ESIMATE OF CHERNOZEM ERODIBILITY LEVEL ACCORDING TO THE HUMIFICATION DEGREE

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A short review of literature sources is presented to characterize the eroded soils according to their humus content. Traditional diagnostic indicators of the soil erodibility level based upon the humus state are the following: (1) decrease in the thickness of humus horizons in eroded soils in percentage of that in the uneroded soil (standard); (2) decline in the humus storage in the eroded soil profile in percentage of that in the uneroded soil (standard). It is worth emphasizing, that the choice of the uneroded soil standard is a rather labor-consuming study in field and assumes an expert (subjective) character that is highly dependent on the soil scientist's skill. It is shown that the main shortcomings of the available gradation for eroded soils consist in the absence of approaches to give their objective estimate and recommendations for tolerable levels of soil erodibility taking into complete account the humus content in these soils. In the Russian Federation there is a gradation of arable soils (including chernozems) according to the humus content in the plough horizon. It contains four classes (less than the humus minimum, low, moderate and high humus content). In this paper it is recommended to give the gradation of eroded soils with the minimal humus content. The level of chernozem erodibility should be estimated as based upon the minimum and critical humus content, the concept of which is interpreted by Kërshens and Kiryushin together with Ganzhara respectively. A gradation scale of soil erodibility is presented to estimate its tolerable, intolerable and critical levels. It is exemplified by the gradation of chernozem soils in Russia and Germany.

Keywords: chernozems, erosion, humus, minimal humus content, critical humus content.

Erosion is one of the forms of soil cover degradation caused by wind, rains and the accompanying runoff upon the soil surface with consequent transportation and redeposition of the soil mass [31].

Chernozems as the main agricultural lands in Russia are subject to water and wind erosion to a considerable extent. Great areas of chernozems have been degraded and sometimes washed out to expose the unfertile layers of underlying bedrocks. In some regions the uppermost fertile layer of chernozems is destructed by dust storms and deposited in places sheltered from the wind [26].

Based upon a comprehensive analysis of literature data it is worth of note that in flat watersheds the topsoil of virgin chernozems used under crops for a long period of time (about 100 years) reveals the humus loss not more than by 20–30% as compared to that in the initial state of these soils [32]. However, in landscapes subjected to erosion the humus loss becomes increased and reaches 50% [4, 9]. Having studied the humus state in chernozems within the Central-Chernozem zone, it has been established that the considerable humus loss due to water erosion takes place in chernozems occupying the slopes of southern exposition and makes up 70%. On slopes of western exposition where the erosion-induced loss is insignificant the humus is lost in dependence on mineralization and redeposition of the soil material [20]. At the same time, the erosion of the soil cover in case of using the forest and pasture lands as arable ones, the humus loss and its redistribution degree in arable lands have been so far examined insufficiently [6].

The diagnostic indicators of soil erodibility based upon the parameters of the humus state in soil are the following: (1) decrease in the thickness of humus horizons in eroded soils in percentage of that in uneroded ones (standard) and (2) decline in the humus state along the profile of the eroded soil in percentage of that in an uneroded soil (standard) [10, 26, 27].

In Russian classification of soils [10] the type and subtypes of chernozems with the humus horizon of more than 50 cm in thickness being plowed at a depth of 22 cm are classified according to the erodibility degree in the following way:

– slightly eroded chernozems – the A horizon is washed out by 30%, the plough layer is not changed in color, the thickness of the subsoil humus layer is decreased to 25% and the humus content becomes lower by 10% as compared to that in an uneroded soil;

– moderately eroded chernozems – the A horizon is washed out by 50%, the plough layer gets somewhat brown in color, the thickness of the subsoil horizon and the humus content are decreased to 50% as compared to those in an uneroded soil;

– severely eroded chernozems – the A horizon is completely and the B1 horizon is partially washed out. The plough layer becomes brownish or brown in color assuming a blocky structure capable to form a surface crust. The thickness of the subsoil humus layer and its humus content are declined to 75% as compared to those in an uneroded soil.

