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THE PROBLEM OF TOLERABLE EROSION SOIL LOSS SUBSTANTIATION AND AN APPROACH TO ITS SOLUTION

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In the paper it is shown that for developing a strategy of rational use of the remaining soil resources a methodology is necessary which must include methods of solving the following tasks: objective evaluation of soil resources; evaluation of their dynamics for the past time; long-term prediction of soil resources dynamics; search for a compromise between the necessity of decreasing soil degradation (erosion) and available economic possibilities. The solution of the tasks mentioned above is discussed, eroded chernozem soils of the arable lands of Kursk Region taken as an example. The quantity of the soil resources was evaluated by the plowland area and the thickness of humus horizon, and their quality (fertility, productivity) was evaluated by the humus supplies in the soil layer 0–50 cm. The dynamics of the soil resources was evaluated by the dynamics of these parameters measured. Data on the reduction of chernozem soil resources approximately within 200–250 years after the virgin land was plowed up are presented. It is shown that it will take thousands of years to restore the thickness of the humus layer of eroded chernozem soils, and hundreds of years to restore humus supplies. It is practically impossible to stop erosion on a large area for a relatively short period of time. A strategy of erosion reduction to the level of soil formation is necessary.The strategy was divided in stages for which an approach to the evaluation of tolerable erosion soil loss (TESL) was suggested. The approach is the search for a compromise between the rate of soil formation, the thickness of humus horizon, soil productivity (quality, fertility), an random character oferosion processes on the one hand, and available economic possibilities on the other hand. The values of TESL must decrease from stage to stage nearing the rate of soil formation.For the first stage (without economic assessment) values of TESL are developed.

Keywords: soil erosion, tolerable soil loss, soil resources, prediction, strategy, chernozem soils.

INTRODUCTION

For all its history the humankind lost two milliard hectares of arable lands, which is more than their area nowadays (1.5 milliard ha). In the late 20th century the area of arable lands decreased yearly: as a result of their degradation by 0.47% and by 0.53% because of their alienation for economic needs [2]. Only because of erosion arable land reduced yearly by 0.4% [4]. Consequently, of all types of degradation soil erosion is a principal cause of area reduction of arable land, and a cause of crop yield decrease as well.

In the world an impetuous growth of human population is taking place. Thus, according to predictions, by 2050 for 40 years the number of the world population will rise 1.3 times and reach 9.1 milliard, and the area of arable land per person will reduce 3.1 times and reach 0.07 ha per person. This entails the necessity of rising crop yield not less than 3 times, and 2.4 times only by reducing arable land area [15].

In Russia as a state of art for 1995 the part of eroded soils of arable lands ranged from 0.7 (Cheliabinsk Region) to 78.1% (the Chuvashskaya Republic) [8]. On arable lands a yearly increment of eroded soil area equalled 0.36% on the average reaching 1% in some regions [3]. Similar data of the alteration of eroded soil area for the last 20 years are not available, that is why it may only be supposed that because of erosion soil degradation continued.

These tendencies create the danger of global food crisis in the future. To avoid the crisis a strategy of rational (sensible) use of the remaining soil resources, including the ones subjected to erosion, is essential.

Admitting that soils "are of key importance for life support on the Earth", the UNO declared the 5th of December to be the World Soil Day, and 2015 was proclaimed the World Soil Year [9].

When planning anti-erosion measures a notion "tolerable erosion soil loss" (TESL) or an equivalent notion "tolerable erosion norm" (TEN) is used. To evaluate TESL different approaches are used [7] which have a common defect: the soil loss is not evaluated from the point of view of long-term prediction of soil resources dynamics.

The aim of the present paper is to substantiateTESL from the point of view of developing a strategy of rational use of erodedsoil resources for crop production.

OBJECT AND METHODS

The object of study is eroded chernozem soil of Central Chernozem Area used for crop production.

