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Protection of soils from erosion at the level of separate land-use in contemporary conditions

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The purpose. To demonstrate algorithm of actions on state-of-the-art erosion-preventive optimization of land-use structure on an instance of the concrete agricultural factory. **Methods.** Cartographical, statistical, geoinformational analysis, mathematical simulation. **Results.** On an instance of lands of a concrete farm nonconformity of existing use of lands to soil-saving demands is established. On the basis of analysis of potential loss of land for territory of agricultural factory zones with the heightened erosive hazard are determined. Change of structure of crop rotations with creation of 4-field soil protection rotation for erosion hazardous plots and 6-field rotation in other territory is offered. Content is justified and order of crop rotation in crop rotations is elaborated. Mathematical simulation of erosion at different scripts of use of territory showed that implementation of the updated structure of crop rotations would lower erosion to a safety level. **Conclusions.** The modern land-use, which is founded on out-of-date schemes of disposition of industrial plots, demands their supervisory control with the purpose of assessment of risk of erosion processes. One of ways of such inspection is mathematical simulation of loss of land which can be spent at the level of separate factory and for separate field. The potential hazard of erosion detected as a result of simulation can be prevented by means of organizational and agrotechnical measures that demands from factory minimum economic expenditures. Namely: on the basis of simulation of processes of erosion it is necessary to change regimen of use of erosion-dangerous plots with selection of crop rotations which ensure observance of admissible level of erosion of soils.

Key words: *water erosion, agrotechnological group, loss of land, mathematical simulation of erosion, crop rotation.*

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Introduction. The cessation and return to land degradation is one of the main objectives of the sustainable development of mankind, as defined in the program document "Transforming our world: Sustainable Development Agenda for the period up to 2030", adopted by the UN General Assembly on September 25, 2015 [1]. The concept of a neutral level of land degradation, under which, in fact, is the lack of a progressive level of degradation was adopted and is currently being actively discussed.

Land degradation, as a complex process of deteriorating land quality, is largely due to soils degradation processes, among which wind and water soil erosion, occupies one of the main places in the world [2, 3].

According to expert estimates [3], on a global scale, various types of soil degradation have been covered: water erosion - 23.7%; wind erosion - 11,9%; chemical degradation - 5,1%; physical - 1.7% of the total area of agricultural land. In Ukraine, the problem of soil erosion is no less acute. According to our source [3], the processes of flat erosion affected 17% of the area of arable land, 3% of the arable area is affected by the formation of gullies. The Conception of achievement of the neutral level of land degradation in Ukraine, developed by the leading Ukrainian scientists, indicates that Ukraine has gained a huge and successful experience of systematically addressing the problem of rational land use and soil conservation in conditions of a potentially high level of erosion [4]. Unfortunately, this experience is obtained in conditions of state ownership of land and is based on the use of a systemic basin approach, which involves a set of interrelated organizational, agrotechnical, hydrotechnical and agroforestry measures.

As a result of the land reform in Ukraine, more than 80.0% of the land fund of the state is transferred to private ownership. Citizens have allocated more than 6.9 million land shares with an average size of 4,0 hectares [5]. As a result, modern agrarian production in Ukraine is characterized by a mosaic structure of land use, which is associated with the specifics of small-scale land degradation with the subsequent transfer of individual shares to agricultural producers. According to source [6], the average size of a modern agricultural enterprise in Ukraine is about 112 hectares, of which the arable land is - 100 hectares, that is, more than 97%. In this case, the land of individual farm, as a rule, is not a whole array, but rather a few isolated, often quite distant from each other plots.

Large objects of the soil protection system after the reform remained in state and communal ownership. Thus, in recent years the functionality of the soil protection system from erosion has been disturbed as a result of the destruction of structure and age-related changes in forests protection [6] and modified structure of land use. Land users in such conditions can not manage the anti-erosion objects and control their operation, and therefore, they are not interested in maintaining their functionality. As a result – neglect of the anti-erosion protection of the territory caused a direct and indirect damage from the manifestations of erosion processes [7].

