

Experience in Ecological and Economic Assessment of Land Degradation in Regions of the Russian Federation

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Abstract—The article presents the results of testing a comprehensive scheme of ecological and economic assessment of land degradation in various regions of the European part of the Russian Federation—Volgograd, Belgorod, Kaliningrad, and Penza oblasts. This scheme includes the use of several methodological approaches—calculation of the amount of damage/harm, which allows one to assess degradation at the present time; determination of land-degradation neutrality (LDN), reflecting the development of degradation processes in dynamics; and assessment of the ratio of the cost of “inaction” to the cost of “action” in relation to the restoration of degraded lands (the methodology of Joachim von Braun), demonstrating the prospects of current land use and predicting the profitability of projects for the restoration of the territory. The originality of the scheme is determined by the possibility of simultaneous detailed analysis of degradation processes in soils and lands in retrospect and at the present time, as well as forecasting them in the future. The results were obtained using the application of the methodology of von Braun. On the one hand, they are based to a certain extent on the methodology of calculating damage from soil and land degradation (here, the cost of restoration or damage is used in the calculations), on the other hand, they come into some contradiction with the results of calculating the LDN for the studied regions. Thus, for the Volgograd oblast with the lowest for the regions value of the neutral balance indicator of land degradation (indicator values of the state of land degradation decay the most), provides a favorable forecast for the success of the implementation of reclamation measures.

Keywords: assessment of “action/inaction,” damage/harm from degradation, land-degradation neutrality, land reclamation

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INTRODUCTION

Prior Art

The following concepts used for the environmental and economic assessment of land degradation as a process and degraded lands as a natural and social object have now been developed.

Economic assessment of damage/harm from land degradation through comparison of degraded and reference soils

In the Russian Federation, this approach dominates; scales of degradation and pollution of soils and lands have been developed based on ideas about the

stability of ecosystems to external stress and about acceptable levels of changes in the quality of the environment as a whole and its individual components [12, 18]. In this case, two main methodological approaches are used to calculate the amount of damage/harm caused to soils and lands [14]:

(1) based on the cost of carrying out the full scope of work to clean up contaminated lands, restore degraded lands, and remove waste from littered areas; and

(2) if the estimation of the indicated cost is impossible, the amount of damage from land pollution is calculated according to formulas that take into account the area, depth and degree of pollution, degradation and littering, the economic characteristics of

the studied region, and special land taxes assigned by the regulations.

The most common damage/harm-assessment methods are as follows.

1. “Procedure for Determining the Amount of Damage from Land Pollution by Chemicals” (approved by the Russian Federation Committee on Land Resources and Land Management on November 10, 1993, and the Ministry of Natural Resources of the Russian Federation of November 18, 1993), which is currently not valid.

2. “Methodology for Determining the Amount of Damage from Soil and Land Degradation” (approved by an order of the Russian Federation Committee on Land Resources and Land Management and the Ministry of Natural Resources of Russia of July 17, 1994), which is currently not valid.

3. “Methodology for Calculating the Amount of Damage Caused by Littering, Pollution, and Land Degradation on the Territory of Moscow” (approved by a decree of the Government of Moscow of July 22, 2008, no. 589-PP), which is currently not valid.

4. “Methodology for Calculating the Amount of Damage Caused to Soils As an Object of Environmental Protection” (approved by an order of the Ministry of Natural Resources of Russia dated July 8, 2010, no. 238), which is the current methodology.

5. “The Methodology for Estimating the Cost of Damage Caused by Pollution of Soils and Lands, the Destruction and Damage of the Soil Layer, and the Loss of Soil Fertility,” which is not approved as officially valid [11].

Concept of land-degradation neutrality (LDN)

This concept has been actively developed in recent years by the UN Convention to Combat Desertification (UNCCD), which took effect in 1996, and is considered in world science and practice as a scientific and practical platform for the efficient use of land resources and rational nature management, and for adoption relevant political and economic decisions. In the UNCCD definition, land-degradation neutrality is a state in which the volume and quantity of land resources required to maintain ecosystem functions and services and enhance food security remain stable or increase at specific time and space scales and ecosystems [19].