By present different approaches for TESL evaluation are suggested, a detailed analysis of which is given in the work [7]. To evaluate TESL values three basic approaches and corresponding parameters are used: 1) *soil formation rate* (soil loss must be compensated by soil formation which is evaluated with great uncertainty); 2) *available soil depth* (the more is the depth, the more is TESL); 3) *soil productivity alteration* (TESL is evaluated from tolerable reduction of soil productivity for a definite time interval and its relation with erosion soil loss).

In the work [5] another approach is offered. It is based on determining tolerable loss of humus supplies in the soil at the first stage, and then determining tolerable soil loss itself. Taking into consideration the dependence of yield on humus supplies [10] the approach can be attributed to soil productivity reduction. As it will be shown below maintaining humus layer thickness but not humus supplies should be in the first place.

Essential defects of those approaches are in the fact that they are not based on long-term prediction of soil resources dynamics and do not consider TESL as an element of the strategy of rational use of soil resources. From this point of view possible future dynamics of soil formation rate, erosion soil loss, soil depth and its productivity dynamics must be taken into account. That means that all the essential approaches must be used simultaneously and their priorities must be determined. Besides, economic conditions which could result in limitations in tolerable soil loss should be taken into consideration (and be predicted).

The main strategic task is the production of necessary quantity and quality of crops in the future. The solution of the task is connected with soil resources which will be required in the future.

At present there is no methodology of rational use of soil resources for crop production which would be brought to practical application. That is why it is suggested here that the methodology must include specifically methods of the solution of the following tasks: 1) objective evaluation of soil resources; 2) evaluation of what happened to the resources in the past and why; 3) long-term prediction of soil resources dynamics; 4) search for compromises between the necessity to reduce soil degradation (erosion) and available economic possibilities.

Taking chernozem soils of Kursk Region as an example, approaches to the solution of the tasks mentioned are discussed below, and it is shown how those solutions can be used to substantiate tolerable erosion soil loss.

RESULTS AND DISCUSSION

Objective evaluation of soil resources from the point of view of crop production. Natural resources are evaluated by quantity and quality. Quality is evaluated by the principle: the more product per unit of resources is produced (under all the other equal conditions), the higher is their quality. Soil quantity is evaluated by two measured parameters: cropland area and humus layer thickness. Soil quality is evaluated by the principle: the greater the yield (the quantity of the produced product per area unit under all the other equal conditions) is, the higher is soil quality, and on the contrary, the higher the soil quality is, the greater is the yield (under all the other equal conditions). It is proved [14, 15] that for the chernozem and grey forest soils of Kursk Regiona verage annual yield of small grain and row crops (under all the other equal conditions) is directly proportional to the humus supplies in the soil layer 0–50 cm.

This means the following: how many times the humus supplies are greater or smaller, so many times greater or smaller is the yield. That is, humus supplies (the third measured soil parameter) at the first approach objectively evaluate soil quality from the point of view of the quantity of produced product. The notion “quality” is a relative notion. Soil quality from the point of view of the quality of the crop product itself will be determined, for example, by the content of harmful substances in the soil which move into the product. In the future (if it is not stipulated specially) under soil quality its quality from the point of view of the quantity of the produced product is understood.

For qualitative description of soil properties the following notions: “fertility”, “productivity” and “health” of soil are used, there being no objective quantitative appraisals for them. To avoid the confusion of these notions in the future we will assume that all the indicated properties are evaluated by the same principle as soil quality (the greater is the yield under all the other conditions, the higher is the quality of the soil). In such a case soil quality, fertility, productivity and health will all improve, deteriorate simultaneously or remain unchanged.

Consequently, for chernozem soils under consideration the dynamics of humus supplies describe the dynamics of soil quality (fertility, productivity and health). And the dynamics of cropland area and humus layer thickness describe the dynamics of soil quantity.

Hereafter, from the three parameters characterizing soil resources only two are considered: humus layer thickness and humus supplies which evaluate soil resources per area unit of cropland, one hectare for example.

