EVALUATION OF RATE OF REPRODUCTION OF SOIL RESOURCES

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A method is given for evaluating rates of formation of the humus horizon and humus accumulation in the main zonal types of soils of the Russian Plain. Calculations are made for maximum rates of reproduction of resources for soils with different degrees of washout, proposed as standardizing indices in soil conservation planning.

The zonal system of farming is a system of which all units are called upon to realize fully the potential soil and climatic resources [2]. In the approach to planning and evaluation of the efficiency of soil conserving and soil restoring systems of farming from such positions, it is necessary to evaluate the degree of maximum activation of the process of reproduction of soil resources. It is advisable to examine some standardizing indices of reproduction of soil resources in combination (rate of formation of humus horizon of soils, rate of humus accumulation). The variation in soil resources as a result of the natural soil-forming process over a period of time t can be described as follows [4]:

$$\int_0 \frac{d(H_h\bar{h})}{d\tau}dt = \int_0 H_h\frac{d\bar{h}}{d\tau}dt + \int_0 \bar{h}\frac{dH_h}{d\tau}dt, \qquad (1)$$

where H_h is the thickness of the humus horizon (mm); $\bar{h}$ is its mean humus content (%).

After replacing integration with summation and changing over to Δt = 1 year, the following equation is obtained:

$$\Delta(H_h\bar{h}) = \sum_1^i H_{h(i)}\Delta\bar{h}_{(s)i} + \sum_1^i \bar{h}_i\Delta H_{h(s)i}. \qquad (2)$$

At present there exists the possibility [5] of generalizing already accumulated data and evaluating the rate of formation of the humus horizon of soils ($H_{h(s)}$) and the process of humus accumulation ($\Delta\bar{h}_s$) at some stages of soil formation. Patterns of formation of the humus horizon for the main zonal types of soils of the Russian Plain on rocks of loamy composition were established by the author by generalizing the data in the literature and regional research carried out on the Lower Trayanov swell (output n = 158). Here, allowance was made for the total age of soils [3], which includes all lengths of time of influence of soil formation factors. Using data from 170 meteorological stations, from 36 soil provinces there were averaged out the quantities of radiation balance and total precipitation, and calculations [1] were made of the annual expenditure

of energy on soil formation - Q (MJ/m^2). The main moment which characterizes the climax condition of the profile is attainment by the soil of a certain maximum thickness of humus horizon which is known for zones and provinces. The established dependence of the maximum thickness of humus horizon on quantity Q made it possible to represent the formation of the humus horizon of soils H_h (mm) during the Holocene (t, years) by a model revealing the main determinate trend of the time series:

$$H_h = Q^{2,1}[0{,}0005\,t - k\,exp(-\lambda t)], \qquad (3)$$

where $\lambda = 95 \cdot 10^{-5}$ for podzolic soils and $34 \cdot 10^{-5}$ for certain subtypes in the class of "typical chernozems and light chestnut soils", $k = 35 \cdot 10^{-5}$ (for podzolic soils), $39 \cdot 10^{-5}$ for typical and ordinary chernozems), $44 \cdot 10^{-5}$ (for southern chernozems and dark chestnut soils), and $40 \cdot 10^{-5}$ (for light chestnut and sward steppe soils). It should be noted that the constancy of parameter λ connects the description of the process of formation of the humus horizon of soils for optimum and inadequate moisture conditions, with models which reflect organic growth processes.

The concept of development shown by Eq. (3) makes it possible for evaluations of the rate of formation of H_h to be approached with more substantiation than was done until now. In traditional calculations of "permissible rates of washout", the thickness of the humus horizon and the time of soil formation are directly or indirectly connected with a linear function, which is not confirmed by existing data. In addition, the use of evaluations obtained from full-profile soils for washed-out (deflated) soils which are already deprived of part of the humus horizon and are again at the stage of formation, does not take into consideration the pattern of formation of the humus horizon. The quantity of error of analytical methods of determining the rate of water erosion (deflation) of soils does not make it possible to study directly the rates of formation of the humus horizon for washed-out (deflated) soils. However, with a certain degree of arbitrariness, such evaluations may be obtained by comparing the corresponding thickness of the humus horizon of washed-out (deflated) soils and soils of different ages. Using function (3), the rate of formation of H_h can be determined from the known thickness of the humus horizon of soils (H_h) with different degrees of washout. The averaged values of the rate, reduced to commonly used units for expressing quantities of washout, are shown in the table.