This methodology allows one to trace, on a retrospective basis, the dynamics of land degradation in terms of the main indicators: land cover, land productivity, and soil organic carbon stocks. However, despite the convenience and relative simplicity of the international methodology, as well as the possibility of conducting a relative analysis of the state of land for the entire territory of the country using a single methodology based on global data and remote sensing materials, the calculation of LDN indicators accord-

ing to the recommendations of the UNCCD and national statistics is not comparable, is contradictory and cannot be carried out by directly replacing the global indicators of NDBD with national analogues [9].

The concept of the economics of land degradation (ELD)

The theoretical foundations for this concept are being developed by the International Institute for Food Policy Research (IFPRI) and the University of Bonn. The developments of these institutions are presented in a number of publications [20–22].

It seems that, from a methodological point of view, it would be interesting to test each of these concepts for the same territories, as which regions (subjects) of the Russian Federation can serve, of which the land-management potential is especially high.

The purpose of the studies reflected in this article is the environmental and economic assessment of land degradation in four subjects of the Russian Federation: Volgograd, Belgorod, Kaliningrad, and Penza oblasts.

MATERIALS AND METHODS

Research Objects

Volgograd oblast

Volgograd oblast is the most important industrial and agricultural territory of the south of Russia, which 80% of its area being occupied by agricultural land. The region has a large production of high-quality grain, maize, cereal crops, oilseeds and vegetable oil, vegetables, fruits, and melons. The area is located within two soil zones—chernozem and chestnut soils, with various variants of chernozems occupying 31.5% of the total area of the region and chestnut soils occupying 31.2% [2]. The soils of the region are characterized by degradation processes typical of arid territories—alkalinization, salinization, wind erosion, depletion by agricultural intensification, etc. At the same time, due to the development of irrigated agriculture in Volgograd oblast, the issues of soil salinization and alkalinization are especially acute.

Belgorod oblast

Belgorod oblast is a territory with intensive industrial and agricultural production in our country. According to Belgorod’s statistical agency, in 2014 the gross harvest of cereal crops and legumes in the region amounted to 3524.8 thousand t (3.35% of the Russian Federation); sugar beet (factory), to 2814.1 thousand t (8.4%); and sunflower, to 314.84 thousand t (3.49%) [10]. The area occupied by the most common soils, chernozems is 2090.8 thousand ha, or 77.1% of the total area of Belgorod oblast, including chernozems of the gully complex (327.6 thousand ha). The area of plowed chernozems reached 1484.9 thousand ha, or

89.9% of the total area of arable land. The soil cover of Belgorod oblast is subject to various degradation processes, among which the following can be distinguished: (a) erosion, the total area of eroded soils is 53.6%, including agricultural land, 50.7%, arable soils, 47.9% [3]; (b) acidification, the proportion of acidic soils in 2010–2014 was 45.8% [10]; (c) dehumification; and (d) pollution (including radionuclides); as a result of the Chernobyl accident, the eastern regions of the region suffered the most, where about 140 thousand ha of arable lands were contaminated with cesium-137 within 1–5 Ku/km².

Kaliningrad oblast. In the total value of agricultural products in Kaliningrad oblast, crop and livestock products in 2018, respectively, amounted to 18024.3 million and 18693.7 million rubles. [5]. At the same time, crop production includes cereal crops and leguminous crops, potatoes, seeds and fruits of oilseeds, sugar beets, etc. In accordance with the scheme of soil-geographical zoning of the Russian Federation and neighboring states [4], this region is mainly located in the zone of soddy–podzolic soils of the southern taiga, the facies of moderate short-term freezing soils, the Belarusian province. Soddy–podzolic soils occupy 42%, brown forest acidic podzolized soils occupy 20.4%, brown-taiga illuvial–humus soils occupy 10.5%, and sod–gley and humus–gley soils occupy 10.1% of the total area of the region [2]. The main degradation processes in the region are depletion by agricultural intensification (decrease in humus reserves, content of mobile phosphorus and exchangeable potassium), water erosion, acidification, repacking, and waterlogging of soils.

Penza oblast

Crop production in the region is mainly represented by oilseeds (camelina seeds) and cereal crops (millet, maize for grain, winter and spring wheat, buckwheat, winter crops spring rye, winter and spring barley, oats, winter and spring triticale), sugar beets, vegetable products, and potatoes. The main land area of Penza oblast is represented by chernozems, which occupy 75% of the area of arable land [13]. Gray, light-gray, and dark-gray forest soils occupy 20%. Potentially rich floodplain soils account for about 3%. As in other areas, gray forest soils are confined to the highest parts of the relief and occupy mainly the Zasura zone of the oblast. Out of the processes of soil degradation, the main ones are depletion by agricultural intensification (decrease in humus reserves, content of mobile phosphorus and exchangeable potassium) and water erosion.