Evaluation of what happened to soil resources in the past and why. In the table (lines 1 to 5) data of the condition of chernozem arable lands of Kursk Region approximately in 200–250 years after plowing virgin lands are presented [15].

In table lines 1–3 data for the comparison of eroded soil with uneroded one are presented. From these data it follows that as a result of soil erosion for 200–250 years soil quantity decreased essentially (the thickness of humus horizon reduced) and soil quality deteriorated (humus supplies in the layer 0–50 cm reduced essentially which resulted in essential drop of yield dependent on humus supplies). For severely eroded chernozem soil (Line 1) the thickness of humus horizon is 24 cm which corresponds to the depth of plowing. That means that 200–250 years after plowing virgin land on severely eroded soil plowing of the upper layer of parent rock already took place.

In table lines 4–5 data of the reduction of humus supplies as compared with virgin land are given, from them there follows a conclusion: in uneroded chernozem soil only as a result of organic matter humification and dehumification humus supplies decreased by 50%, andin addition by 12–30% humus supplies decreased as a result of erosion. Consequently, humus loss caused by erosion is less than that caused by the processes of humification and dehumification.

All that was caused by the following: after virgin land had been plowed up, changing of vegetative cover took place, it resulted in sharp decrease of organic matter incoming into the soil which resulted in decrease of humus supplies, and in abrupt increase of erosion soil loss when the surface was inclined.

Data of the condition of chernozem arable lands of Kursk Region

Line Nr	Parameter	Uneroded soils	Degree of eroded state		
			slight	moderate	severe
	Eroded chernozem soils as compared with uneroded ones*				
1	Humus horizon, cm	74±1	55±1	35±1	24±2
2	Reduction of humus horizon, %	0	24±1	52±1	67±3
3	Reduction of humus supplies in the layer 0–50 cm, %	0	23±1	48±2	59±3
	Chernozem soils as compared with those of virgin lands**				
4	Reduction of humus supplies in the layer 0–50 cm, %	50	62	74	80
5	Reduction of humus supplies in the layer 0–50 cm because of erosion,%	0	12	24	30
	Tolerable soil loss: decrease of erosion rate				
6	Rate of humus horizon reduction for 200 yr, mm yr^{-1}	0	1.0	2.0	2.5
7	Tolerable erosion soil loss I_{tol}, mm yr^{-1} (t ha^{-1} yr^{-1})**	0.53(6.4)	0.39(4.7)	0.25(3.0)	0.17(2.0)
8	Erosion decrease, relative units	0	2.6	8	>15
	Tolerable soil loss: decrease of yield				
9	Decrease of yield on eroded soils, % ***	0	18	35	52
10	Additional decrease of yield in 50 yr at I_{tol}, %	3.6	2.6	1.7	1.2

* Data [15].

** I_{tol} (t ha^{-1}) = 10ρ(g cm^{-3})I_{tol} (mm yr^{-1}) at soil consistence ρ = 1.2 g cm^{-3}.

*** Small grain crops and row crops on chernozem and grey forest soils of forest-steppe and steppe zones of Russia, Ukraine and Moldavia [10].

That leads to an obvious conclusion: the strategy of rational use of soil resources must be orientated towards increasing of organic matter incoming into the soil (plant residues, specifically) and towards decreasing of soil loss from erosion.