It is worth emphasizing that the choice of an uneroded soil “standard” in field is not objective by nature being highly dependent on soil scientist’s skill [27]. Some researchers believe that the soil profile on slope under natural vegetation should to be considered as this standard [25, 28], the others propose to consider as the standard a profile of the uneroded soil located within the watershed area [33, 21, 31]. According to available Guidelines (1973) it is recommended to determine the soil erodibility as based upon generalizing standard values in every natural region to show the thickness of humus horizons in uneroded soils independent on their location in relief.

In a new version of Russian soil classification (2004) the orders of abrazems and agroabrazems are recognized. These soils lack surface diagnostic horizons because of erosion or mechanical cutting in the course of land leveling, etc. The diagnostic horizon of agroabrazems is the specific horizon formed only at the expense of the subsoil, i.e. the material of any middle-profile horizon or parent material. This horizon preserves the color of the initial material because of the low humus content ranging within 1–1.5%. There are exceptions: migration-mycelium and segregationary subtypes of carbonate-accumulative agroabrazems are permitted to have gray color with their humus content from 1.5 to 2.5%. These two subtypes are derived from strongly eroded chernozems in the forest-steppe and steppe, they have lost their initial thick (60–129 cm) humus horizon and only their lowest transitional part with the content of humus close to 2% remains.

The topsoil is not only mechanically washed out as resulted from water erosion, the soil properties reveal great changes as well [25]. For example, the humus content and its group composition are changed due to increasing the erodibility degree of dark-gray forest soils in the Tula region. It is impossible to differentiate uneroded and slightly eroded soils according to their morphology and analytical data [27]. Following the statement of Shurikova [1987, p. 89] the detailed studies of the soil cover structure in watersheds and on slopes showed that the question about the uneroded soil standard remains open to discussion because all the approaches to determine it are not perfect.

The available gradation of eroded soils suffers from shortcomings due to the absence of approaches to give an objective assessment and recommendations for the permissible level of soil erodibility as based upon the account of the humus state in soil. In the Russian Federation the arable soils including chernozems are divided into four classes according to the humus content in the plough horizon (lower as the minimum humus content, low, moderate and high humus content) [14].

The first class – the humus content is less than its minimum in soils which partially have lost an inert humus component due to erosion-induced transportation of the soil material, mixture of the humus horizon with underlying layers in the course of plowing, mechanical removal of fine-dispersed particles due to harvesting of tilled crops, etc. The second class includes the soils, in which the humus content is low and the third class of moderately humus soils that have lost the organic matter due to biological mineralization as compared to its content in virgin soils. The fourth class includes arable soils, the humus content of which is close to that in virgin ones. An attempt was made to use these classes for rating of soil erodibility levels, it being known that the first class includes only eroded soils. This rating of typical and leached chernozems in the Middle-Russian upland looks like in the following way: heavy loamy eroded soils – <5%; severely eroded soils – 5.0–5.9%; moderately eroded soils – 5.9–6.9%; slightly eroded soils – >6.9%; medium-loamy eroded soils – <4.5%; severely eroded soils – 4.5–5.4%; moderately eroded soils – 5.4–6.3% and slightly eroded soils – >6.3% [12].

To the author's opinion the eroded soils with the humus content in the plough horizon that is less than the minimum (the class 1) can be further subdivided.

According to Kőrschens (1992) the total humus consists of inert fraction which remains unchanged and depends on habitat conditions and transformed fraction, the latter being easy decomposed in dependence on the land use system and different management practices. The transformed fraction of humus is reversible and can be supplied and renewed by organic fertilization. However, the inert fraction of humus is hardly reproduced; radiocarbon dating of the organic matter showed that 2–4 thousand of years are required to enrich the plough layer of chernozems with the initial content of humus.