Under these conditions, the first place in the system of soil protection from erosion in Ukraine is the application of agrotechnical and organizational measures consisting in erosion-based selection of crop rotation, as well as areas and methods of cultivation for each working area, taking into account the parameters of the relief and soil properties [8]. In addition, the shape and size of the work areas should also be adjusted in accordance with the requirements of erosion safety.

Carrying out work on the development of a system of anti-erosion measures for each particular enterprise is possible only on the basis of mathematical modeling of erosion processes taking into account the action of these factors (shape and size of the working sites, their orographic position, the nature of the use and properties of soils) [8]. Our experience shows that the implementation of this approach is most effective in conditions of complicated relief [9].

The purpose of this work is to demonstrate an algorithm of action on modern anti-erosion optimization of land use structure on the example of a particular agricultural enterprise.

The research methodology included geoinformation analysis of the terrain with GIS (work was carried out in Quantum GIS). The digital model of terrain of the territory (SRTM) was built on the basis of the data of topographic maps of scale 1:10 000, and on the basis of its maps the surface of the slope and zone distribution by agrotechnological groups were received.

Also, data on the slope of the surface and the length of the runoff line were used in the simulation of erosion processes. Calculations of potential runoff were carried out in accordance with the current DSTU 7904: 2015 [10]. The research was conducted in early 2018 in three stages. In the first stage, on the basis of the SRTM analysis, the distribution of the investigated farmland by agrotechnological groups was carried out and the share of land in each group for each individual field was determined. The second stage involved the development of proposals for changes to the land management scheme (allocation of areas, land use which is subject to certain restrictions, the formation of crop rotation). In the third stage, the mathematical modeling of soil losses from the fields was carried out in the conditions of application of the land use structure modified in accordance with our recommendations to verify the correctness of the recommended changes.

Research results. Since the peculiarity of accelerated soil erosion is its considerable differentiation in space and time, the most important task for creating a system of soil protection from erosion is the development of adequate information support [11, 12]. In determining the regime of use of land, the requirements of "Methodological recommendations for the development of land management projects that provide ecological and economic rationale for crop rotation and land management" are guided by the requirements [13]. According to this document, the allocation of agrotechnological groups of land is made according to the angle of inclination of the surface: I group - up to 3^0, II group - $3\text{-}7^0$, group III - more than 7^0 and determination of soil protection technologies for growing crops [13].

On the lands of group I, it is recommended to grow locally adopted crops using intensive technologies. On the lands of group II, it is recommended to organize grain-grass and soil protection crop rotation, with the exception of the placement of clean fallow, cultivated crops and other erosion-unstable crops. Land I and II agricultural technology groups are further subdivided into subgroups with special requirements for the cultivation of crops (Ia, Ib, IIa and IIb, respectively). It is recommended that the III technology group be excluded from intensive use, subjected to turn into meadows and withdrawn from the arable land.

We maintain the view [14] that using the angle of inclination as the only criteria for planning the use of land is unacceptable. This characteristic in many cases does not reflect the actual erosion of the territory - the effect of the objects of the soil protection system against erosion, field infrastructure has not taken into account. In addition, a fairly common phenomenon in Ukraine – is the combination within the limits of one production site (field) of land of two agro-technology groups in roughly equal proportions when it is quite difficult to determine the prior mode of use. At the same time, the main owners criteria for choosing a crop is economic, which often does not comply with the requirements of anti-erosion protection.

Objective criteria in such cases as it is recommended, to take the value of potential runoff, that calculated with use of one or another mathematical model of erosion. Currently, DSTU (State Standard of Ukraine) 7904: 2015 is used in Ukraine, was created on the basis of the model of soil runoff by TS.E. Mirzhulava in modification of S.Yu. Bulygin [15]. Below are the results of such approach working out on the example of one of the agricultural enterprises located in Kegichivsky district of the Kharkiv region.

In the zonal relation the land of the farm are located in the Steppe zone of Ukraine, the soil cover of the investigated area is presented by Chernozem ordinary with various degrees of erosion. The development of water soil erosion processes is facilitated by the complex of water-erosion relief of the area with fluctuations of heights of 150 m in the watersheds up to 105 m in thalweg (Figure 1).

