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DEGRADATION, REMEDIATION, AND CONSERVATION OF SOILS

On Inclusion of Ecosystem Services in the Assessment of Damage from Land Degradation

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Abstract—In the assessment of damage arising from land degradation at the Training and Experimental Soil–Ecological Center of Moscow State University, the cost of unfulfilled and underfulfilled ecosystem surfaces of soils should be taken into account. The following soil services were considered for the territory studied: direct provision with resources, protection, maintenance of ecosystem life and cultural services. A relationship between the concepts of ecosystem services and ecological functions of soils is shown. The concept of function is wider in some respect than the concept associated with it. In the definition of ecosystem service, only the manifestation of the soil function, which can have an economic interpretation, is selected. A simulation of ecosystem services proposed in the ecological and economic evaluation of damage arising from land degradation can be a real mechanism of nature conservation and development of systems of sustainable management at various levels of the administrative structure of the country.

Keywords: ecological and economic assessment of land, economy of land degradation, soil functions, natural capital

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STATE OF THE PROBLEM

By now, among soil scientists–ecologists and specialists in the field of economics of land management, there is the idea that the value of land damage due to degradation includes the cost of work on restoration of a land area up to its initial undisturbed state and the amount of lost profits [9].

Damage from land degradation

= Cost of works on land restoration (reclamation) (1)

+ Lost profit

The interpretation of the damage shown is based on the provision of part 1 of Article 15 of the Civil Code of the Russian Federation, according to which a loss (damage) ...*is referred to the expenses that a person, whose right is violated, made or must make to restore the violated rights, the loss or damage of his property (real damage), as well as unreceived income that this person would have received under normal conditions of civil turnover, if his right had not been violated (lost profit*) [2][1].

For evaluation of the real damage, that is, the cost of works on land reclamation, two principally different methods are used [14]:

(1) Elaboration of a project for land reclamation of an area is one possibility. The project contains a list of activities and reflects technical conditions for their implementation, including the volume of transported soil and ground; planting of industrial crops and other plants; calculated costs of each of the planned activities, including the cost of materials; special software packages, for example, Smeta WIZARD are used to determine the amount of these costs.

(2) When it is impossible to evaluate expenditures for reclamation, the amount of damage is calculated by formulas that take into account the area, degree of degradation, pollution and littering, economical characteristics of the investigated region, and land taxa appointed according to standards or orders, taking into account the type of land use or zones of functional purpose area, and, sometimes, soil type [10–12, 14].

In contrast to the definition of actual damage, when assessing the lost profits, it is not always clear what and how much are lost as a result of non-use or under-utilization of land. Losses due to crop failure or because of incomplete crop growth due to land degradation are more often calculated. Sometimes, when evaluating the lost profits, lost income, which could be obtained if some financial resources were not spent for

[1] According to [15], "the term 'loss' is fundamental in the current legislation, and the terms 'injury' and 'damage' are its verbal equivalents having sometimes a narrower content (loss of profit is nonrefundable). There are no reasons to oppose these terms, as some authors do." Talking about the damage, we will not take into account the narrow interpretation of this term.

the elimination of actual damage, is taken into account. At last, if the land degradation leads to reducing its market cost, the difference between the initial and final costs of a land area can be also considered as a variety of lost profit [9].

It is clear that the focus is mainly on losses from unharvested or incompletely harvested crops in the calculation of lost profit considerably decreases this damage component from land degradation, since, as a rule, in this case, not only the soil fertility decreases, but also some other soil functions in ecosystems are violated [6].

If to evaluate soil functions of ecological systems in monetary units, equation (1) could be modified in the following way:

$$\text{Damage caused by land degradation} = \text{Cost of land restoration (reclamation)} + \text{Lost profit} + \text{Monetary estimation of unfulfilled/underfulfilled soil functions in ecosystems.} \quad (2)$$

However, the experience of quantifying the ecological soil functions in individual biogeocenoses and the biosphere, also using cost equivalent, is insufficient up to date [6].