The content of inert humus is identical to its minimum that is precisely determined in the course of continuous bare fallowing (>20 years). There exist two methods to determine the minimum humus content in soil including empiric [3, 16] and experimental ones [13, 22]; they prove to be applicable for determining the minimum content of humus in several subtypes of chernozems. For instance, it is known that in the Central-Chernozem zone of Russia the strongly and moderately humus arable, abandoned and even virgin typical and leached chernozems with the accumulative-humus horizon 70 cm thick reveal the minimum content of humus in the plough or the uppermost 0–25 cm horizon as equaled to the 30–50 cm layer, i.e. the layer that is penetrated by plants and receives the minimal amount of phytomass in the continuous bare fallow [13]. Having generalized literature sources [1, 18, 23], it is possible to point out that the content of organic carbon within the 30–50 cm layer makes up 2.9% in arable and virgin chernozems of the Kursk region; the same layer displays 3.0% of organic carbon (n = 33) in typical chernozems in the Middle-Russian upland [19]. These average values seemed close to the minimum humus content that has been determined in three long-term field experiments carried out on the continuous bare fallow of typical chernozem in the Kursk region [15].

Kiryushin (1987) and Ganzhara (1988) proposed to use a concept of critical humus content (less than 2% in soils of chernozem type) when the vital agronomic properties including the bulk density, structure, physical-mechanical characteristics are similar to those inherent to underlying bedrocks.

Based upon the values of minimum and critical humus content for different soil taxa, it seemed reasonable to propose a gradation scale of arable eroded soils according to the humus content in the uppermost layer and to distinguish tolerable, intolerable and critical levels of soil erodibility. Let us consider two examples of chernozem soils characterized by the minimum and critical levels of the humus content [7, 8].

1. Example 1 – a scale gradation of typical chernozem erodibility according to the humus content in the 0–25 cm plough layer (Kursk region):

2. Tolerable level of soil erodibility – the humus content is > 5.0–5.5%

3. Intolerable level soil erodibility – the humus content is 5.0–2.0%

Critical level of soil erodibility – the humus content is < 2.0%.

Example 2 – a scale gradation of gaplic chernozem erodibility according to the humus content in the 0–25 cm plough layer (Bad Lauchstadt, Germany):

1. Tolerable level of soil erodibility – the humus content is >2.8–3.1%

2. Intolerable level of soil erodiility – the humus content is 2.8–2.0%

3. Critical level of soil erodibility – the humus content is <2.0%.

CONCLUSION

As a result of summarizing and generalizing the literature data it is shown that the available gradations of eroded soils suffer from shortcomings because the approaches are absent to give an objective assessment and recommendations for tolerable levels of soil erodibility as based upon the humus content in soils. A new approach is proposed to determine the level of soil erodibility in dependence on the humus content in the topsoil using its relative assessment and taking into complete account the minimum and critical humus content in definite soils. The tolerable level of soil erodibility should be inherent to uneroded soils, recognized in “Classification and Diagnostics of Soils in the USSR (1977); the intolerable level – to slightly and moderately eroded soils and the critical level – to severely eroded soils. It is worth emphasizing that the chernozems regarded to the class of those characterized by the tolerable level of their erodibility are distinguished from each other not only by the total content of humus but also the value of its transformed and reversible fraction, what is especially important from the viewpoint of the near reserve in the soil fertility. The eroded chernozems with intolerable and critical levels of their erodibility are characteristic of the inert humus loss as a hardly reproduced soil resource. The data about the permissible rate of erosion-induced soil loss presented in some publications should be based upon the estimate of soil erodibility levels according to the humus content in soils.

