UDC 631.421:57.087

Interaction of actual and admissible indexes of erosion-hydrological processes on a probable basis

Belolipskiy V.[1], **Poluliakh N.**[2]
National Scientific Center «Institute for Soil Science
and Agrochemistry Research named after O.N. Sokolovsky»,
4 Chaikovska Str., Kharkiv, 61024, Ukraine;
e-mail: [1]belolipskiy-42@ukr.net, [2]nick_pol2015@ukr.net

The purpose. To determine influence of interaction of actual and admissible indexes on development of erosion-hydrological processes with the purpose of their minimization on a probable basis. **Methods.** On laboratory-field, mathematical-statistical, topometric, morphological methods they studied erosion-hydrological situations on basin principle at different hierarchical levels (drainage basin → natural boundary reservoir), interaction of actual and admissible indexes of erosion-hydrological processes. **Results.** By means of creation of hyper surfaces of response of combinations of components of agrolandscapes of reservoirs of basin of river Aydar and factors of formation of Qmax on hydroposts (Belolutsk, Kuriachovka, Starobelsk, Bakhmutovka) they analyzed interaction of actual and admissible indexes of erosion-hydrological processes on 1 – 50% level of probability. Such regularities were fixed: 1) at high plough up of reservoirs of Starobelsk and Bakhmut hydroposts (accordingly 65 – 75 and 70 – 80%) with use in ploughland of downslopes more than 1° — 40 – 55% expenditures of drainage of 10% probability are maximum (25 – 58 and 38 – 63 m3/s); 2) decrease of plough up of reservoirs of Kuriachovka hydropost up to 55 – 60% decrease the maximum expenditures of drainage of 10% probability up to 10 – 15 m3/s at use in ploughland of downslopes more than 1° — 45 – 55% from reservoir; 3) high plough up of reservoir of Belolutsk hydropost (65 – 75%) are run a level by use in ploughland of slope lands more than 1° within the limits of 35 – 45% in formation of the maximum losses of drainage of 10% probability up to 16 – 36 m3/s. Such regularity of formation of the maximum losses of drainage is observed and at other probabilities of their development. **Conclusions.** Study of ratio of prognostic (admissible) and actual characteristics of combinations of components of agrolandscape (40 – 60% of ploughland, 35 – 40% of downslopes more than 1°, 0,3 – 0,5% of forest belts of cross arrangement on the background of humus 3,5 – 5,5% at the level of 10% probability of the maximum losses of drainage) testify to their objective effect and decrease of hydrological characteristics on 65 – 75% up to the level of low indexes of expenditures of drainage: 3 – 5 m3/s — Belolutsk, Kuriachovka, and 10 – 15 m3/s — Starobelsk, Bakhmutovka hydroposts.

Key words: *basin, reservoir, hydropost, agrolandscape, soil, erosion, humus, criterion, expenditure of drainage, model.*

DOI: https://doi.org/10.31073/agrovisnyk201908-09

Soils are the main natural resource on which natural and anthropogenic landscapes are formed. In recent years, as repeatedly stated at the congresses of soil scientists of Ukraine, the soil of our country degrade. The creation of anti-erosion complexes requires large financial resources, so it is necessary to build a system of land use, soil and water protection on the basis of the basin concept, using natural mechanisms of self-regulation and self-restoration.

The territory of the basin of the river Aydar in Luhansk region within Novopskov, Staroblsk, Novoaydar districts is, on the one hand, an object with a high degree of agricultural development of the territory, and on the other with power a manifestation of the erosion processes and other types of degradation of soil cover. Surface erosion of the soil reaches 13-

20 t/ha, runoff of stormwater and meltwater – 15-20 mm with its accompanying processes, gully formation along and landslides that lead to the silting of the river and the elimination of its tributaries.

The results of recent studies (justification of the direction of research). Various aspects of basin nature management and soil loss are considered in the works of scientists – G.I. Shvebs, F.M. Lisetsky [1]; V.A. Trifonova [2]; foreign – Wischmeier W.H., Smith D.D. [3], Van der Knijft [4].