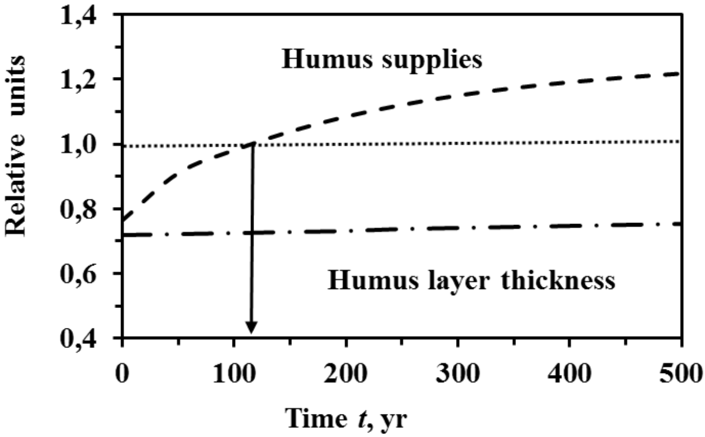
Long-term prediction of soil resources dynamics. All resolutions made for the future must be substantiated on objective predictions of the consequences of such decisions. In Russia long-term prediction of the dynamics of soil resources its quantity and quality) is at the stage of origination, and that restrains the development of long-term predictions of crop production (its quantity and quality).

Recently for the chernozem soils of Central Chernozem Area a model [11], describing the dynamics of three soil processes: erosion, organic matter transformation and humus horizon formation, have been developed. Testing of the model showed that the alteration of the thickness of humus horizon for 200 years was understated by the model by 13% on the average [12]), and humus supplies were understated by 15% [11]. Consequently, the model can be used for long-term prediction. The results of predicting led to the following conclusions [11]: in present-day agriculture soil resources will continue to decrease, yield depending on humus supplies will drop, but this process can be essentially decelerated.

When developing a strategy it is important to set practically solved tasks. There is a question: can eroded soils be restored to become uneroded?

Restoration of humus layer thickness. From the facts of the dependence of soil humus layer thickness on soil age [1] it follows thatNature needed 2, 4 and 5 thousand years, respectively (the soil was in the state of virgin land), to increase the thickness of humus layer from 55, 35 and 24 cm to 74 cm (uneroded chernozem soil, Kursk Region, Line 1 in the table). If eroded soils (Line 1 in the table) are transferred into idle land which in the course of time turns into virgin land, it will take the same time, i.e. thousands of years, to restore the thickness of humus layer. Two important conclusions follow from this: 1) humans lost for 200–250 years what Nature had created for thousands of years; 2) the lost soil humus layer practically cannot be restored.

Restoration of humus supplies. Using the model [11] for an eroded slope 500 m long and 3 degrees of inclination an optimistic prediction for the restoration of eroded chernozem soil was developed under the following conditions: vegetation on the slope is the same as it is on virgin land but the productivity decrease of the eroded chernozem soil taken into account; erosion (soil loss) is absent. In the figure the obtained data for the humus supplies in the layer 0–20 cm and the thickness of humus layer are presented “1.0” on the vertical axis corre-



Optimistic prediction for the dynamics of humus supplies in the layer 0–20 cm and humus layer thickness at the bottom of eroded slope.

sponds to the conditions of uneroded soil at the top of the slope at the initial time moment at $t = 0$ (the thickness of humus horizon was 80 cm, and humus content in the topsoil was 5.8%).

From the data of the figure it follows that at the best it will take approximately 120 years (the vertical arrow in the figure) to restore humus supplies in the soil layer 0–20 cm. By the prediction the humus supplies in the layer 0–50 cm will be restored in 250 years. The thickness of humus layer for 500 years will increase by 28 mm at the average rate 0.06 mm yr^{-1}.

From the optimistic prediction it follows that soil resources lost as a result of erosion practically cannot be restored.

Consequently, while developing the strategy, it is necessary to proceed from the following: 1) when crops are produced soil resources are reduced on account of erosion, practically the reduction can be only decelerated; 2) the task of maintaining the thickness of humus layer (soil quantity) must be in the first place, because it takes thousands of years for its restoration; 3) the task of maintaining humus supplies (soil quality, fertility, productivity, health) must be in the second place, because crop yield depends on them.

All that leads to the search of a compromise between the necessity to stop the reduction of soil resources and the necessity to produce different crop products (of given quantity and quality).