In recent decades, an ecological direction related to the count of ecosystem services—profits obtained by people from ecosystems—has been actively developing [22]. The main problem, which is solved using the suggested approach, is an elaboration of principles of sustainable land management as a whole and sustainable land use in particular. In addition, in studying the ecosystem services, including those from soils and lands, extensive experience of their cost expression was obtained [1, 3, 13, 16–22].

The aim of this investigation is to study the principal possibility of including the ecosystem services into the system of evaluating the damage arising from land degradation.

The discussion of the problem was accompanied by field investigations in the Training and Experimental Soil–Ecological Center of Moscow State University located in Solnechnogorsk district, Moscow oblast. All the lands of the Center are referred to the category of agricultural lands.

RESULTS AND DISCUSSION

Types of ecosystem services, methods of their ecological and economic analysis and criteria of economic interpretation. Contextually, the concept of natural services is related to natural capital. As is well known, natural capital for a human is the totality of natural resources or a combination of environmental assets [13]. The use of natural capital is associated with the services—direct provision with resources, protection, cultural services (aesthetic, recreation, scientific and educational, religious, etc.) and maintenance of ecosystems' life—that all the environmental components partially or completely provide. The ecological and economic analysis of the services mentioned can be provided by two ways: starting from an abstract set of benefits from the environment (direct way "from services") or in terms of the functions performing by the natural object analyzed in the biosphere (indirect way "from functions").

The indirect way "from functions" is more correct, since, other things being equal, it allows revealing more ecosystem profit than using the direct way "from services." This way is systemic in nature and ecologically oriented to a greater extent.

The following criteria of economic interpretation for ecosystem services can be distinguished:

(1) The conversion of ecosystem services in monetary terms is implemented by searching of an adequate analog in the market under conditions of local economy at the current time; there are no independent markets for ecosystem services, therefore, modeling of these markets is necessary.

(2) The evaluation of ecosystem services, as in the evaluation of market value, is implemented only when the investigated system is useful for humans, i.e. it corresponds to the principle of usefulness in assessment.

(3) The spectrum of ecosystem services in each particular case and its assessment related to the particularities of the region studied are determined.

Ecosystem services of soils. Ecosystem services of lands can be divided according to their belonging to one or another component of biogeocenosis: services related to soil (edaphotope), vegetation (phytocenosis), animals (zoocenosis), etc. Thus, ecosystem services of lands are much wider than ecosystem services of soils.

In these works, the main attention is paid to the investigation of soil ecosystem services that were based on studying the soil functions in the environment [4–6]. As is known, according to Dobrovolsky and Nikitin [5], soil functions are divided into global and biogeocenotic. Among the global soil functions, lithosphere, atmosphere, hydrosphere, and biosphere ones are distinguished; among biogeocenotic functions, physical, chemical, physicochemical, information, and integral ones. Overall, all the soil functions are used by a human, therefore, they can be differentiated by their belonging to one or another category of ecosystem services (Fig. 1).

