%.

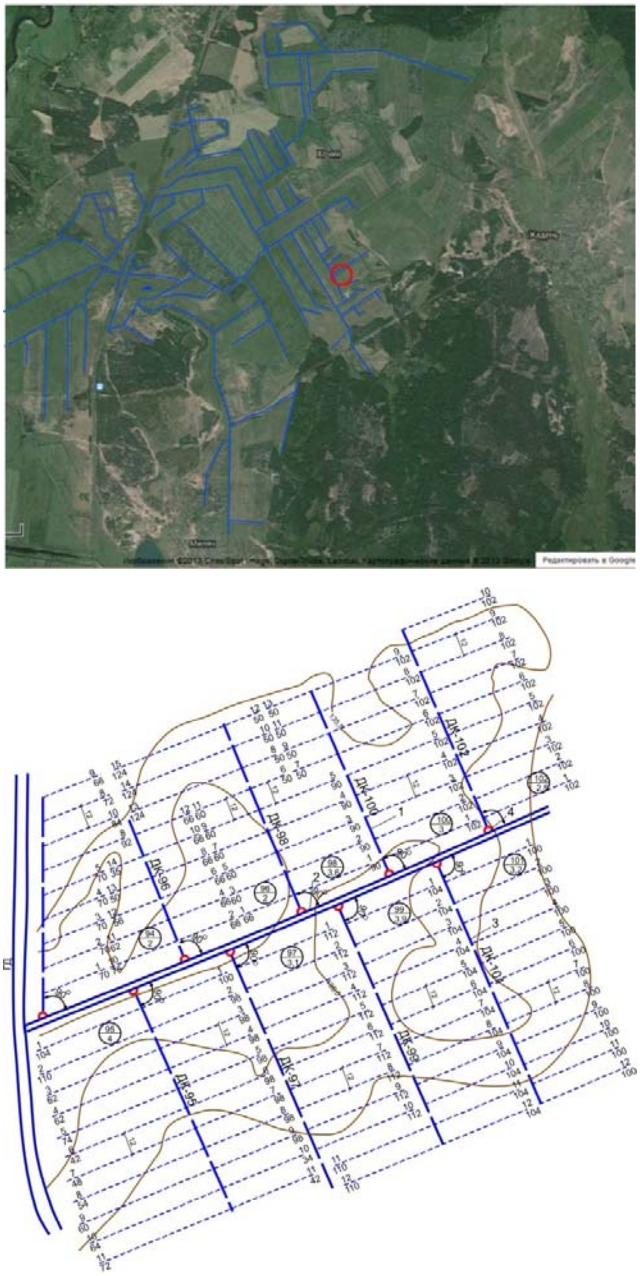

Fig. 1. Photo of the drainage system and scheme of experimental area of the drainage system "Ikva" Dubnovsky district of Rivne region; *1* = collector; *2* = channel leading network; *3* = drain; *4* = field number / field area; source: own elaboration

CONCLUSIONS

In the conditions of changing to market relations, the economic-mathematical method does not allow to determine the optimal drainage parameters and therefore needs further improvement.

The complex optimization model of drainage parameters is based on interconnected structural and prediction-simulation and optimization technological schemes.

Thus, this approach enables the assessment of drainage with predetermined or specified parameters in the construction or renovation of drainage systems on different