In general, in our time in Ukraine at the regional level and within the basin structures for the purpose of practical arrangement of small and medium rivers, studies of the natural potential of soils of the Aidar river basin [5] were carried out, and maps of the probabilistic erosion-hydrological characteristics of Q_{max} flow rates were developed [6].

In the agro-landscape aspect the problem of soil protection from erosion is solved comprehensively and provides for the formation of the ecological organization of the agricultural unit and soil protection structure of crop rotation (Bulygin S.Yu., 2005 [7], the study of the impact on soil erosion of climate potential (Tarariko O.G., Grekov V.O, etc., 2011) [8].

Despite significant advances in studies of the mechanism of erosion-hydrological processes, their prediction and quantitative assessment in the practice of land management is carried out taking into account the interface (length and steepness of slopes) on a limited part of the catchment with differentiation into agrotechnological groups.

An attempt to solve this problem in a more reliable way was carried out (Kutsenko M.V., 2012), due to the use of the land erosion hazard index as a ratio between the predicted and washout flow rates [9]:

$$I_e = \frac{v_.}{v_p}, \quad (1)$$

where: I_e – erosion index;

v – water flow velocity (average or bottom);

v_p – washout rate of water flow (average or bottom).

This also does not lead to accurate characteristics of the erosion process, as it is based on normative indicators (safety coefficient of the agricultural zone of the K_r and erosion properties of the lands of the K_s), which are served in a limited area (site) of the catchment. The use of this approach to large catchments of beam systems with the restriction only to the technological unit of AL does not lead to the solution of the goal. Therefore, this technique cannot claim to be universal use in design work on land management.

It is not enough to consider the essence of the natural mechanism of erosion (flushing) in the interaction of relief factors (length and steepness). First of all, the natural protective mechanism is determined by a group of interrelated factors, of which the vegetation cover and the physical structure of the soil, which determine the absorption capacity and the formation of runoff, are presiding. Therefore, in the catchment area, the formation of runoff under anthropogenic use is subject to a system of interrelated hierarchy of catchments: basin-beam catchment-slope.

Objects and methods of research. *The aim of the research* is to determine the influence of the interaction of actual and acceptable indicators on the development of erosion-hydrological processes in order to minimize them on a probabilistic basis.

The object of study – the eroded ordinary black soils of agrolandscapes of a system of watersheds, river Aydar within the 4 administrative districts of Luhansk region to the closing of locations of gauging stations (Bilolutsk, Kuryachivka, Starobilsk, Bakhmutivka).

The subject of research is erosion-hydrological situations on the basin principle at different hierarchical levels of the river basin (river basin → beam catchment).

The methodological basis of the research is the spatio-temporal analysis of the factors influencing the erosion-hydrological processes on the basis of the basin concept in the system: small river basin → beam catchment, its mathematical modeling, mathematical and statistical analysis and digitization of the obtained models by means of GIS technologies in the form of TIN-surfaces.

Results and discussion. The analysis of the interaction between actual and permissible levels of erosion and hydrological processes of slope watersheds of the basin of the river Aydar is made by using the build tools of the hypersurface response combinations of components AL and factors on the formation of Qmax according to the scheme shown in Fig. 1.

Hypersurface of the response combinations of components AL and factors on the formation of Qmax (fact indicator).

Hypersurfaces of the response of combinations of erosion-hydrological factors on the average-maximum flow rates in the system of beam catchments along the hydroposts in the Aidar basin of different security are calculated by the formula:

$$Q_{10} = A \cdot F^{0,3113} \cdot X^{2,7757} \cdot f_n^{7,7193} \cdot S_{slop}^{0,4171} \cdot F_{hum}^{-0,427} \cdot S_{gull}^{-0,089} \cdot S_{ter}^{-0,013} \cdot F_{for}^{-0,011} \cdot S_{pl}^{-0,014} \quad (2)$$

where: A – coefficient for probability 10% = $4,0 \cdot 10^{-18}$;

F – the fate of the area of the catchment a gauging station in the catchment area r. Aydar; X – rainfall, mm; f_n – ploughing, %;

