

Substantiation of the crop yield on the drained lands in the water management and reclamation projects

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The purpose. To develop scientific-and-methodical approaches to justification of design productivity of crops on sewed lands. **Methods.** Method of simulation modeling of productivity of crops, techniques of water regulation of soil and climatic conditions of locality is applied. By consideration of classes of productivity on reclaimed lands the method of analysis and synthesis is used. **Results.** Principles of construction and implementation of model of yield of crops on the basis of long-term forecast of plural volatile natural-agro-reclamative conditions of real object are developed. **Conclusions.** On framework of construction, levels of complexity, data support and reliability of the gained results (70-90 %) the developed approach meets the requirements of practical application. Bibliogr.: 10 titles.

Key words: justification, productivity, sewed lands, water-reclamative designs.

Introduction. One of the main tasks of land-reclamations development in the modern operating conditions of Ukrainian agricultural complex is support of existing land-reclamation fund by reconstruction of the land-reclamation systems. Particularly acute, this problem arose in the humid zone of Ukraine, where as a result of underfunding and breach technical operation of the land-reclamation systems (LRS) don't providing the project efficiency of their functioning [4].

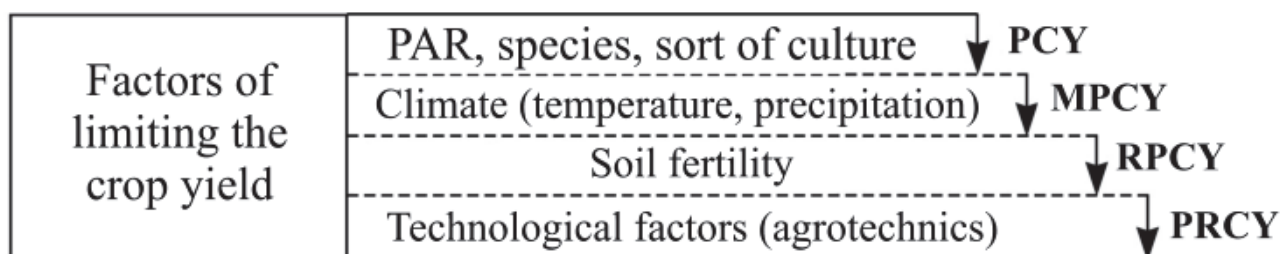
Therefore, the problem of obtaining the project level of agricultural products with the least negative ecological consequences becomes important. Its solution is possible due to the prognosis of the grown cultures crop yield (productivity of reclaimed lands) since crop yield and corresponding ecological effect determining the choice of optimal project solutions while building, reconstruction and exploitation of LRS, taking into account economical and ecological conditions.

Existing system of crop yield rationing, which is used in the projects of building, reconstruction and exploitation of LRS, does not fully reflect situation and take into account the characteristic features, inherent reclaimed lands in the specific conditions of their exploitation and does not allow carry out an informed assessment of the impact of the determining factors on crop yield. In this regard, is exist the need of creation the approach which will allow take into account all noted factors on the stage of project.

Current state of a task. It is well known that the formation of crop yield on the reclaimed lands and, in particular, on the drained lands, is an extremely complicated process and happens due to the influence of natural, agrotechnical and land-reclamation factors, namely: heat, moisture, air, nutritional regime and growing technologies, and water regulation technology [3, 5, 9, 10].

The availability of the particular culture of external factors determining first of all by the natural and climate conditions of zone and vegetation period of culture. The integral index coordination of existing resources is establishment of resources-provided crop yield for the respective zones of its growing.

The level of availability of the particular culture of external factors is expedient to determine by the possible harvests due to existing resources. The basic categories of resources-provided crop yield by H.G. Tooming [1] are followings (fig.1).



PCY – the potential crop yield; **MPCY** – the meteorological possible crop yield;

RPCY – the really possible crop yield; **PRCY** – the production crop yield

Fig. 1. Classification of the crop yield categories (by H.G. Tooming)

Content of approach. The crop yield categories classification that was improved by us with taking into account all basic factors of influence on development of the growing cultures on the reclaimed lands as a corresponding block diagram is shown in fig. 2.