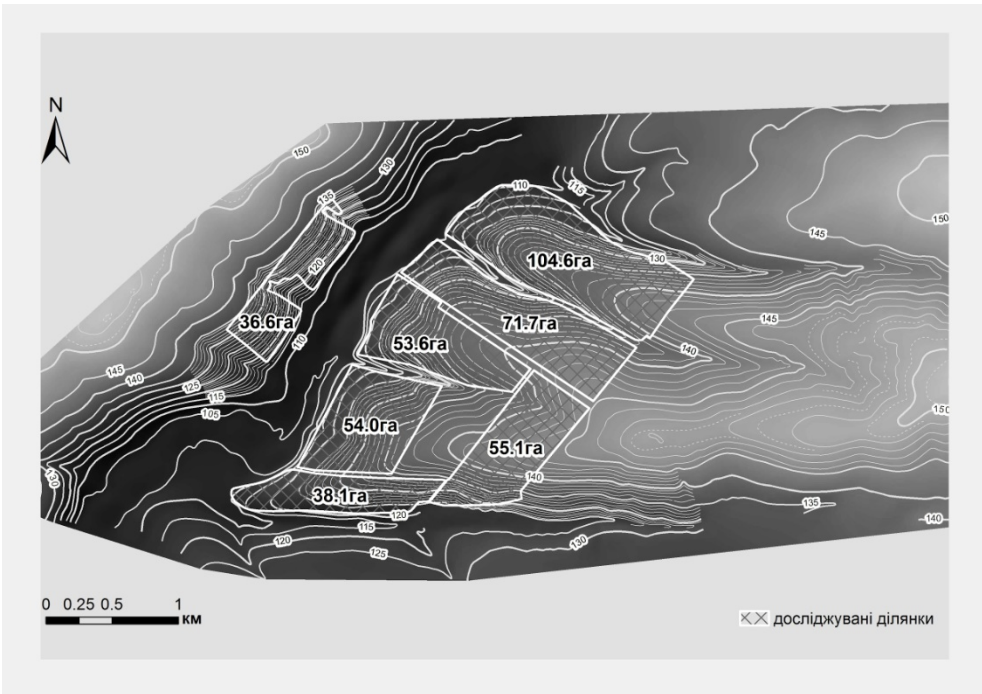

Fig.1 Scheme of fields placement on the investigated farm area, imposed on the digital model of the terrain territory

The land of farm for which research was conducted presented by a few isolated arrays (Figure 1), that clearly illustrates the current problem of mosaic land use, as mentioned above. Our research was conducted on part of the farm land, located on the banks of the river Voshiva, which are characterized by a complicated relief (Figures 1 and 2).