S_{slop} – slopes > 1^0, %;

F_{hum} – humus content, %; S_{gull} – gully network, %;

S_{ter} – the first terrace of the river to 1^0 %; F_{for} – cross forest belts, %;

S_{pl} – plateau (slopes up to 1^0), %

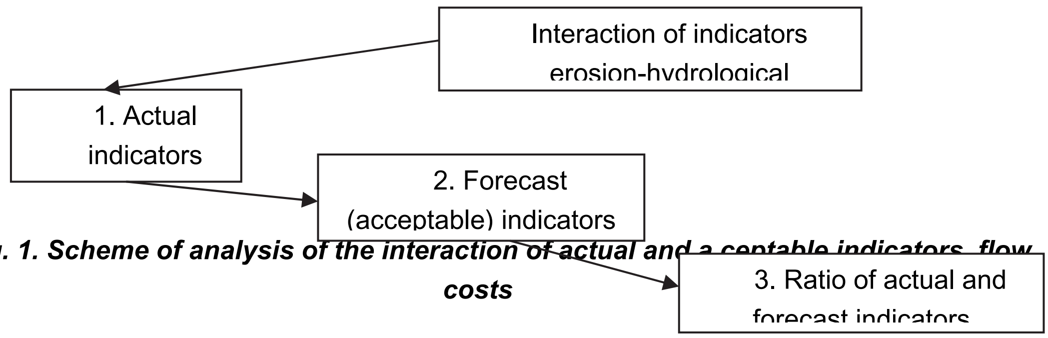

Fig. 1. Scheme of analysis of the interaction of actual and a ceptable indicators flow costs

To construct hypersurfaces selected adjustable (in the process of formation of ecologically sustainable agricultural landscape and soil measures) factors: the content of humus, %; plowed, %; slopes > 1^0, %; cross forest belts, % (table 1).

1. Critical factors of models for medium-maximum cost of flow gauging stations catchment of the r. Aydar

Gauging stations	The factors in the model								
	F, %	X, мм	S_{gull}, %	S_{ter}, %	S_{pl}, %	$F_{gum,\%}$	F_{for}, %	f_n, %	S_{slop},%
Bilolutsk	0,2820	79,2	32,00	5,160	14,0	4,57	0,42	69,4	41,84
Kuryachivka	0,1028	78,7	36,00	0,001	12,0	4,13	0,56	62,7	46,00
Starobilsk	0,5162	83,7	17,79	7,310	16,6	4,10	0,58	68,3	50,66
Bakhmutivka	0,0990	93,5	18,00	10,500	15,0	3,58	0,57	72,6	46,50

The actual average-maximum flow rates are calculated at the probability levels of 1, 5, 10, 50% and at the 10% m level differentiated (taking into account the situation downstream of the Aidar river) at level 4 (low, medium, high, high) – table 2.

2. Medium-maximum cost flow in the catchments of gauging stations G. Aydar

Gauging stations	The wastage rate, m^3/s			
	low	medium	high	high
Bilolutsk	16,4	16,5-24,0	24,1-35,0	> 35,0
Kuryachivka	10,0	10,1-14,9	> 15,0	
Starobilsk	25,6	25,6-38,5	38,6-55,0	> 55,0
Bakhmutivka	38,0	38,1-49,0	49,1-63,0	> 63,0

Graphical generalization of runoff costs for the 10% probability level. With high ploughing of watersheds a gauging station Starobilsk and Bakhmutivka (respectively 65-75 and 70-80%) and the use of arable slopes of more than 10 (40-55% of the area) flow rates of 10% probability maximum (25-58 and 38-63 m^3/s).

Reducing the ploughing of the catchment area to the Kuryachivka gauging station up to 55-60% reduces the maximum flow rate of 10% probability up to 10-15 m^3/s when using more than 10 slopes in arable land (45-55% of the catchment area).

One double plowed a gauging station Bilolutsk 65-75% offset by the use of the arable land sloping land more than 10 in the range of 35-45% in education cost maximum flow of 10% probability to 16-36 m^3/s. The same laws of formation of the maximum cost flow can be observed with other probability of their manifestation.