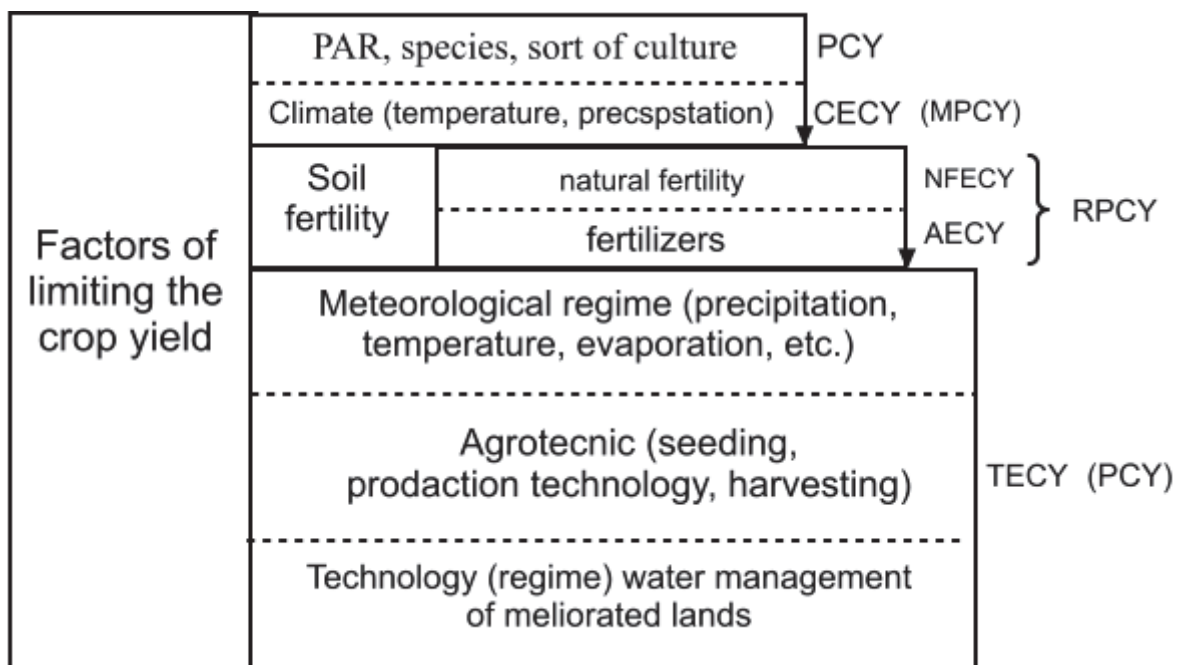


Fig.2. Improved classification of the crop yield categories on the reclaimed lands

On the basis of application of these categories of the crop yield and taking into account difficult character of process of forming the harvest, general model of the really possible crop yield of the growing cultures (the calculation analogue of the really crop yield in the conditions of object), for the stage of the reconstruction project or the new building of LRS, can be presented as a difficult complex model of multiplicative type, that expressed through the product of influence functions the determining factors on its formation

$$Y_{k\omega gsp} = Y_{\omega kp}^F \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot K_6, \text{ ц/га} \quad (1)$$

Where $Y_{\omega kp}^F$ – the climate ensured harvest of culture for the vegetation period; K_1 – coefficient of the soil productivity rate influence on the crop yield ($0 \leq K_1 \leq 1$); K_2 – coefficient of the mineral and organic fertilizers influence on the crop yield ($K_2 > 1$, but $0 < K_1 \times K_2 \leq 1$); K_3 – coefficient of the term deviation seeding influence on the crop yield of culture (recovery of vegetation) from the optimum ($0 \leq K_3 \leq 1$) on the conditions water regulation s ; K_4 – coefficient of the current naturally and reclamation conditions (climate and water regulation technology) influence on the crop yield of culture of vegetation period ($0 \leq K_4 \leq 1$); K_5 – coefficient of the term deviation harvesting influence on the crop yield of culture from the optimum ($0 \leq K_5 \leq 1$); K_6 – decrease of the crop yield due to the losses during the harvesting and transportation (barn harvest of grown products) ($0 < K_6 \leq 1$).