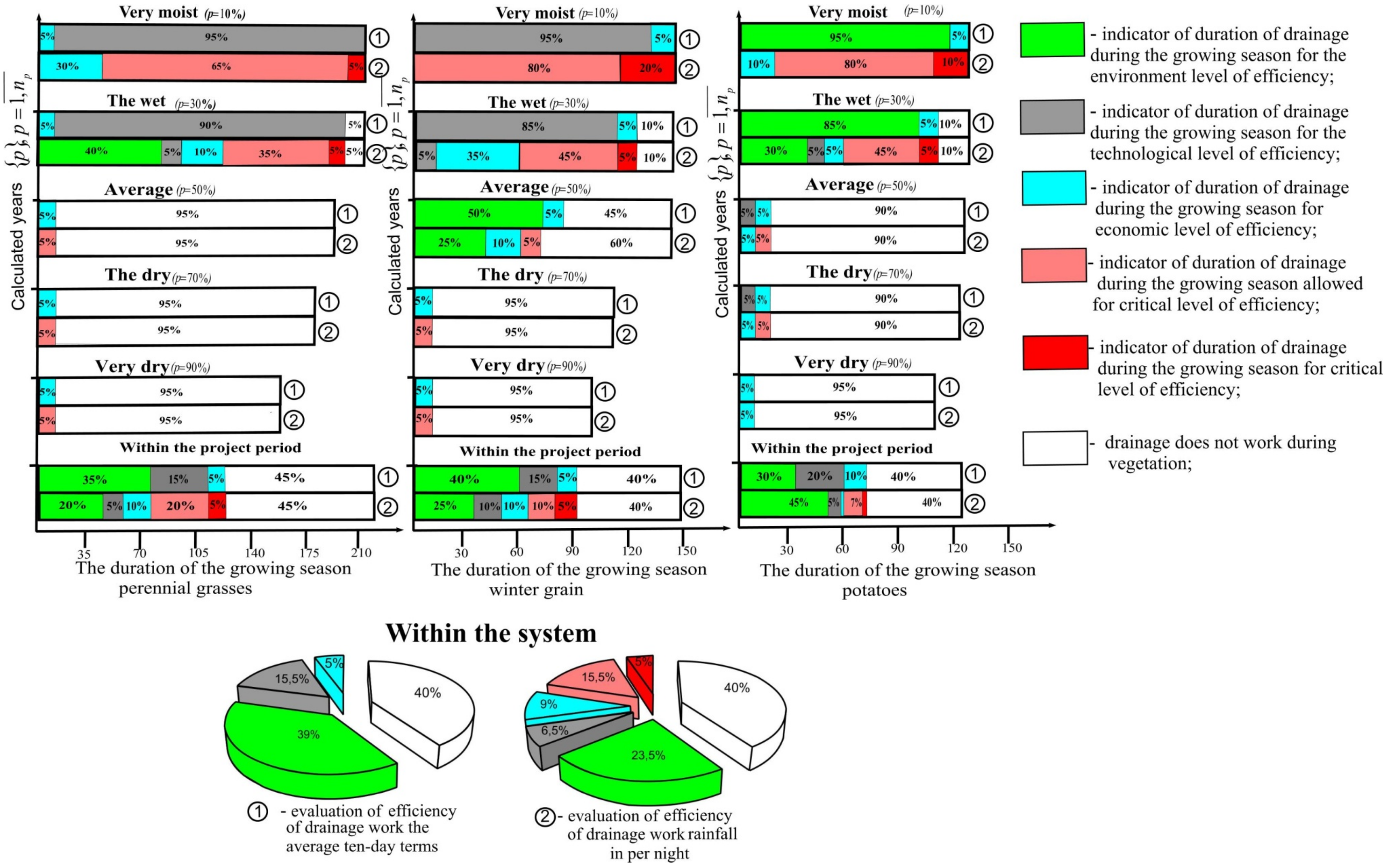

Fig. 2. Estimation of drainage system effectiveness on base optimization for conditions of investigated reclamation lands; own study

levels of effectiveness. It can be effectively used in the overall complex predictive and optimization calculations to substantiate the design and parameters of agricultural drainage, taking into account the variability of natural agrotechnical and reclamation conditions of a real object.

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Przewidywana ocena wydajności rolniczego drenażu na terenach zdrenowanych

STRESZCZENIE

W pracy rozwinięto zasady projektowania i wdrażania złożonego modelu oraz zoptymalizowano parametry projektowe drenażu. Badania oparto na wdrożeniu wzajemnie powiązanych symulacji strukturalnych i technologicznych oraz na optymalizacji bloków modelowych, co pozwoliło uzasadnić optymalne parametry projektowe z uwzględnieniem wielu czynników przyrodniczych, rolniczych i urządzeń melioracyjnych. Jako przykład oceny działania systemu drenarskiego przyjęto rzeczywisty projekt wdrażany na ziemiach przedsiębiorstwa rolniczego „May Day” usytuowanego w systemie drenarskim „Ikva” regionu Równe. W warunkach panujących na badanym obiekcie (dekadowe średnie warunki przepływu wód w uprawie wieloletnich traw, zbóż ozimych i ziemniaków) oszacowana długość sezonu wegetacyjnego wynosiła 214 dni (100%), przy czym przez 60% tego czasu woda była drenowana. Efektywność zależała w 39% od czynników ekologicznych, 15,5% – technologicznych i 5,5% – ekonomicznych. Długość operacji krytycznych (przekraczających wartość planowaną) była mniejsza niż 5%. Prezentowane podejście umożliwia ocenę drenażu ze wstępnie ustalonymi szczegółowymi parametrami w warunkach budowy lub renowacji systemów odwadniających o różnym stopniu wydajności. Może być zatem wykorzystane w złożonych obliczeniach prognostycznych i optymalizacyjnych jako wsparcie projektów rolniczego drenażu z uwzględnieniem zmienności naturalnych warunków agrotechnicznych i melioracyjnych konkretnego obiektu.

Słowa kluczowe: *odwadnianie rolnicze, parametry, wydajność, złożony model*