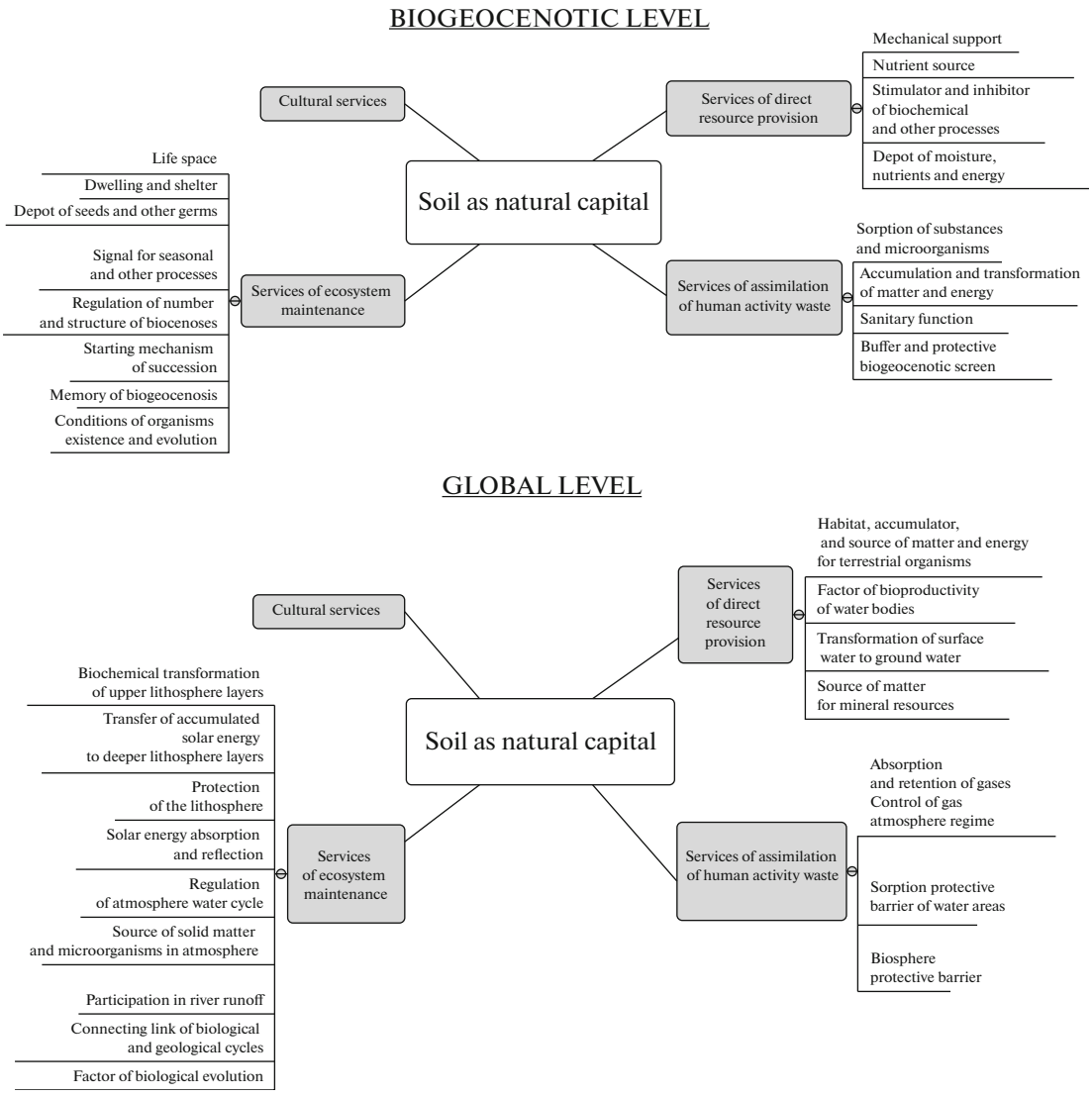

Fig. 1. The soil as natural capital: the classification of soil functions belonging to the categories of ecosystem services.

Note the fact that a set of soil functions described in works by Dobrovolsky and Nikitin [4–6] does not suggest distinguishing cultural soil services, although they exist: for instance, ritual burial services in many cultures. On the other hand, cultural ecosystem services are more correctly considered for land (land area, landscape) but not for soil.

The proportion of ecosystem and ecological soil functions. Ecosystem services and ecological functions of soils are not identical notions. On the one hand, each of the four categories of ecosystem services is characterized by a list of functions, which is made based on specific studies. On the other hand, any function is wider than the service related to it: in the determination of an ecosystem service, only the manifestation of soil function that can have economic interpretation is selected. For instance, in the assessment of a soil service on protection in radio-contaminated regions or in territories with a high risk of such pollution, the manifestation of the function as a buffer and protective screen, i.e. shielding from radiation, is suggested to be studied [17, 19].

Another feature of the soil service–function proportion is that the function can be positive or negative in relation to a human, whereas service is always positive: by definition, ecosystem service is profit. For instance, the ecological function "absorption and retention of some gases" is manifested through the fixation of carbon dioxide (a favorable phenomenon from the standpoint of the control of global warming) and its emission (negative process from the same standpoint). A service can be fixed only when there is a positive balance, when the fixation exceeds emission (in the case of bog soils).