In turn, the climate ensured crop yield can be determined by the known approach of M.K. Kayumov [2]

$$Y_{\omega kp}^F = 10^4 \cdot \eta_k \cdot a_k \cdot \frac{\sum Q_{kp}}{q_k}; \quad p = \overline{1, n_p}, \quad \text{ц/га}, \quad (2)$$

where η_k – efficiency of photosynthetic active radiation, culture or sort in the optimal meteorological conditions, %; a_k – coefficient of economic efficiency of harvest of the share of basic products in the total biomass; $\sum Q_{kp}$ – total arrival of PAR for the vegetation period, kJ/cm²; q_k – calorie content of harvest, kj/kg.

For determining the influence of water regulation technology on the productivity of the drained lands using the generalized results of the long-term (1978–1986) complex field researches and computer experiment with the modeling of water regime and balance of the drained lands in the different naturally and reclamation conditions and the corresponding values of growing cultures crop yield.

According to these results, for solving this problem proposed the most common and tested in practice approach to measure the changes of potential possible value (climate and agrotechnical ensured) of crop yield of certain culture to the really possible (actual or effective), caused by the current heat and moisture conditions of seeding during vegetation, through the index β can be given accordingly as an integral index of development level of culture during the vegetation period through the dynamics of its water consumption in relative form [4].

$$\beta = \frac{\sum_{\phi=1}^{n_{\phi}} \phi ET_{\phi}}{\sum_{\phi=1}^{n_{\phi}} \phi ETV_{\phi}}, \quad (3)$$

where ϕET , ϕETV – effective and potential possible water consumption of culture for ϕ phase of its development.

The component of this crop yield model is the functions of decline of product processes, that mediated can be presented through the dynamics of the cultures water consumption during the vegetation period and allows to carry out consider the inconsistencies of the really heat and moisture conditions of seeding in relation to the optimal. It has a next form

$$\lambda(t, w) = \lambda_1(t) \cdot \lambda_2(w) . \quad (4)$$

Then, if these functions present in the corresponding denotations, we get:

a) for the temperature regime of the ground layer of air

$$\lambda_1(t) = \begin{cases} 0,485 - 0,385 \arctg \left[\frac{3,65(0,9t^0 + \underline{t}) - 7,3t}{t^0 - \underline{t}} \right], \underline{t} \leq t \leq t^0; \\ 0,485 + 0,385 \arctg \left[\frac{3,65(\bar{t} + 0,9t^0) - 7,3t}{\bar{t} - t^0} \right], t^0 \leq t \leq \bar{t}; \end{cases} \quad (5)$$

б) for the water regime of active layer of soil

$$\lambda_2(w) = \begin{cases} 0,485 - 0,385 \arctg \left[\frac{3,65(0,9w^0 + \underline{w}) - 7,3w}{w^0 - \underline{w}} \right], \underline{w} \leq w \leq w^0; \\ 0,485 + 0,385 \arctg \left[\frac{3,65(\bar{w} + 0,9w^0) - 7,3w}{\bar{w} - w^0} \right], w^0 \leq w \leq \bar{w}, \end{cases} \quad (6)$$

where \underline{t} , t^0 , \bar{t} – bottom, optimal and top temperature limits of vital functions for this type (sort) of plant;
 \underline{w} , w – mean values of temperature of air and humidity of active layer of soil in recent moment of time.