Hypersurfaces of the response of combinations of AL components and factors to the formation of Q_{max} – predictive (acceptable) indicators

When analyzing the response of combinations of components of the agricultural landscape to the formation of runoff losses for the Aidar catchment, the conditions that are formed as a result of the withdrawal of low-productive and degraded lands from arable land according to the Regional soil fertility protection program for 2014-2020 are accepted as acceptable indicators [10] (table 3). The calculations of the forecast indicators of the flow expenses were performed by the levels of security 1, 5, 10, 25, 50, 75%.

3. Factors predictive data models medium-maximum cost of flow gauging stations catchment of the river Aydar

Gauging stations	indicators				
	level	$F_{gum, \%}$	F_{for}, %	f_n, %	S_{slop},%
Bilolutsk	actual	4,57	0,42	69,4	41,84
	predictive	4,5-5,5	0,4-0,6	40-60	30-40
Kuryachivka	actual	4,13	0,56	62,7	46,00
	predictive	4,0-5,0	0,6-0,8	40-60	35-45
Starobilsk	actual	4,10	0,58	68,3	50,66
	predictive	4-5	0,6-0,8	40-60	40-50
Bakhmutivka	actual	3,58	0,57	72,6	46,50
	predictive	3,5-4,5	0,6-0,8	40-60	35-45

Acceptable indicators of average-maximum flow costs of 10% security are differentiated into 3 levels (low, medium, high). For watershed conditions of hydraulic posts they have the following values (table 4).

4. The forecast medium-maximum cost flow in the catchments of gauging stations the river Aydar

Gauging stations	The wastage rate, m^3/s		
	low	medium	high
Bilolutsk	5,6-8,4	8,5-14,5	> 14,5
Kuryachivka	0,9-1,2	3,1-3,9	8,1-10,3
Starobilsk	1,6-1,9	5,1-6,3	13,6-16,8
Bakhmutivka	1,2-1,5	4,0-5,1	10,6-13,4

To determine the nature of the interaction of forecast (permissible) and actual indicators of the development of erosion-hydrological processes in order to minimize them on a probabilistic basis (1, 5, 10, 50%) their ratio coefficient (K_c) is calculated for the corresponding flow loss indicators.

$$K_c = \frac{Q_{01-50\,forecast}}{Q_{01-50\,fact}} \quad (3)$$

The value of the coefficient K_c characterizes the degree of reduction of values of losses of runoff with a decrease in the ploughing of land catchments (table 5).

5. Attitude $Q_{forecast}$ / Q_{fact} different security at the gauging stations of the catchment the river Aydar

Gauging stations	The plowed, %	Probability, %			
		Q_{01}	Q_{05}	Q_{10}	Q_{50}
Bilolutsk	40	0,09	0,08	0,07	0,02
	50	0,19	0,16	0,15	0,07
	60	0,31	0,29	0,27	0,16
Kuryachivka	40	0,20	0,18	0,17	0,08
	50	0,38	0,36	0,35	0,22
	60	0,62	0,60	0,61	0,49
Starobilsk	40	0,09	0,08	0,07	0,02
	50	0,19	0,17	0,15	0,07
	60	0,32	0,29	0,27	0,16
Bakhmutivka	40	0,07	0,05	0,04	0,01
	50	0,14	0,12	0,10	0,04
	60	0,23	0,21	0,19	0,10

According to the results of the calculations, the response of the o-Gnostic messages of erosion-hydrological factors to the ratio of forecast and actual indicators of flow losses was made, which has a generalized form, presented in Fig. 2.

The smallest impact on reducing runoff losses observed at the maximum projected ploughing – 60% (the value of the coefficient on toposcale Bilolutsk – 0,13–0,31, Kuryachivka – 0,49-0,62, Starobilsk – 0,16–0,32, Bakhmutivka – 0,10–0,23. The greatest impact occurs at the minimum predicted ploughing – 40% (Bilolutsk – 0,02–0,09, Kuryachivka – 0,08–0,20, Starobilsk – 0,02–0,09 and Bakhmutivka – 0,01–0,07). And the intermediate value of the influence is observed at the average level of predicted ploughing – 50% (Bilolutsk – 0,07–0,19, Kuryachivka – 0,22–0,38, Starobilsk – 0,07–0,19 and Bakhmutivka – 0,04–0,14).

