The Place of Soil Formation Values in the Problem of Rate Setting Soil Loss Tolerance

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Usually when speaking about the use of erosion protection measures in terms of the rate of reproduction of soil profile, the notion of the average annual rate of forming the fertile (humus) horizon is used. Three main groups of methods for establishing soil erosion tolerance values (T) can be distinguished according to the differences in correlating the erosional (wind erosional) soil losses with the rate of forming the humus horizon (V):

1) T = W-V, where W - soil losses under the condition of high soil protecting effectivity of the vegetable cover. The value T is understood as the rate of normal (geological) erosion. According to the generalized data for the USA [7] and other evaluation the mean value of normal erosion is 0.5 $t \cdot ha^{-1} \cdot yr^{-1}$;

2) T = V, that is identification of the soil loss tolerance with the rate of the natural soil formation process. Elaboration of this approach was done in Bennett's work [2], according to the results of this work the top limit of the T-level for the USA soils was explained. Later on this principle was used in many elaborations by the European and Soviet erosion scientists. That is why it can be considered to be the traditional method;

3) $T = W_{tol}$, that is explanation of a certain soil loss value, which does not lead to the decreasing of the harvest of agricultural crops.

It is essential to note, that the above-mentioned principles of T-level grounding don't accord to present-day level of knowledge. There is an urgent need to begin modeling the resource-forming processes in soil and develop algorithms of long-term soil resources management instead of the method of expert estimation. The variation of the regional

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(landscape) levels of the soil fertility, exceeding the interzonal differences (in the connection with the soil types, great groups etc.), the aspiration for the adaption of the projected soil conservation systems of agriculture to the local landscape conditions cause the need in the correlating level of discretization of the estimations of the soil loss tolerance and the erosion yield.

We are suggesting the use of mathematical methods for the estimation of the values T, which are based on the choice of the scenario of optimal soil use, on the estimation of the main characteristics of the soil resources, on the dependence of the resource forming processes rate on ontogenetic maturity of the soil profile, and on the most important processes of soil formation.

Taking into consideration the quantitative (thickness of humus horizon, mm - H) and qualitative (contents of humus) characterization of the soil fertility resources [6], it is possible to present the change of soil as the result of soil formation in such a form

$$\int_0^t \frac{d(HG)}{d\tau}\,dt = \int_0^t H\frac{dG}{d\tau}\,dt + \int_0^t G\frac{dH}{d\tau}\,dt \qquad (1)$$

The general direction of change in thickness of humus horizon during holocene depended mostly on zonal-longitudional level of the top thick ness (H_∞) and on the function of time (F(t)):

$$\frac{dH}{dt} = \lambda\, H_\infty\, F(t) \qquad (2)$$

where λ - coefficient, depending on the bioclimatic conditions of soil formation.

The trend of holocene evolution of soil forming processes in automorphical soils (figure) with the general regularity of the processes of soil evolution in ecosystems, follows an S-shaped curve in terms of describing the function F(t). Given the approximating functions - logistical and Gompertz - the latter is more preferable because of asymmetry. Considering this, the formation of the humus horizon can be represented as"

$$H_t = H_\infty \left(e^{-e^{a+\lambda t}} - e^{-e^{a-2000\lambda}}\right) \qquad (3)$$

where t is changing from -2000 (for the USA territory from -4000) up to 0 (prehistory of the soils) and from 0 to 10,000 years (holocene history). The portion of the curve, expressed by the equation (3) in the interval 0 - 10,000 years, used for the applied problems can be simplified. Solving the differential equation:

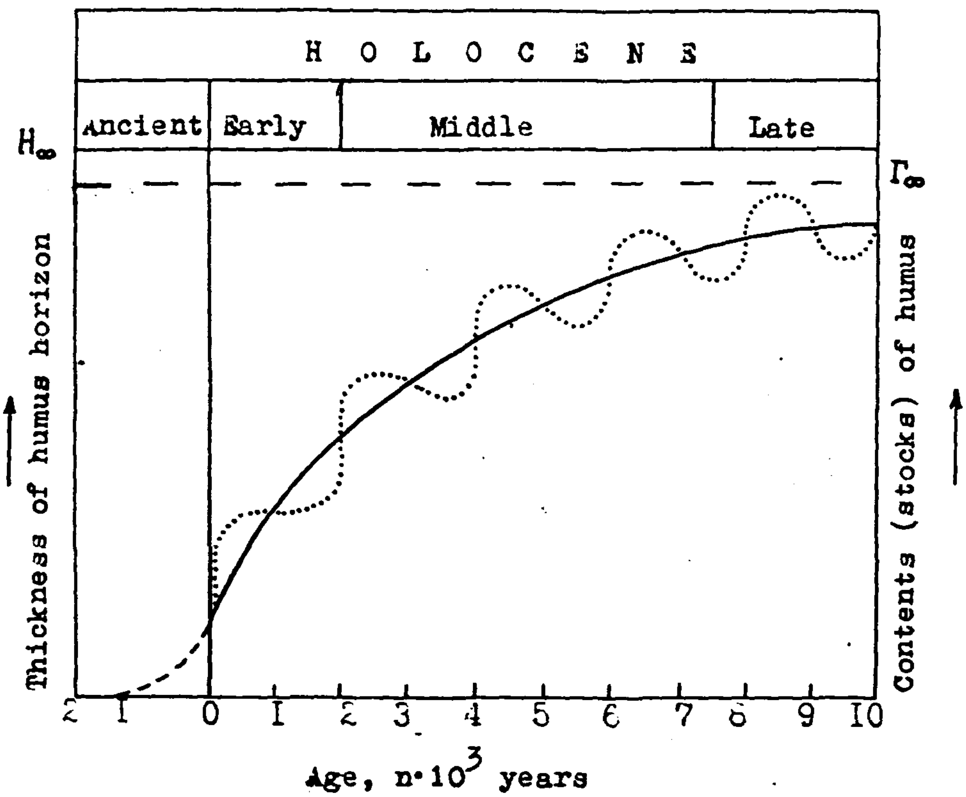
$$\frac{dH}{dt} = \lambda \left(H_\infty - H\right) \qquad (4)$$

we obtain, accordingly:

$$H_t = H_\infty \left(1 - ke^{-\lambda t}\right) \qquad (5)$$

where k characterizes the level of the initial fertility of the parent rocks in the zero-moment of soil formation, which was during the period of the ancient holocene.

Taking into consideration the dependence of the thickness of humus horizon of the main soils in the Eastern European plain on heat and moisture, the establishment of vegetation, time and composition of the parent rocks, we will get the final depth of the humus horizon formation process (H_t, mm):



Holocene evolution of automorphical soil on loose parent rocks and formation of its resources characteristics (H and G).

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$$Ht = 10,85\ g \left(\frac{F_f}{F_z}\right)^{0,37} \cdot e^{0,0044Q}(1 - ke^{-\lambda t}) \qquad (6)$$

where g - coefficient, which reflect granulometric composition (0,72÷1,40); F - annual production of vegetation, t ha-1 yr-1: Ff - actual; Fz -zonal: $Fz = 8,7 \cdot 10^{-8} \cdot q^{2,69}$; Q - annual outlay of energy on soil formation, MJ m-2yr-1:

$$Q = 41,87\ [R\ \exp(-18,8R^{0,73}/P)]$$

in accordance with [3], where R - annual value of the radiation balance, ccal/cm2; P - annual sum of precipitations, mm; k, λ - coefficients, which were received from pedochronological facts [4].

The calculations of the medium rates of forming the humus horizon under the condition of the natural soil formation (Vn) is carried out, setting the thickness H, mm according to the adjoining categories of the degrees of erosion (Hi, Hj) and calculating the corresponding values ti, tj according to (6):

$$Vnj = \left(\frac{Hi - Hj}{ti - tj}\right)$$

The estimations (table) reflect the values of exceeding of the rate of natural soil forming process over the rate of normal erosion. That is why the table data should be increased adding 0,5 t/ha. For the prognosis of the rate of soil resources reproduction, considering also the programs of conservation and reserve of soils destroyed by erosion ,the index VR - rates of recent soil formation (see table) is suggested. The medium rate of soil formation, providing formation of first 20 cm of humus horizon is what is considered here.