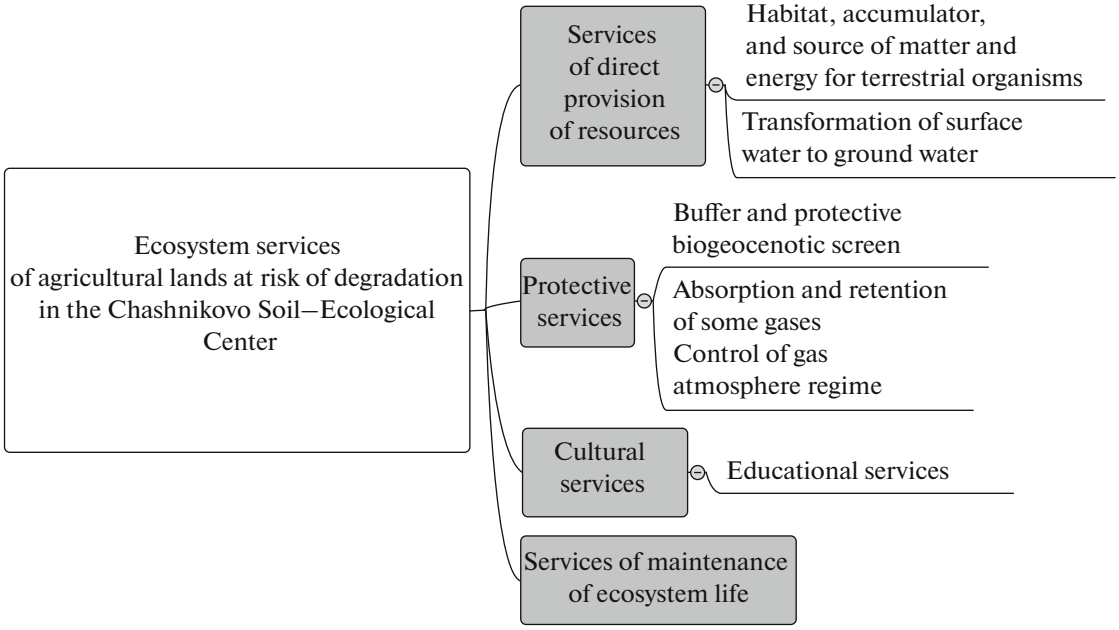

Fig. 2. A reduced list of ecosystem services of soils at the Training–Experimental Soil–Ecological Center of Moscow State University.

Selection of soil ecosystem services in economic evaluation of land degradation. It should be emphasized that despite the fact that *all* services can be evaluated theoretically, the purpose and object of the study applied various restrictions on the choice of specific ecosystem services for their assessment[2]. Thus, in studying the land degradation, it is proposed to estimate only those soil services whose characteristics change in the course of degradation processes. If the object for study is degraded agricultural lands, it should be recognized that they are human-transformed, and, therefore, many of their performed functions in the specific agrocenosis and biosphere are reduced or absent. Despite this circumstance, newly created soils on agricultural lands can be considered as an independent ungraded object having a limited set of ecological functions. Thus, to assess ecosystem services of soils intended for agriculture as services of natural soils is incorrect.

Ecosystem services of soils in the system for evaluating the damage of the lands at the Training–Experimental Soil–Ecological Center of Moscow State University. The list of services and functions providing them for the soils studied (Fig. 2) is somewhat smaller as compared to the one discussed above, since the soils are investigated on agricultural areas. Only the services that are exposed to the risk of degradation due to soil erosion and pollution by heavy metals of the first and second danger classes are distinguished.

Services of direct resource provision are manifested through the soil functions—"habitat, accumulator, and source of matter and energy for terrestrial organisms" and "transformation of surface water to ground water." For agricultural lands, the first function as a service is manifested dually: through soil fertility and sum of soil characteristics affecting the fertility.