Search of a compromise between the necessity of soil erosion reduction and available economic possibilities. To stop erosion for a short time is practically impossible. It is conditioned by the following reasons. 1. The development and adoption of adequate laws is required. 2. The vast area of plowland is subjected to erosion. 3. Agriculture has great inertness (it will take a lot of time just to introduce new conservation technologies all over the area of plowland). 4. When tolerable soil loss from erosion is decreased costs for anti-erosion measures increase sharply [6]. These costs can be insufficient even to reduce erosion to the level of soil formation. 5. The only known method which guarantee the restoration of eroded soils is the transference of plowland into an idle land with its subsequent transition to the conditions of a virgin land. It is practically impossible to transfer all the eroded soils into an idle land because it is necessary to increase the quantity of produced crops.

All that leads to the necessity of developing a strategy of rational (sensible) use of soil resources subjected to erosion when producing crops. The strategic task is decreasing erosion soil loss to the rate of soil formation (soil humus layer formation). This strategy as any other must have stages. For every stage tolerable erosion soil loss which is a compromise between the necessity of stabilizing humus layer thickness (strategic task) and available economic possibilities must be substantiated. Tolerable soil loss must decrease from stage to stage approaching the rate of soil formation. Having solved this strategic task one can put the task of increasing the thickness of soil humus layer.

Let us introduce the notion “planned period” which determines the time interval T_{plan} (year) in which a certain event will take place, for example, the soil layer lost as a result of erosion will reach a certain value, or the productivity (quality) of soil will drop by a certain value.

The whole strategy is divided into n stages with the duration T_i (year), $i = 1, 2, \ldots n$. For every stage tolerable soil loss $I_{\text{tol.i}}$ is substantiated. This loss decreases from stage to stage striving for the rate of soil formation.

Taking into consideration that soil erosion is a random process we will introduce the following values: ΔH_{aver} (mm) is the average value of the out washed soil for the time T_{plan}; ΔH_P (mm) is the soil layer lost as a result of erosion, corresponding to the probability P (%); $K_r = \Delta H_P / \Delta H_{aver}$ is the coefficient of reliability corresponding to the probability P. Then the average erosion soil loss for a year (mm yr^{-1}) will be written as

$$I_{aver} = \frac{\Delta H_{aver}}{T_{plan}} = \frac{\Delta H_P}{T_{plan} K_r}. \quad (1)$$

Let us indicate by ΔH_{tol} (mm) a tolerable layer of outwashed soil for the time T_{plan}. In the dependence (1) we will replace ΔH_P for ΔH_{tol} and will obtain dependence for tolerable erosion soil loss (mm yr^{-1})

$$I_{tol} = \frac{\Delta H_{tol}}{T_{plan} K_r}. \quad (2)$$

When designing anti-erosion measures average annual erosion soil loss I_{cal} (mm yr^{-1}) are calculated. Such measures are chosen which satisfy the condition: $I_{cal} \leq I_{tol}$. The dependence (2) was obtained earlier [13, 16] and has the following meaning: for the planned period of time T_{plan} with probability (100% – P) erosion soil loss will not exceed tolerable loss ΔH_{tol}. To use the dependence (2) it is necessary to substantiate the magnitude of three values: T_{plan}, P and ΔH_{tol}. Below their substantiation for the first stage of the strategy is presented. For the following stages having the data of monitoring the condition and the use of eroded soils and also improved methods of prediction it is necessary to correct the magnitude of these values.

Planned period T_{plan}. The results of [11] showed that appreciable reduction of the thickness of humus layer, humus supplies and yield drop can be established approximately in 50 years. The same period (what is known as horizon of planning) is assumed in the US Act of Soil and Water Conservation [7]. That is why it is assumed T_{plan} = = 50 years.