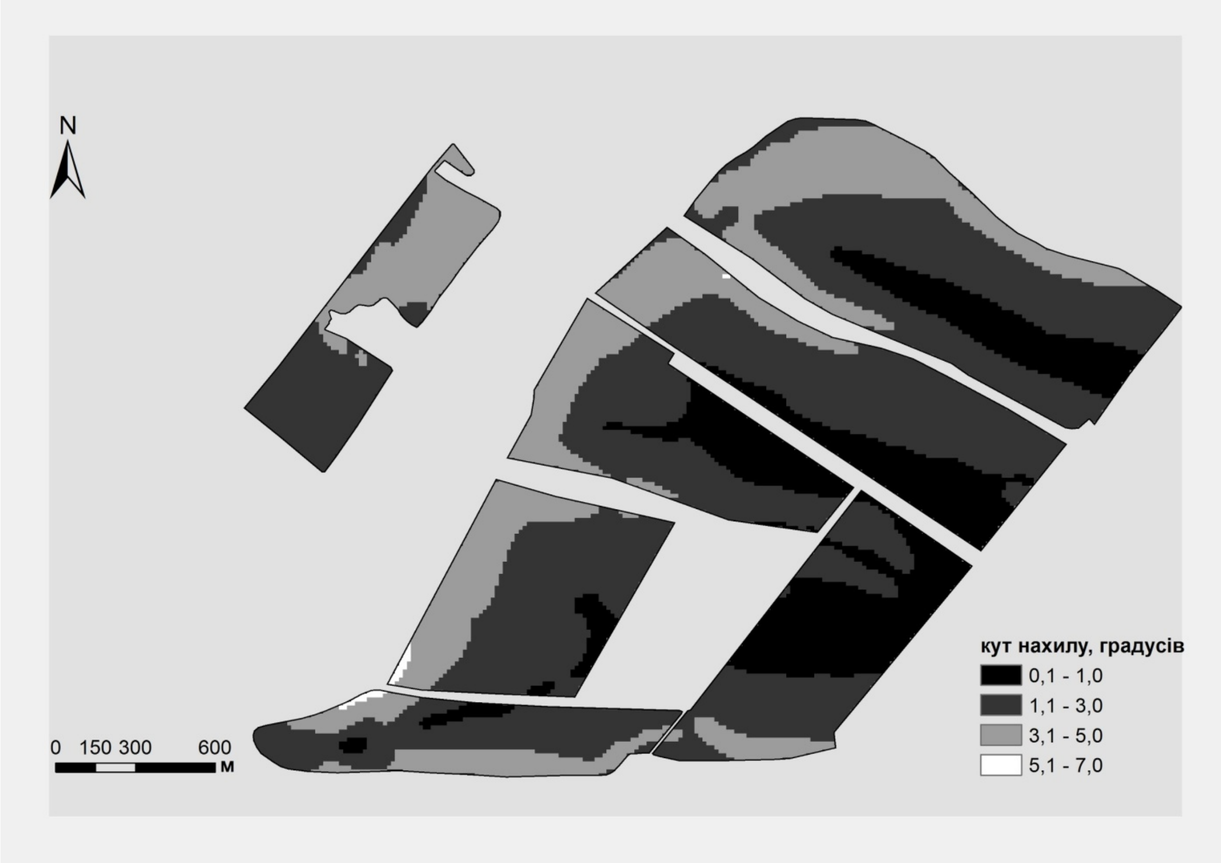

Fig. 2. Cartogram of the surface angles for the investigated area

GIS-analysis of the digital elevation model (DEM) of relief showed a high spatial heterogeneity of the slope surface for unitary work areas - fields of crop rotation (Figure 2, Table 1). As can be seen from Table 1, according to the existing land use structure, the only homogeneous relief is for field number 3, the main part of which belongs to the first agrotechnological group, and only 8% - to the second. The other 6 fields presented by a significant part of second agrotechnological group lands (from 19 to 48%). Regulatory documents [10] directly indicate on the need for a land area correction, in particular regarding the placement of agricultural crops.

1. Explication of lands according to the inclination of the surface, in%

Number of fields	Area, ha	the inclination (agrotechnological group)			
		0-1 (Ia)	1-3 (Iб)	3-5 (IIa)	5-7 (IIб)
1	36,6	0	52	48	0
2	38,1	6	60	33	1
3	55,1	48	44	8	0
4	54,0	6	61	32	1
5	53,6	25	52	23	0
6	71,7	23	58	19	0
7	104,6	16	53	31	0

In addition, the verification of the necessity for adjusting the scheme of land management was carried out by modeling the runoff according to DSTU (State Standard of Ukraine) 7904: 2015 "Soil quality. Determination of potential soil erosion threat under the influence of rain" [10]. The simulation results for the experimental fields are shown in Figure 3.