In turn, the value of really possible crop yield of growing culture $Y_{\omega g s p}$ is the basis of determination of the project crop yield on the drained lands by model that can be represented as

$$\bar{Y}_k = \sum_{\omega=1}^{n_{\omega}} \sum_{g=1}^{n_g} \sum_{p=1}^{n_p} Y_{k \omega g s p} \cdot f_{\omega} \cdot f_g \cdot \alpha_p, \text{ ц/га}, \quad (7)$$

where Y_k – project crop yield of culture by the defined water regulation technology in the given conditions;

$Y_{\omega g s p k}$ – really possible crop yield of culture obtained in the corresponding climate ω , soil g reclamation s (water regulation technology) conditions in different (calculation) by the heat and moisture conditions of vegetation period p ;

f_{ω} , f_g – the share of distribution respectively natural, climatic and soil differences within the object;

α_p – values of repeatability (shares) of possible states of typical schemes of meteorological regimes in a calculation of the heat and moisture conditions of vegetation period $P = \{p\}$, $p = 1$, n_p ($p=10\%$ – very wet, $p=30\%$ – wet, $p=50\%$ – middle, $p=70\%$ – dry, $p=90\%$ – very dry) within the project lifetime of the object, $\sum_{p=1}^{n_p} \alpha_p = 1$

Methods and technique of researches. Realization of this approach is based on the using of complex prognosis-imitation models: climate conditions of locality with taking into account their change within the period of LRS exploitation, water regime and productivity of the reclaimed lands [5, 7]. Determination of necessary values of components of the really possible crop yield model carried out by solutions of the complex tasks on the basis of application of methods of mathematical modeling with the use of computer. Principles of realization of this models complex are regulated by the corresponding particular branch norms [6-8].

Results of researches. Verification of this calculation method was executed for the conditions of drain and moisten reclamation system with the area 397 hectares, that located in a riverhead Pripyat' on the lands of private agricultural farm "Ukraine" (Lyuboml district of the Volhyn region).

The final results of the project crop yields calculation of potatoes and perennial herbs on hay on the example of their growing on soddy podzolic soil (30 points) for the most common on drained lands water regulation technologies are presented in a table 1.

Total results of calculation of design productivity are given in table 1 on the example of potatoes and perennial herbs on hay at their cultivation on soddy podzolic soil (site class of 30 points) when using the drained lands which are the most extended on of technologies of regulation of the water mode.

The comparative characteristic of calculated values of effective productivity of cultures of a design crop rotation concerning their design and actual values in the studied conditions is provided in table 2. Verification of model was carried out also on reclamation objects of bilateral regulation of the water mode in the Kiev and Zhytomir areas which showed, as well as in case of its identification that on structure of construction, level of complexity, information support and reliability of the received results (70... 90%) it meets the requirements of practical application.

Table 1

Calculated values of the project crop yield of potatoes and perennial herbs for hay

$p, \%$	$Q_{kp}, \text{kJ/cm}^2$	$Y_{okp}^F, \text{c/hectare}$	$Y_B, \text{c/hectare}$	$Y_A, \text{c/hectare}$	K_4	$Y_{kogs p}, \text{c/hectare}$	$\eta_{\Phi}, \%$
Potato (efficiency of PAR $\bar{\eta}_k=2,0\%$)							
Preventive locking							
10%	83	230	69	248	0,721	179	1,55
30%	96	265	80	258	0,843	218	1,64
50%	118	327	98	277	0,814	225	1,38
70%	141	392	118	296	0,658	195	0,99
90%	177	492	148	326	0,594	194	0,79
	123	341	102	281	0,734	$\bar{Y}_k=204$	1,27
Wetting locking							
10%	83	230	69	248	0,721	179	1,55
30%	96	265	80	258	0,843	218	1,64
50%	118	327	98	277	0,832	230	1,41
70%	141	392	118	296	0,731	216	1,10
90%	177	492	148	326	0,616	201	0,82
	123	341	102	281	0,760	$\bar{Y}_k=212$	1,31
Drainage							
10%	83	230	69	248	0,721	179	1,55
30%	96	265	80	258	0,821	212	1,60
50%	118	327	98	277	0,759	210	1,29
70%	141	392	118	296	0,601	178	0,91
90%	177	492	148	326	0,479	156	0,64
	123	341	102	281	0,684	$\bar{Y}_k=189$	1,20
Perennial herbs (efficiency of PAR $\bar{\eta}_k=3,0\%$)							
Preventive locking							
10%	113	72	22	71	0,476	34	1,41
30%	130	83	25	74	0,612	46	1,65
50%	160	102	31	80	0,757	61	1,79
70%	190	121	36	86	0,636	55	1,36
90%	236	150	45	95	0,576	55	1,09
	166	106	32	81	0,629	$\bar{Y}_k=51$	1,49
Wetting locking							
10%	113	72	22	71	0,476	34	1,41
30%	130	83	25	74	0,612	46	1,65
50%	160	102	31	80	0,780	63	1,84
70%	190	121	36	86	0,682	59	1,45
90%	236	150	45	95	0,594	56	1,12
	166	106	32	81	0,648	$\bar{Y}_k=53$	1,54
Drainage							
10%	113	72	22	71	0,476	34	1,41
30%	130	83	25	74	0,645	48	1,74
50%	160	102	31	80	0,699	56	1,65
70%	190	121	36	86	0,542	47	1,15
90%	236	150	45	95	0,393	37	0,74
	166	106	32	81	0,570	$\bar{Y}_k=46$	1,37