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REFERENCES

1. Afanas’eva E.A. *Chernozemy Srednerusskoi vozvyshennosti* (Chernozems Upland), Moscow, Nauka, 1966, 224 p.
2. Chichagova O.A., Cherkinskii A.E. Problema radiouglerodnogo datirovaniya pochv, *Pochvovedenie*, 1985, № 11, pp. 63–75.
3. D'yakonova K.V. (sostavitel') *Otsenka pochv po soderzhaniyu i kachestvu gumusa dlya proizvodstvennykh modelei pochvennogo plodorodiya (rekomendatsii)*, (Evaluation of soil on the content and quality of humus for production models of soil fertility (recommendations)), Moscow, Agropromizdat, 1990. 28 p.
4. Egorov V.P., Dyuryagina N.I. Sravnitel'naya agrokhimicheskaya kharakteristika tselinnykh i pakhotnykh chernozemov Zaural'ya, *Agrokhimiya*, 1972, No 4, pp. 66–73.
5. Ganzhara N.F. *Gumusoobrazovanie i agronomicheskaya otsenka organicheskogo veshchestva podzolistykh i chernozemnykh pochv evropeiskoi chasti SSSR*, (Humification and agronomic evaluation of organic matter podzolic and black soils of the European part of the USSR), Doctor’s thesis, Moscow, 1988, 410 p.
6. Gennadiev A.N., Zhidkin A.P., Olson K.R., Kachinskii V.L. Eroziya i poteri organicheskogo ugleroda pochv pri raspashke sklonov, *Vestn. Mosk. un-ta. Ser. 5. Geografiy*a, 2010, No 6, pp. 32–38.
7. Kershens M. Znachenie soderzhaniya gumusa dlya plodorodiya pochv i krugovorota azota. Posvyashchaetsya 100-letiyu so dnya rozhdeniya professora, akademika I.V. Tyurina, *Pochvovedenie*, 1992, No 10. pp. 122–131.
8. Kiryushin V.I. Upravlenie plodorodiem pochv v intensivnom zemledelii,*Zemledelie*, 1987, No 5, pp. 2–6.
9. Kiryushin V.I., Lebedeva I.N. Izmenenie soderzhaniya gumusa chernozemov Sibiri i Kazakhstana pod vliyaniem sel'skokhozyaistvennogo ispol'zovaniya, *Dokl. VASKhNIL*, 1984, No 5, pp. 4–7.
10. *Klassifikatsiya i diagnostika pochv Rossii, (*Classification and diagnosis of soil Russia),Smolensk: Oikumena, 2004, 342 p.

11. *Klassifikatsiya i diagnostika pochv SSSR*, (Classification and diagnosis of soil USSR), Moscow, Kolos, 1977, 224 p.
12. Kogut B.M. Otsenka stepeni vypakhannosti chernozemov po soderzhaniyu gumusa, *Antropogennaya degradatsiya pochvennogo pokrova i mery ee preduprezhdeniya,* (Anthropogenic degradation of soil and its prevention measures). Proceedings of the Conference Title, Moscow, 1998, pp. 47–49.
13. Kogut B.M. *Transformatsiya gumusovogo sostoyaniya chernozemov pri ikh sel'skokhozyaistvennom ispol'zovanii,* (The transformation of the humus state of chernozems in their agricultural use), Doctor's thesis, Moscow, 1996, 353 p.
14. Kogut B.M. Assesment of the humus content in arable soils of Russia,*Eurasian Soil Science*, 2012, Vol.45, No.9, pp.843–851.
15. Kogut B.M., Frid A.S., Masyutenko N.P., Kuvaeva Yu.V., Romanenkov V.A., Lazarev V.I., Kholodov V.A. Dinamika soderzhaniya organicheskogo ugleroda v tipichnom chernozeme v usloviyakh dlitel'nogo polevogo opyta, *Agrokhimiya*, 2011, №12, pp. 37–44.
16. *Körschens M.* Die Abbhangigkeit der organishchen Bodensubstanz von Standortfactoren und acker-und planzenbaulichen Massnahmen, ihre Bziehungen zu Bodeneigenschaften und Ertrag sowie Ableitung von ersten Bodenfuchtbarkeitskennziffern für der Gehalt des Bodens an organischer Substanz. Berlin: Akad. Landwirtsch., Wiss. DDR. Dis. B. 1980.
17. Kuznetsov M. p. and Abdulkhanova D. R. Contamination of Soils with Heavy Metals and Metalloids and Its Ecological, *Eurasian Soil Science*, Vol. 46(7), 802–810 (2013). DOI: 10.1134/S1064229313050074.
18. Lavrent'ev V.V. *Mobilizatsiya azota gumusa v chernozemnykh pochvakh Evropeiskoi chasti SSSR*, (Mobilization of nitrogen in humus black soils of the European part of the USSR), Moscow, 1972, pp. 142–182.
19. Lebedeva I.I. *Chernozemy Vostochnoi Evropy* (Chernozems of Eastern Europe): Extended abstract of Doctor's thesis, Moscow, 1992, 48 p.
20. Nakonechnaya M.A., Yavtushenko V.E. Poteri gumusa na sklonovykh pochvakh TsChO, *Pochvovedenie*, 1989, No. 5, pp. 19–26.
21. Naumov P. V. K voprosu klassifikatsii smytykh pochv, *Pochvovedenie*, 1965, No. 5, pp. 50–68.
22. Pat. na izobretenie № 2519149, prioritet izobreteniya 24.04.2012. Kogut B.M., Semenov V.M., Lukin p. M., Sharkov I.N. *Sposob opredeleniya pokazatelei transformiruemogo i inertnogo organicheskogo ugleroda v pochvakh*, (Method of determining parameters, and a transformable inert organic carbon in soil).