The dependence of the rate of humus accumulation on its contents in the soil under the natural conditions can be put down as following [1]:

$$\frac{dG}{dt} = \frac{G(G_{\infty} - G)}{c(G + a)}$$

The potential renewal rates of humus horizon (Vn) and rates of recent soil formation (VR), t/ha·yr-1

Soils	Erosional Degree			
	weak	middle	strong	VR
Podzolic	0,47	-	-	0,7
Chernozems of forest-steppe	0,59	1,30	2,22	4,0
Chernozems ordinary	0,54	1,06	1,82	2,6
Chernozems southern, dark-chestnut soils	0,50	0,95	1,35	2,3
Soils of semi-desert	0,27	0,55	0,88	1,1

Having integrated (7), we will get the formula indicating the dependence of the humus (G) contents on its initial value Gi and interval of time (t - ti):

$$\frac{c \cdot a}{G\infty} \ln \frac{G(G\infty - Gi)}{Gi(G\infty - G)} - c \ln \frac{G\infty - G}{G\infty - Gi} = t - ti \qquad (8)$$

The data on main genetic types (subtypes) of Eastern European plain's soils are generalized for getting the coefficients a and c in (8). foe the applied aims it is suggested to calculate the optimal rates of humus accumulation (ΔG_{opt}, % p. y.) according the formula:

$$\Delta G_{opt} = \frac{(G_{init} - G_{opt})(e^{-b_z t_1} - e^{-b_z t_1})}{t_2 - t_1} \qquad (9)$$

where G with indexes init and opt - initial and optimal contents of humus in the controlled layer of soil, %; t1 + t2 - the time of the control over the process of reproduction; bz - parameter, the meaning of which is grounded according to the model (8). Foe the podzolic soils bz = 0,032, for the chernozems - 0,019-0,022, for the dark-chestnut soil - 0,027.

For agrolandscape it is better to carry out the groundation of the soil loss tolerance in the point of profile of slope after the preliminary estimation of the supply of soil resource - (HG)init and comparing it with the optimal value - (HG)'opt [4]. The following scenarios of soil resources use are possible here.

1. (HG)init > (HG)'opt - scenario I, in which during the controlled time the nonbalancing of the results of manifestation of erosion processes by the soil formation is permissible. In this case (in the time interval t2 - t1) values T (mm/yr) are calculated according to the formula:

$$T = \frac{[(HG)'opt - (HG)init](e\text{-}bt1 - e\text{-}bt2)}{p(t2\text{-}t1)G0\text{-}10}$$

where G0-10 - the contents of humus in a washing layer, %; p - the coefficient of exceeding of the contents of humus in a solid discharge comparing to the contents of humus in a solid discharge comparing to the initial value (fluctuates from 1,2 (leached chernozem) to 3,2 (irrigated dark-chestnut soil), approximately forms 1,7); b - parameter, depending on the ecological limits (possibility of gully erosion, rate of silt-filling of water reservoirs, worsening of quality water).

2. (HG)"opt ≤ (HG)init ≤ (HG)'opt - scenario II, which is connected with the problem of the stable supporting of the quality of the soil resource, so the managing influences in agroecosystem should be adequate in the materially-energy potential to the soil loss tolerance. The calculation of T-level is carried out according to the scheme:

$$T = \frac{200\left(\frac{1}{t_2 - t_1}\sum_{y=1}^{t_2-t_1} KgyAy + 0,18\alpha \cdot D + \frac{1}{t_2 - t_1}\sum_{y=1}^{t_2-t_1} 0,009(K_N\Theta)y + 0,1\gamma G_{0-20}V_n\right.}{G_{0-10}(1+2\rho)} - \frac{\frac{1}{t_2 - t_1}\sum_{y=1}^{t_2-t_1} Kpy\,Yy - 0,02\gamma G_{0-2}}{G_{0-10}(1+2\rho)}$$

where Ay - the quantity of the vegetable residues, coming with the crops (y) of rotation, t/ha; Kgy - the coefficient of humification; D - doses of the inserting of organic fertilizes, t/ha; α - the coefficient of the overcounting of different kinds of fertilizes in the literal manure; Θ - the quantity of the inserting nitrogen containing mineral fertilizes, kg/ha; KN - the part of nitrogen in the mineral fertilizes; Yy - harvest of the main production, t/ha; Kpy - the coefficient of spending of nitrogen from humus; G0-10, G0-20 - maintenance of humus in a layer 0-10 and 0-20 cm, %; γ - density of the layer 0-20 cm, g/cm3; t2-t1 - period of crop rotation.

3. The program of reproduction of soil resource according to the optimal rates of humus accumulation, calculated according to (9), taking into consideration the zonal rates of forming the humus horizon (see table) is realized in the scenario III ((HG)init < (HG)"opt).

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