For detail relationship allowable and actual amounts of the runoff carried out graphical analysis of regularities of formation of factor of their relationship with the plowed, security and toposcale (Fig. 3).

A

Humus, %	The plowed, %	Slopes > 1 degree, %								
		30-35			35-45			45-50		
		0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04
5,0-4,5										
4,5-4,0	40	0,7–0,20								
4,0-3,5										
5,0-4,5										
4,5-4,0	50	0,14–0,38								
4,0-3,5										
5,0-4,5										
4,5-4,0	60	0,23–0,62								
4,0-3,5										

B

Humus, %	The plowed, %	Slopes > 1 degree, %								
		30-35			35-45			45-50		
		Cross forest belts, %								
		0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04
5,0-4,5										
4,5-4,0	40	0,05–0,18								
4,0-3,5										
5,0-4,5										
4,5-4,0	50	0,12–0,36								
4,0-3,5										
5,0-4,5										
4,5-4,0	60	0,21–0,60								
4,0-3,5										

C

Humus, %	The plowed, %	Slopes > 1 degree, %								
		30-35			35-45			45-50		
		Cross forest belts, %								
		0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04
5,0-4,5										
4,5-4,0	40	0,04–0,17								
4,0-3,5										
5,0-4,5										
4,5-4,0	50	0,10–0,35								
4,0-3,5										
5,0-4,5										
4,5-4,0	60	0,19–0,61								
4,0-3,5										

D

Humus, %	The plowed, %	Slopes > 1 degree, %								
		30-35			35-45			45-50		
		Cross forest belts, %								
		0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04	0,7-0,6	0,6-0,5	0,5-04
5,0-4,5										
4,5-4,0	40	0,01–0,08								
4,0-3,5										
5,0-4,5										
4,5-4,0	50	0,04–0,22								
4,0-3,5										
5,0-4,5										
4,5-4,0	60	0,10–0,49								
4,0-3,5										