Probability P (%).The probability evaluates the risk that for the time T_{plan} erosion soil loss can exceed tolerable soil loss ΔH_{tol}. At present when choosing anti-erosion measures it is not taken into consideration, i.e. it is assumed that $K_r = \Delta H_P/\Delta H_{aver} = \Delta H_{aver}/\Delta H_{aver} = 1$. In such a case the risk will be very great, for example, for a specific case it equals P = 45%[12]. For the first stage it can be assumed that P = 5% and to calculate the coefficient of reliability K_r for this magnitude using models which describe soil erosion as a random process. For example, for the chernozem soils of Central Chernozem Area an approximate magnitude K_r= 1.4 is obtained using the model [12].

Tolerable layer of outwashed soil ΔH_{tol} (mm) for the time T_{plan}. Let us indicate by ΔH_{sf} (mm) the increment of the thickness of humus layer by soil formation for the time T_{plan}. If economic conditions allow to decrease erosion soil loss to soil formation ($\Delta H_{tol} = \Delta H_{sf}$, i.e. to the stabilization of humus horizon thickness), the strategy will consist of one stage. In such a case tolerable soil loss will be determined by the rate of soil formation; that is the first of the three above mentioned basic approaches. Such a situation can be rare by the following reason. For moderately eroded chernozem soil (Line 1 in the table) an average rate of erosion for 200 years I_{er} = (740 – 350)/200 = 2 mm yr^{-1}. An average rate of humus layer formation by the optimistic prediction I_{sf} = 0.06 mm yr^{-1}. Consequently, on the plow land the erosion soil loss must be reduced 30 times which can be impossible economically because the costs for anti-erosion measures rise sharply with the decrease of the tolerable erosion soil loss [6]. In such a case for the first stage $\Delta H_{tol} > \Delta H_{sf}$, and concrete magnitudes of ΔH_{tol} will be determined by economic substantiation (possibilities).

As far as there is no such substantiation, an absolute error (standard deviation) ΔH_{err} of measuring a humus layer can be assumed as ΔH_{tol} and as a relative error a coefficient of variation ε_{err} = 100 ($\Delta H_{err}/H_{hum}$), where $H_{hum}$is the average value of the thickness of soilhumus layer [13]. The minimal value ε_{err} = 5% have uneroded chernozem soils. For evaluating $\Delta H_{tol} = \Delta H_{err}$ = = ($\varepsilon_{err} H_{hum}$)/100 for eroded chernozem soils ε_{err} = 5% is also assumed. Then the dependence (2) may be written

$$I_{tol} = \frac{\varepsilon_{err} H_{hum}}{100 T_{plan} K_r}. \quad (3)$$

The dependence (3) has the following sense: when erosion soil loss is tolerable (I_{tol}), in T_{plan}= 50 years with the probability (100 – 5) = 95% the layer of outwashed soil will be within the error of measurement of the thickness of humus horizon, i.e. it may be assumed that for 50 years within the error of measurement the humus layer will not change. The dependence (3) shows that tolerable soil loss is determined proceeding from the available thickness of humus layer H_{hum} ; this is the second of the three mentioned above basic approaches.

In table line 6 there presented values of the average for 200 years rate of the reduction of the thickness of humus layer. The rate of soil formation (for the optimistic prediction it equals 0.06 mm yr^{-1}) is much less than the mentioned rate of the reduction of humus layer. That is why approximately it may be assumed that the rate of the reduction of humus layer equals the rate of erosion excluding severely eroded soil for which in some moment the thickness of humus layer reduced to the thickness of topsoil (24 cm) and then it remained constant. This means that for this soil the rate of erosion is more than 2.5 mm yr^{-1} (line 6 in the table).

In table line 7 there presented values of tolerable erosion soil loss calculated by (3) with the following magnitudes: T_{plan}= 50 years; K_r = 1.4 (when P = 5%); ε_{err} = 5%; magnitudes $H_{hum}$are taken from the table (line 1).