The basic indices of soil fertility are actual harvest of crops in rotation; *economic interpreters* are costs of planting of crops (by categories) and profits from their implementation. Degradation of lands may be manifested through loss of harvest for a definite time interval, which is easily determined.

When evaluating the *direct resource services* for the area studied, the potential crop harvest in the optimal rotation and standard expenses were used. These indices were compared with current characteristics of economy management. The difference between the potential and the fact is considered as the degradation associated with the management of the area estimated.

In addition to fertility, for the final fixing of the "habitat, collector and the source of matter and energy for a terrestrial organism" function, the following soil properties, which are mostly related to soil fertility, on the one hand, and are vulnerable to degradation, on the other, were distinguished [18]: the humus content (the economic interpreter is production and application of biohumus), the content of nutrients (the economic interpreter is production and application of

[2] Ecosystem services can be compared to intangible assets in the economy, for which methodical and methodological approaches to the assessment are designed; even the most abstract of them may be evaluated [19].

complex fertilizers), and pH (the economic interpreter is production and application of lime).

The registration of these properties allows assessment of the land degradation, even in the situation when the soil characteristics deteriorate and the yield capacity grows.

The soil function "transformation of surface water to groundwater" also contributes to direct resource services—supply of pure water to humans. In the territory of the Soil–Ecological Center of Moscow State University, the water intake for people is made through a well in the territory of the camp. The water is not purified and not repeatedly used; therefore, water use estimated according to the current rates is the desired ecosystem service. In addition, land degradation may be manifested via a reduction of the water quality (economic interpreter is the establishment and operation of industrial filters).

Protection services are provided by the performance of such functions as "protective barrier of biogeocenosis" and "absorption and retention of some gases."

The territory of the Soil–Ecological Center was found to be contaminated with heavy metals. This fact resulted in the creation of a service for the inactivation of these pollutants. In this case, it is expedient to proceed from the fact that the excessive heavy metal pollution leads to the higher morbidity of population. Soil capable of inactivating pollutants reduces this risk.

In these conditions, the basic rating indices were the heavy metal content in the soils studied and their potential buffer capacity relative to the heavy metal spectrum distinguished. An estimated cost of treatment of each of the diseases related to the presence of high heavy metal concentrations in the territory analyzed is proposed as an economic interpreter. The buffer capacity of the soils was evaluated using the method of Il'ina [7, 8]. The degradation of this soil service was evaluated by the remained buffering capacity as compared to the actual content of heavy metals in the soil.

The "*absorption and retention of certain gases*" function performs another protection service, one for the *fixation of some greenhouse gases*, mainly of carbon dioxide. As the volumes of CO_2 fixation are revealed only in the bog soils, and the main areas of arable lands in the Soil–Ecological Center are represented by soddy-podzolic soils on moraine loams, this service is not manifested here. Since water erosion is active in the soils of the Center, additional CO_2 emissions are associated with the destruction of humus. The economic interpreter here is the market cost of a ton of CO_2.

Cultural services of soils are associated with the educational and scientific activities at the Soil–Ecological Center of Moscow State University. The educational services are determined by the fact that here, students and postgraduates of the Faculty of Soil Science have summer practice on soil science, soil cartography, and other disciplines related to the necessity to study undisturbed reference soils in the field.

Degradation of soils can be the basis for the organization of a series of trips to see soils of the same type beyond the territory of the Center. One can suggest that the cost of the organization of such trips is an adequate economic interpreter of the educational service.

For the assessment of the degradation index for this ecosystem service, the value obtained was correlated with the situation where the administration of the Faculty of Soil Science would be forced to completely abandon the use of the soils of the Soil–Ecological Center as an educational material.