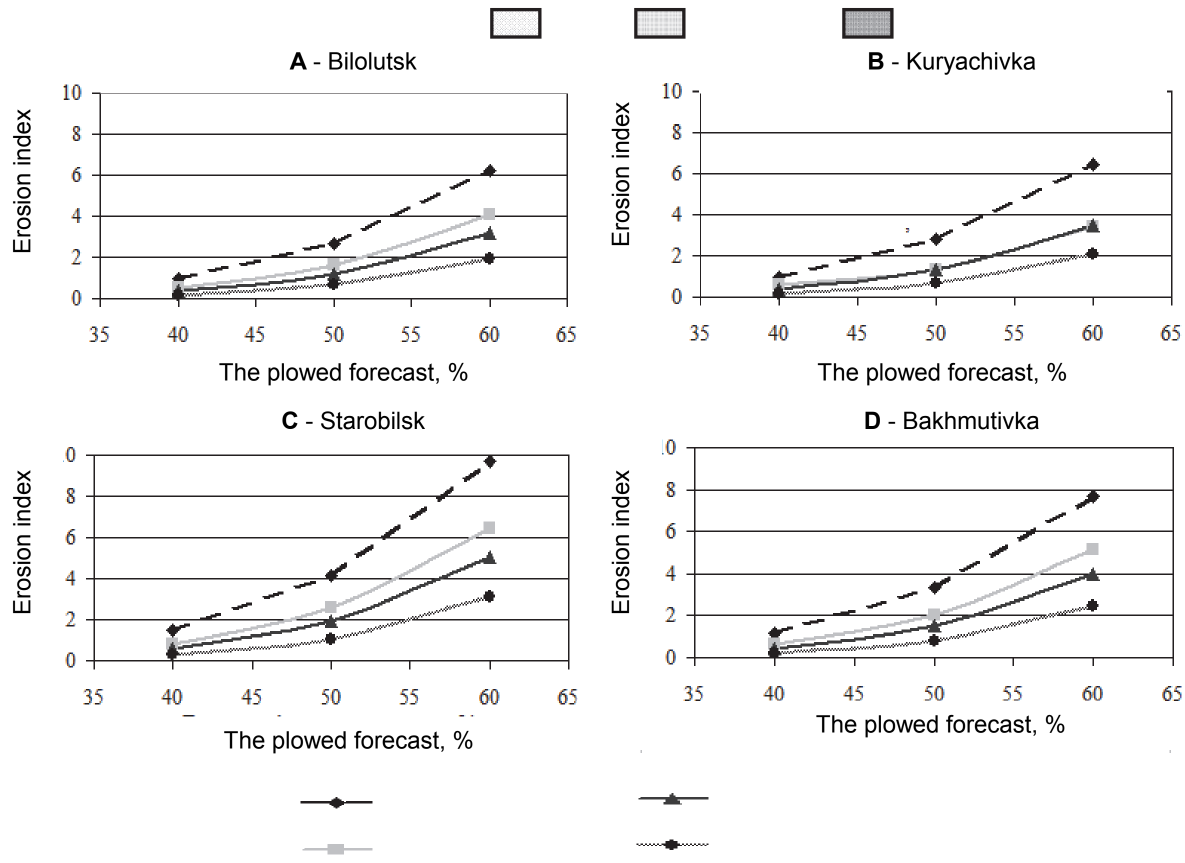

Fig. 3. The ratio of forecasted and actual indicators of the cost of the flow by a factor of tilled soil. Gauging station: A – Bilolutsk, B – Kuryachivka, C – Starobilsk, D – Bakhmutivka; – probability – 1%, – probability – 10%, – probability – 5%, – probability – 25%

With the increase in security, there is a decrease in the ratio of forecasted and actual flow rates, and, moreover, they increase by an order of magnitude behind ploughing.

There is a strong tendency to strengthen the conservation actions of reducing ploughing all toposcale and probabilities of runoff losses, which is clearly reflected in a reduction of the forecasted and the faculty of political expenditure, runoff, and especially notable is the 50% probability.

At the gauging stations downstream the river Aidar (Bilolutsk → Starobilsk → Bakhmutivka) in the upper and middle part is almost the same forecasted and actual expenditure, runoff and decreases in the lower part (Bakhmutivka). Separately relatively high in this respect, stands the catchment garapolo Kuryachivka because it is an independent catchment r. White arenot coefficient of gully K_g = 0,95 km/km^2 (in comparison: Bilolutsk – 0,75, Starobilsk is 0,81, Bakhmutivka – 0,88 km/km^2).

Studies of humus content in the range of 4,5–5,5% for groups of arable land areas of 40-60% revealed a constant decrease in Q_{max} in the range of 8-9%. Therefore, the detail of minimizing the erosion-hydrological process should be considered in the development of a set of anti-erosion measures in the agricultural block of the agricultural landscape for groups of eroded soils.

In the unit on ecological relationships valid indicators of the combinations of components of the agricultural landscape of the area of cross belts (0,3–0,5%) contribute to a slight decrease in Qmax in dependence (F_{for} -0,011).

Conclusions

Hypersurfaces of the response of combinations of erosion-hydrological factors to the formation of Q_{max} by actual indicators are constructed (1, 5, 10, 25, 50-and on 10% probability and the corresponding regularities are revealed:

– the ploughing of the catchments of gauging stations Starobilsk and Bahmutivka of gauging stations (respectively 65-75 and 70-80%), the use of arable land slopes more than 1^0 40-55% costs drain the 10% probability maximum (25-58 and 38-63 m^3/s);

– reducing the ploughing of the watersheds of the gauging station Kuryachivka to 55-60% reduces the maximum flow rate of 10% probability to 10-15 m^3/s when used in the arable slopes of more than 1^0 45-55% of the catchment;

- high plowed catchment a gauging station Bilolutsk 65-75% offset by the use of the arable land sloping land more than 1^0 in the range of 35-45% in education cost maximum flow of 10% probability to 16-36 m^3/s. Such a pattern of formation of the maximum cost flow can be observed with other probability of their manifestation.