Characteristics of Research Methods

Methodology for determining the amount of damage/harm from soil and land degradation

For calculation of the amount of damage from land degradation in all the studied regions, the “Methodology for Determining the Amount of Damage from Soil and Land Degradation” was used, which was approved by an order of the Russian Federation Committee on Land Resources and Land Management and the Ministry of Natural Resources of Russia of July 17, 1994. These calculations were carried out according to formula (1):

$$Da = Nc \times S \times Ke \times Kd \times Kp + Ia \times S \times Kt, \quad (1)$$

where Da is the amount of damage from soil and land degradation (rubles); Nc is the normative price of the plot, rub./ha (usually it is determined based on the cadastral value in accordance with the orders of the relevant committees for the management of state property of the regions); Ia is the annual income per area unit, rub./ha; S is the area of degraded soils and lands, ha; Ke is the coefficient of the ecological situation of the territory; Kt is the conversion factor depending on the time period for the restoration of degraded soils and lands; Kd is the conversion factor depending on the change in the degree of soil and land degradation; and Kp is the coefficient for specially protected areas.

As indicators of land degradation, the following parameters were used: the decrease in the content of exchangeable potassium, the decrease in the content of mobile phosphorus, the decrease in the content of humus, the change in the acidity index of soils. In addition, for Volgograd oblast, the indicator of soil salinization was used, and the soil erosion was used as the indicator for Belgorod oblast.

When determining the degree of land degradation (this indicator is necessary for calculating Kd from formula (1)), we used the reference values of indicators of soil properties from the following monographs and methodological developments, including those of regional nature:

(1) for Volgograd oblast, the monographs “Zonal–Provincial Standards for Changes in Agrochemical, Physicochemical, and Physical Parameters of the Main Arable Soils of the European Territory of Russia under Anthropogenic Impacts” [16] and “The Red Book of Soils of Volgograd Oblast” [8];

(2) for Belgorod oblast, the monographs “Agroecological State and Productivity of Soils in Belgorod Oblast” [6] and “Belgorod Model of Adaptive Landscape Agriculture” [7];

(3) for Kaliningrad oblast, the monograph “Zonal–Provincial Standards for Changes in Agrochemical, Physicochemical, and Physical Indicators of the Main Arable Soils of the European Territory of Russia under Anthropogenic Impacts” [16]; and

Table 1. Assessment of damage from soil and land degradation in regions of the Russian Federation (only agricultural land was assessed)

Region	Total damage, rub.	Specific total damage, rub./ha
Volgograd oblast	191 584 303 000	25 176
Belgorod oblast	589 907 063 200	294 600
Kaliningrad oblast	93 286 615 575	118 301
Penza oblast	849 171 406 800	111 774

(4) for Penza oblast, the monograph “Evaluation of Soils” [15].

*Method of evaluation
of the land-degradation neutrality indicator*

National methods for determining degraded lands in different countries often differ, therefore, for the comparison of the results of studies at the global level, the specialized module Trends.Earth has been developed [23]. By analyzing satellite data from some global and available national-level databases, the Trends.Earth platform integrates data into a convenient user GIS-interface.

The Trends.Earth module processes satellite images and assesses trends in land use using the main SDG 15.3.1 indicator (proportion of land degraded) and, as noted earlier, three supporting subindicators: land productivity, land cover, and soil organic carbon (SOC) stocks in the 30-cm layer. All indicators are applied with the given parameters recommended by the UNCCD, i.e., for the period from 2001 to 2015 [17]. Trends.Earth displays information for each sub-indicator in the form of three raster maps that form the final SDG 15.3.1 indicator map. In addition, result tables are automatically created showing the land areas of the following categories: “deteriorated condition,” “stable condition,” and “improved condition.” Integration of the main sub-indicators is carried out according to the “one-out, all-out” principle, in other words, the study area is considered degraded if the category “worse” is identified for at least one of the three indicators.