Note: Y_B - potential crop yield by the soil fertility rate, Y_A - crop yield by the agrotechnical measures. The values of the project crop yield of the cultures presented in bold type.

Table 2

Comparative characteristics of calculated values of effective productivity with the set on the project and actual values on lands of the private agricultural enterprise "Ukraine" of the Lyuboml'sky district (Volhyn region)

Cultures	Calculated values of effective productivity, c/hectare		Productivity, c/hectare		Productivity deviation from the values set by the project, %		Productivity deviation from the actual values, %	
	with application of fertilizers	without application of fertilizers	set on the project	fact	with application of fertilizers	without application of fertilizers	with application of fertilizers	without application of fertilizers
1. Fodder beet	330,8 – 417,7 ¹⁾	152,6 – 192,2	300,0	$\frac{129,0 - 524,3}{291,0}$ ²⁾	9,3 – 28,2	96,6 – 56,1	12,0 – 30,3	47,6 – 34
2. Flax	6,6 – 8,3	3,2 – 4,1	5,5	-	16,7 – 33,7	71,9 – 34,2	-	-
3. Potatoes	158,0 – 201,9	69,1 – 87,1	140,0	$\frac{48,6 - 154,0}{89,9}$	11,4 – 30,7	102,6 – 60,7	43,1 – 55,5	23,2 – 3,1
4. Tomato	181,3 – 216,7	84,4 – 100	140,0	-	22,8 – 35,4	65,9 – 40,0	-	-
5. Winter grain	21,7 – 24,6	9,5 – 11,4	27,0	$\frac{11,3 - 13,6}{12,6}$	24,4 – 9,8	184,2 – 136,8	41,9 – 48,8	14,6 – 9,5
6. Perennial herbs on hay	37,7 – 49,5	16,6 – 21,4	28,0	$\frac{19,0 - 22,1}{20,6}$	25,7 – 43,4	68,7 – 30,8	45,4 – 58,4	19,4 – 3,9
7. Corn on a silo	193,5 – 222,6	91,7 – 104,3	200,0	$\frac{153,0 - 295,0}{236,0}$	3,4 – 10,2	118,1 – 91,8	22,0 – 6,0	61,2 – 55,8

Notes:

1. Values of effective productivity are given respectively for drainage conditions (the minimum productivity) and irrigation conditions against precautionary locking (the maximum productivity) for herbs and vegetables and moistening locking for other cultures;

2. The given actual values of productivity on object during 1991 - 1995 are presented: in numerator respectively the minimum and maximum values; in a denominator - average values.

Conclusions

The developed approach can be used for justification of optimum design decisions at construction, reconstruction and operation of LRS in a zone of sufficient and unstable moistening of Ukraine taking into account technological, economic and ecological aspects of their functioning, and also an assessment of their investment efficiency.

Design and operational divisions of the State agency of water resources of Ukraine, the relevant services of the Ministry of an agrarian policy, the Ministry of ecology and natural resources and other interested departments which field of activity extends on agricultural grounds with the regulated water mode of a humid zone of Ukraine can act as the interested organizations.

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