Mean Rate of Formation of Humus Horizon of Soils (t/ha) with Bulk Density of 1.2 t/m^3

Type of soil	Degrees of soil washout		
	low	medium	high
Sward podzolic	0,3	—	—
Typical chernozems	0,5	1,4	2,6
Ordinary chernozems	0,4	1,2	2,0
Southern chernozems and dark chestnut	0,4	0,8	1,6
Light chestnut and sward steppe	0,2	0,6	0,8

Allowing for peculiarities of the original data, it must be pointed out that the evaluations reflected in the table characterize conditions of a soil intake of an optimum quantity of organic matter. In this case and with corresponding restoration of water conditions of slopes, washed-out soils may have a high rate of reproduction of potential resources. Probably, in regions with inadequate moisture it is possible to increase the rate of formation of the humus horizon by organizing irrigation of sloping land. The variation in the quantity of the parameter of "precipitation" determines the increase in expenditure of energy on soil formation and, allowing for function (3), the acceleration of the process of formation H_h on the basis of a trend towards a greater maximum thickness.

On the whole, processes of humus accumulation and formation of the zonal thickness of the humus horizon of soils are synchronous, and the main stage of formation of the humus profile is completed after 500 years. This has been shown by systematic generalization of published works reflecting radiocarbon, historial and archeological age dating of soils, the results of studying young soils in technogenic landscapes, and results of long-term stationary trials with organic fertilizers (n = 350). Calculations were made on a BESM-6 high-speed electronic calculator. The variation in time of the mean rate of humus accumulation (V, %) in the accumulative horizon of soils can be approximated by an equation of the following kind:

$$V=0{,}14(t+1)^{-0{,}62}. \qquad (4)$$

Mean annual rates of humus accumulation (ΔH_s, % per year) which characterize the highest possible evaluations of the process for soils of certain categories of washout were determined from the formula

$$\Delta\bar{h}_s=\frac{t_1V_1-t_1V_1}{t_1-t_1}. \qquad (5)$$

Values of time (t) were calculated, using Eq. (3):

$$t=\frac{\ln k-\ln\left(0{,}00051-\frac{H_h}{Q^{2.1}}\right)}{\lambda}. \qquad (6)$$

In the class of "typical chernozems and light chestnut soils," slightly eroded soils may be characterized by a mean rate of humus accumulation of 0.0002% p.a., medium eroded soils 0.0005-0.0004%, and badly eroded soils 0.001-0.0008%. Using the bioenergy approach, annual rates of humus accumulation in some types of soil, expressed in terms of energy characteristics, may be related to total annual expenditure of energy on soil formation (Q) and be used as the basis of the criterion for assessment of regional conditions of humus formation.

Thus the techniques developed make it possible to evaluate from Eq. (2) the variation in soil resources in the natural soil-forming process.

However, under conditions of cultivated soil formation, the humus formation process has considerable differences. Taking into account areas occupied by the main groups of crops (winter and spring cereals, row crops, annual and perennial grasses), areas of uneroded, slightly, medium and badly eroded soils and corresponding quantities of intake of plant remains (from the results of finding in 1981-1985), and coefficients of humification (for surface and root remains of crops), the authors determined intake of humus for administrative regions of the Black Sea coast (Odessa, Kirovograd, Nikolaevka and Kherson Oblasts of the Ukraine). The intake of humus for subtypes of chernozems was calculated as the average for administrative regions in which these subtypes are the predominant

1. For conditions of a cultivated soil-forming process, the rate of humus formation from plant remains is 36% in typical chernozems, 27% in ordinary chernozems, and 30% in southern chernozems, of the quantity which characterized conditions of natural soil formation (virgin soil). Without applying organic fertilizers, the rate of humus accumulation ($\Delta\bar{h}_s$), as a rule, does not compensate for processes of humus mineralization. It is obvious that under these conditions there will accordingly also be a change in the rate of formation of the humus horizon of soils. It may be calculated from the experimentally established rate of humus accumulation in the cultivated soil-forming process ($\Delta\bar{h}_{cs}$), allowing for Eq. (5) and the data in the table:

$$\Delta H_{n(cs)} = \frac{\Delta\bar{h}_{cs}}{\Delta\bar{h}_s}\Delta H_{n(s)}. \qquad (7)$$

Thus an evaluation of maximum rates of reproduction of the quantity of soil resources (thickness of humus horizon) indicates the arbitrariness of referring plowed soil to renewable natural resources. Strictness in limiting the rate of accelerated anthropogenic erosion, emerging as an inevitable condition of agricultural use of soils with the optimum thickness of humus horizon or less, poses the problem of reproduction of quality of soil resources, and particularly the maintenance of humus condition. The effectiveness of soil-restoring measures must be correlated with maximum rates of humus accumulation.

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