The study of the ratio of expected (valid) and the actual characteristics of the connection components of the agricultural landscape (40-60% of arable land, 35-40% slopes over 10, 0.3-0.5% of the belts transverse to the background of the humus content of 3.5-5.5% at the 10% level of probability maximum discharges runoff showed their objective effect and reduction of hydrological characteristics at 65-75% to the level of the lowest cost figures 3-5 flow m3/s – a gauging station Bilolutsk, Kuryachivka and 10-15 m^3/s – Starobilsk and Bahmutivka.

There is a strong tendency to strengthen the conservation actions of reducing ploughing all toposcale and probabilities of runoff losses, which is clearly reflected in a reduction of the forecasted and the faculty of political expenditure, runoff, and especially notable is the 50% probability.

References

1. Shvebs, G.I., Liseckij, F.N. (1989). Proektirovanie konturno-meliorativnoj sistemy pochvozashitnogo zemledeliya [Design of contour-reclamation system of soil conservation agriculture]. *Agriculture, 2,* 55-59. [in Russ.].

2. Trifonova, T.A. (2005). Razvitie bassejnovogo podhoda v pochvennyh i ekologicheskih issledovaniyah [Development of basin approach in soil and ecological researches]. *Soil science*, *9*, 32-39. [in Russ.].

3. Wischmeier, W.H. Smith, D.D. (1978). *Predicting Rainfall Erosion Losses*. Agriculture Handbook, № 537. Washington, U.S. Departament of Agriculture.

4. Van der Knijft, J.M., Jones, R.J.A., Montanarella, L. (2000). Soil erosion risk assessment in Europe. *European Soil Bureau*, *34*, 8.

5. Belolipskyi, V.O., Poluliakh, M.M., Druhov, O.N. (2016). Heoinformatsiina otsinka pryrodnoho potentsialu gruntiv baseinu r. Aidar [GIS assessment of natural potential of the soils of the basin of the river Aydar]. *Bulletin of agricultural science. Special issue*, Oct., 42-47. [in Ukr.].

6. Belolipskyi, V.O., Baliuk, S.A., Poluliakh, M.M., Timchenko, D.O. (2018). Otsinka intensyvnosti eroziino-hidrolohichnykh sytuatsii za baseinovym pryntsypom (metodychni rekomendatsii ta analiz) [Assessment of the intensity of erosion-hydrological situations on the basin principle (guidelines and analysis)]. V.O. Belolipskyi (Ed.). Kharkiv. [in Ukr.].

7. Bulygin, S.Yu. (2012). Pochvovodoohrannaya optimizaciya agrolandshaftov [Soil and water protection optimization of agrolandscapes]. Monograph. Kyiv: Agrarian science. [in Russ.].

8. Tarariko, O.H., Hrekov, V.O., Panasenko, V.M. (2011). *Okhorona ta vidnovlennia dehradovanykh gruntiv vidpovidno proektu Gruntovoi Dyrektyvy Yevrosoiuzu* [Protection and restoration of degraded soils in accordance with the draft soil Directive of the European Union]. *Bulletin of agricultural science, 5,* 9-13. [in Ukr.].

9. Kutsenko, M.V. (2012). *Heosystemni osnovy rehuliuvannia eroziino-akumuliatyvnykh protsesiv: heomorfosystemnyi aspekt* [Geosystem framework for the erosion and accumulation processes: geomorphically aspect]. Monograph. Kharkiv: KP «City printing house». [in Ukr.].

10. *Rehionalna prohrama okhorony rodiuchosti gruntiv na 2014 – 2020 rr.* (2013). [Regional program of soil fertility protection for 2014-2020] Luhansk regional state administration, Department of agro-industrial development, Luhansk branch of the state institution «Institute of soil protection of Ukraine», Luhansk regional main Department of land resources of the State Committee of Ukraine on land resources, Luhansk state agricultural experimental station of the Institute of crop production V.Y. Yuryev. Luhansk. [in Ukr.].