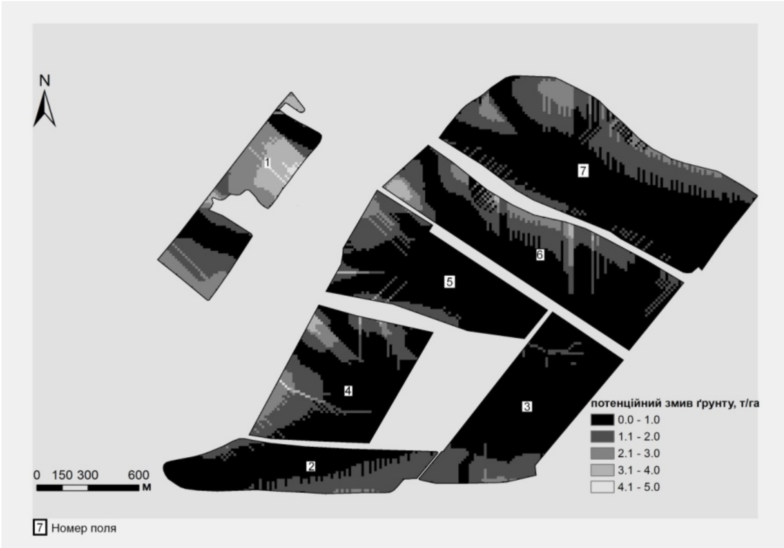

Fig. 3. Cartogram of potential soil erosion for the area under the existing land use structure

The analysis of Figure 3 showed that there are 3 main centers of accelerated erosion in the studied territory - the central part of the field number 1 and the western part of the fields with numbers 4 and 6. That is why these lands need additional protection against erosion processes.

For this purpose, it is recommended to isolate their most erosion vulnerable lands in soil protective crops rotation. Figure 4 shows the proposed scheme of field lands differentiation and soil protective crops rotation. To comply with the requirement of field's simplification, the territory of the field number 7 was divided into two parts (Fig. 4).

The second stage of simulation is the definition of a set of crops, the protective effect of which will be adequate to the degree of erosion hazards.

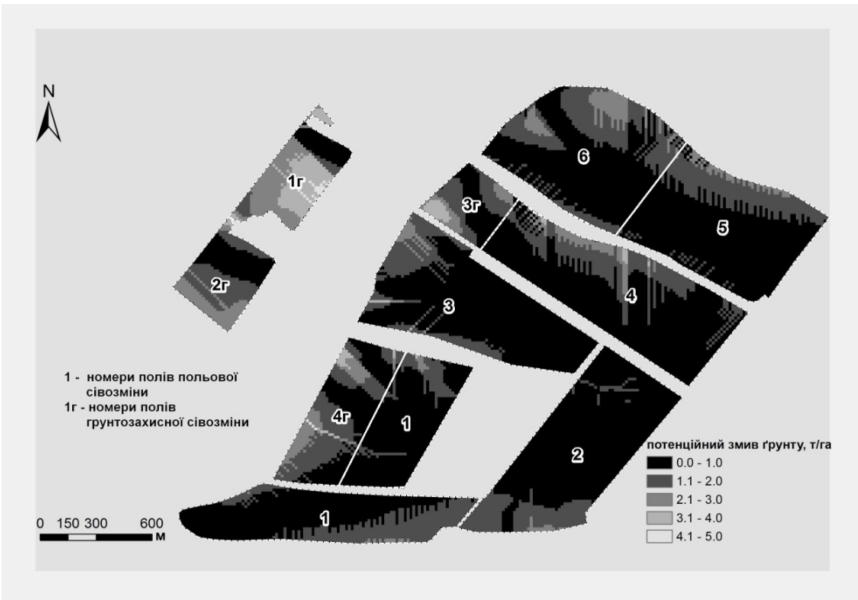

Figure 4. Recommended scheme of fields placement and crop rotation of investigation area.

Thus, four-fields soil protective crop rotation with an area of 83,3 hectares (fields №№ 1g, 2g, 3g and 4g) and a six-field field crop rotation with an area of 330 hectares (correspondingly, fields №№ 1-6) was formed. Taking into account the specialization of the farm and the requirements of the current market situation, the following alternation of crops is recommended:

a) field crop rotation: 1 - winter wheat, 2 - corn silage, 3 - winter wheat, 4 - maize for grain, 5 - barley, 6 - sunflower.

b) soil protective crop rotation: 1 - winter wheat, 2 - barley with sowing perennial grasses, 3 - perennial grasses (1 year of using), 4 - perennial grasses (2 years of using).