The economic interpretation of soil ecosystem services, along with the calculation of damage by pollution and soil degradation using Russian federal methodology based on the cost of land reclamation and reduction of the market cost, permitted determination of the whole damage of the land at the Soil–Ecological Center of Moscow State University according to equation (3) (Fig. 3).

$$\begin{aligned}\text{Damage by land degradation} = {} & \text{Cost of land restoration (reclamation)} \\ & + \text{Losses of ecosystem services of soils (including losses from absence/shortcoming of harvest)} \\ & + \text{Reduction in market cost of lands.}\end{aligned} \quad (3)$$

CONCLUSIONS

The proposed modeling of ecosystem services in terms of ecological and economic evaluation of damage of lands due to their degradation should be an actual mechanism of nature conservation and elaboration of systems for sustainable land management at different levels of the administrative structure of Russia.

In addition, the proposed approach can be also used for the solution of other important ecological and economic problems. It may be the basis for the formation of payments for the needs of land management, such as fines. The method considering the land evaluation in general instead of the solution of degradation problems will be useful for the formation of ecology-

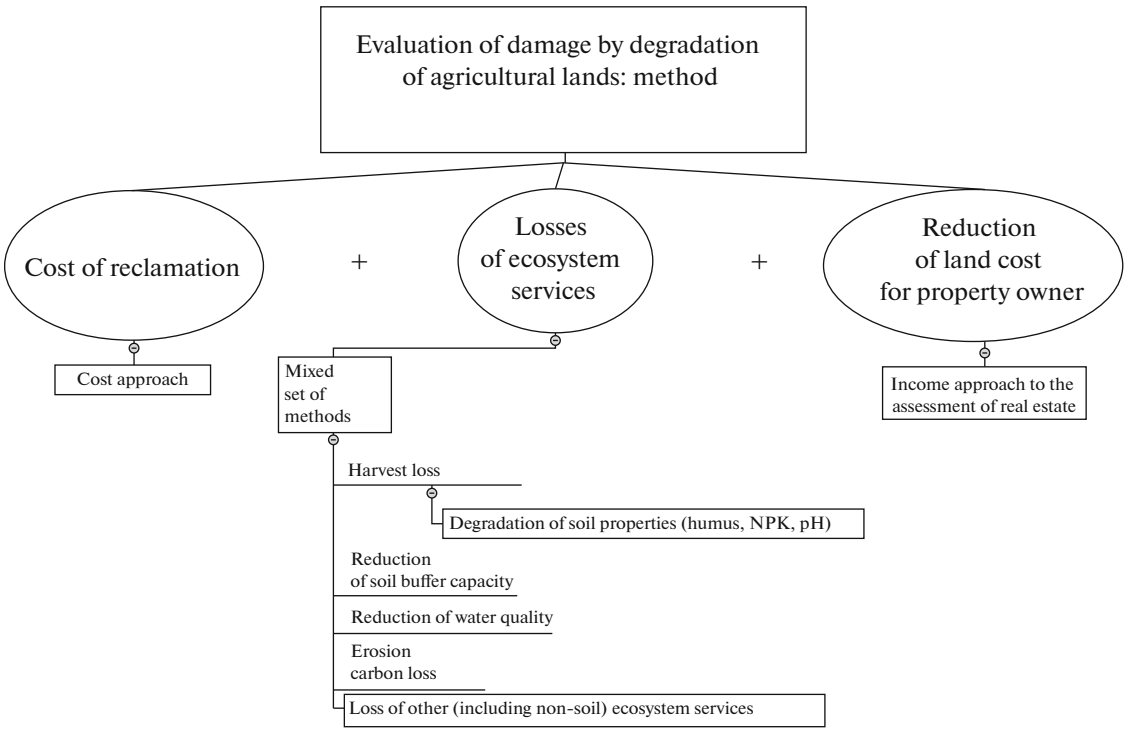

Fig. 3. A formal scheme of evaluating the damage by degradation of agricultural lands taking into account ecosystem services (by the example of lands at the Training–Experimental Soil–Ecological Center of Moscow State University).

oriented taxation. Presently, the land tax is based on its cadaster cost. The use of the land value as a tax base taking into account ecosystem services will promote the possibility to form a new system of environmental relations in society and allocate funds to maintain the ecological and economic equilibrium and sustainable development of the society itself. The restoration of a system of ecological funds will promote development of this activity [18].

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