In table line 8 data of erosion reduction are presented, i.e. how many times the erosion rate will decrease (as compared with the last period of agriculture), if the values of the tolerable soil loss in table line 7 are taken. For the first stage of the strategy it is a good result.

In search for a compromise it is necessary to evaluate by how much soil quality (productivity) will decrease at different magnitudes of its tolerable loss.

In table line 9 data of yield drop on eroded soils are presented. Let us evaluate by how much will the yield decrease additionally when erosion soil loss ΔH_{tol}= ΔH_{err} forT_{plan} = 50 years.

The following dependences for eroded (in relation to uneroded) chernozem soils of Kursk Region. 1. $\varepsilon_{yield} = a_{hum}\,\varepsilon_{hum}$, where ε_{yield}, $\varepsilon_{hum}$are the relative decrease of the yield and humus supplies in the soil layer 0–50 cm, respectively, a_{hum}= 0.82 [15]. 2. ε_{hum}= $a_{hor}\ \varepsilon_{hor}$, where $\varepsilon_{hor}$is the relative decrease of humus horizon thickness, a_{hor} = 0.87 [11].

It follows from these dependences that $\varepsilon_{yield} = a\varepsilon_{hor}$, where a = = $a_{hum}a_{hor}$ = 0.71. Then the relative yield decrease on eroded soils in 50 years will be written as

$$\varepsilon_{yield+50} = a\left[\frac{H_0 - (H_{er} - \Delta H_{tol})}{H_0}\right] = \varepsilon_{yield} + \varepsilon_{50}, \qquad (4)$$

where H_0, $H_{er}$is the thickness of humus horizon of uneroded and eroded chernozem, respectively; $\varepsilon_{yield}= a(H_0 – H_{er})/H_0$ is the yield decrease on already eroded chernozem soils; $\varepsilon_{50}= a\ \Delta H_{tol}/H_0$ is the additional decrease of the yield in 50 years when there is tolerable erosion soil loss I_{tol}. If tolerable yield decrease $\varepsilon_{50,tol}$is set, tolerable soil loss will be determined by the dependence $\Delta H_{tol}= \varepsilon_{50,tol}\ H_0 /a$; this will be the third of the three above mentioned basic approaches, which is based on the tolerable decrease of soil productivity.

In table line 10 estimated values $\varepsilon_{50}$are presented,theylead to the conclusion that suggested tolerable soil loss already at the first stage of the strategy will not result in significant deterioration of soil quality (productivity) in 50 years.

For the following stages values I_{tol} must decrease and reach the rate of soil humus layer formation, i.e. provide the stabilization of the thickness of humus horizon (a strategic task). By this the deterioration of soil quality will decelerate. The figures of tolerable erosion soil loss must correspond to economic possibilities. The duration of the stages corresponds to the stages of the general strategy of rational use of all soil resources of the country.

CONCLUSION

On the example of the chernozem soils of Kursk Region the solution of three tasks is discussed: objective evaluation of soil resources; evaluation of what happened with the soil resources in the past and why; long-term prediction of the dynamics of the soil resources. The obtained solutions resulted in the following conclusions: the soil resources lost as a result of erosion practically cannot be restored; in present-day agriculture erosion can be only decelerated; developing the strategy of rational use of the remaining soil resources including the resolution of the forth task, i.e. search for a compromise between erosion deceleration and economic possibilities.

A strategic task is the stabilization of humus horizon thickness, i.e. erosion reduction to the level of soil formation (after that the following task of increasing humus layer horizon of eroded soils will be able to be solved). The strategy is divided into stages for which an approach to evaluating tolerable erosion soil loss must be developed and its values must decrease from stage to stage. For the first stage (without economic estimation) values of tolerable soil loss are suggested which guarantee with the probability of 95% that for the planned period of 50 years soil loss will not exceedthe tolerable magnitude, and the yield of small grain and row cropsdepending on humus supplies will drop no more than 3%.

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