To take into account the anti-erosion action of agrophons, we used the approach proposed in source [16]. Based on the average annual coefficients of soil protection efficiency of agrophons proposed by F.T. Morgun et al. [17] determined the weighted coefficients of soil protection efficiency for rotation of crop rotation. For crop rotation proposed by us, they were, respectively: for field crop rotation - 0,62 and for soil protective crop rotation - 0,15. For a clean fallow, the value of this coefficient is 1, for perennial grasses, depending on the year of use – from 0,1 to 0,01 [17].

By 2017, for the whole research area, the actual coefficient of soil protection effectiveness of agrophons was 0,76, that is, as introduction of the proposed change in the structure of land use will contribute to strengthening the protective anti-erosion action of crops. Similar results of the land use structure optimization were obtained by us before on the example of the other farm [18], where, as a result of the restructuring of the land due to improving the soil protection efficiency of agrophons, the value of the average weighted coefficient of soil protection effectiveness of crop rotation was changed from 0,74 to 0,66 in the arable field and up to 0,17 – in soil protective crop rotation, which ensured the reduction of erosion to an acceptable level for the prevailing part of the whole farm territory.

In order to evaluate the anti-erosion efficiency of the proposed land use structure, we conducted a mathematical modeling of the soil loss based on the average weighted coefficient of agrofons soil protection efficiency for crop rotation under the conditions: 1 - active structure of crop areas in 2017, 2 - clean fallow, 3 - the structure of crop areas recommended by us.

2. Forecast of soil washing in the territory of the experimental site

Number of field	Area, ha	Potential runoff, t/ha for year		
		Structure of 2017 year	Clean fallow	Recommended structure for the year of assimilation
Field crop rotation				
1	66,1	1,0	1,2	0,8
2	55,1	1,4	1,8	1,2
3	53,4	1,5	1,9	1,3
4	51,0	1,0	1,2	0,7
5	52,3	1,5	2,0	1,3
6	52,3	1,1	1,3	0,8
Soilprotect crop rotation				
1	18,3	2,8	4,1	0,6
2	18,3	2,8	4,2	0,7
3	20,7	2,2	3,1	0,5
4	26,0	2,1	3,0	0,5

The criteria for the need for soil protection measures was exceeding the value of a potential runoff over the allowable runoff value, which is 1,2 – 1,3 t / ha per year. As can be seen from Table 2, in the conditions of the structure of 2017 (with the predominance of cultivated crops), the majority of the studied area is observed to exceed the permissible level of runoff. In condition of absent protective effect of cultured vegetation (clean fallow) erosionally dangerous supposed to be almost the entire area under study.

The proposed land use structure allows us to reduce soil losses to an acceptable level without applying additional measures of anti-erosion. According to the results of our research (Table 2), on the erosion-hazardous parts of the territory where introduction of erosion-optimized crop rotation has taken place, it is possible to reduce the forecast of soil losses to the acceptable losses level. Moreover, in the field crop rotation, the predicted soil losses is reduced by 1,3 times, and in soil protective crop rotation - 6 times (compared with the existing level).

Conclusions

The requirements for the accomplishment of the neutral level of land degradation presented by Ukraine for the implementation of the National Action Plan “For combating land degradation and desertification” require the introduction of effective measures to prevent water erosion of soils. The most effective and proven by time preventing erosion degradation measure is the systematic application of a complex of anti-erosion activities at the level of catchment basins. However, in existing conditions, when land of individual consists of separated from each other relatively small land sites, implementation of such approach is almost impossible.

The existing land use structure in Ukraine, which is based on outdated layouts of production sites, requires an estimation of the risk for developing of erosion processes within each particular site with the help of mathematical modeling. Identified by the modeling potential threat of erosion can be prevented by using organizational and farming practices that requires minimal economic costs economy. Namely: on the basis of modeling of erosion processes, a change in the mode of use of erosion-hazardous areas with selection of crop rotation should be carried out, application of which provides observance of the acceptable level of soil erosion.

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