23. Ponomareva V.V., Nikolaeva T.A. Soderzhanie i sostav gumusa v chernozemakh Streletskoi stepi, *Tr. Tsentral'no-Chernozemnogo gos. zapovednika*, 1965, Vol. 8, pp. 209–235.
24. Presnyakova G.A. Eroziya pochv na Pravoberezh'e Oki, *Tr. Pochv. in-ta im.* V.V. Dokuchaeva, 1953, T. 40, pp. 240–275.
25. Presnyakova G.A. O klassifikatsii smytykh pochv, *Pochvovedenie,* 1956, No 10, pp. 69–90.
26. Rozhkov V.A. Otsenka erozionnoi opasnosti pochv, *Byulleten Pochvennogo instituta im. V.V. Dokuchaeva*, Vol. 59, pp. 77–91.
27. Shurikova V.I. Diagnostika i klassifikatsiya erodirovannykh pochv,*Erodirovannye pochvy i effektivnost' pochvozashchitnykh meropriyatii:* Nauch. tr. Pochv. in-ta im. V.V. Dokuchaeva, pp. 88–96.
28. Skorodumov A.S. *Eroziya pochv i bor'ba s nei*, Kiev: Izd-vo AN USSR, 1955, 148 p.
29. Sukhanovskii Yu.P., Bakhirev G.I. Otsenka dopustimykh erozionnykh poter' pochvy, *Dokl. RASKhN.* 1998, No 1, pp. 27–28.
30. Surmach G.P. Klassifikatsiya smytykh pochv i ee primenenie pri sostavlenii krupnomasshtabnykh pochvenno-erozionnykh kart, *Pochvovedenie*, 1954, No. 1. pp. 71–80.
31. Surmach G.P. *Rel'efoobrazovanie, formirovanie lesostepi, sovremennaya eroziya i protivoerozionnye meropriyatiya*, Volgograd, 1992, 175 p.
32. Titova N.A., Kogut B.M. Transformatsiya organicheskogo veshchestva pri sel'skokhozyaistvennom ispol'zovanii pochv, *Itogi nauki i tekhniki* (Ser. pochvovedenie i agrokhimiya), Moscow, 1991, T. 8, 156 p.
33. Zaslavskii M.N. Nekotorye voprosy klassifikatsii i kartografirovaniya erodirovannykh pochv, *Voprosy erozii i povysheniya produktivnosti sklonovykh zemel' Moldavii*, Kishinev, 1962. T. 2.
34. Zayavka na izobretenie № 2013113329 ot 27.03.2013. Kogut B.M. *Sposob opredeleniya urovnei erodirovannosti pochv (A method for determining levels of soil erosion)*.