*The methodology of von Braun
 (“assessment of action/inaction”)*

This methodological approach of “assessment of action/inaction” within the framework of the studies was modified to assess the feasibility of carrying out restoration work within the obtained damage values. The calculation methodology was based on determining the costs and benefits of “action” or “inaction” in relation to the degraded land-restoration program. The hypothesis behind the methodology is that measures to combat land degradation are more likely to be

adopted if the cost of “inaction” and the price-effectiveness of taking these measures are known. The planning horizon was 20 years (for Kaliningrad oblast, it was 4 years). The cost of the “action” to change all types of land use was estimated: from “expensive,” undegraded land into “cheap,” i.e., degraded and vice versa.

The main indicator of the economic efficiency of land restoration was the ratio of the cost of “inaction” to the cost of “action” in relation to the restoration of degraded lands: if it was more than 1, then restoration made sense and vice versa.

RESULTS

*Assessment of Damage/Harm from Soil
and Land Degradation*

Analysis of the information presented in Table 1 indicates a significant scatter in the values of specific total damage from soil and land degradation in various regions of the Russian Federation. High values of this indicator were found for the chernozem soils of Belgorod and Penza oblast, which may be due to the significant values of the normative value of land (which in this case was their cadastral value) for these territories. The significant value of the specific total damage for Kaliningrad oblast, which was calculated only on the basis of indicators of soil depletion by agricultural intensification (increase in acidity, decrease in the content of humus, mobile phosphorus and exchangeable potassium), first of all, revealed the shortcomings of agricultural practices.

*Assessment of the Land-Degradation
Neutrality Indicator*

The results of applying the land-degradation neutrality methodology (Table 2) revealed the following regularity: the total LDN indicator increased in the series Volgograd oblast → Belgorod oblast → Kaliningrad oblast → Penza oblast. In other words, the high-activity of degradation processes was noted in Volgograd oblast, and the most favorable trends in changing the state of land according to the assessed indicators/subindicators (share of degraded land, land productivity, land-vegetation cover, and soil organic carbon reserves in the 30-cm layer) were observed for Penza oblast.

*Assessment of the ratio of the cost of “inaction”
to the cost of “action” in relation to the restoration
of degraded lands*

The results of testing the EDL methodology for the subjects of the Russian Federation are given in Table 3. This study proposes a specification for this method that allows estimating the cost of restoring degraded land based on the assumption that a degraded site generates less income (“cheap” land in Table 3) than a

Table 2. Calculation of the land-degradation neutrality of arable-land degradation in the regions of the Russian Federation for the period 2000–2015 (Volgograd, Belgorod, Kaliningrad oblast) and 2000–2010 (Penza oblast)

Territory	Area of arable land in Volgograd oblast (total area of arable land 112088.06 km ² (100%))		Area of arable land in Belgorod oblast (total area of arable land 25420 km ² (100%))		Area of arable land in Kaliningrad oblast (total area of arable land 4810.66 km ² (100%))		Area of arable land in Penza oblast (total area of arable land 20976 km ² (100%))	
	km ²	% of total area of arable land in region	km ²	% of total area of arable land in region	km ²	% of total area of arable land in region	km ²	% of total area of arable land in region
With no data	4233.68	3.78	0	0	1.97	0.0	36.86	0.18
With degradation	67744.51	60.44	3454.2	35.06	389.44	8.1	2142.95	10.22
In stable condition	28157.40	25.12	8913.4	13.6	3044.85	63.3	3965.98	18.91
With improvement	11952.47	10.66	12721.5	50.05	1374.40	28.6	14829.98	70.70
Final LDN indicator	–55792.04	–49.78	3808.2	14.98	984.96	20.5	12687.03	60.48

future option (“expensive” land in Table 3). The model allows estimating the level of cost for restoring land fertility in order to obtain higher revenue; e.g., in fact, an economic justification for the possible transformation from “cheap” land to “expensive” land, where high revenue can be obtained with a sustainable type of land use. Accordingly, the applied model calculates the profitability of the project over a certain period of time and allows to assess if the current type of farming (“inaction”) is more expensive than the future type, supposedly sustainable farming (“action”). If the cost of “inaction” exceeds the cost of “action,” then investing in a new type of land use does not make economic sense and does not provide a monetary return (efficiency). If, on the contrary, “action” exceeds “inaction” in a given area and in a selected region, then it is profitable and efficient to invest in the restoration of these degraded lands. The planning horizon in calculating the cost of “inaction” and the cost of “action” for all the studied regions was 20 years.

To assess the level of costs and benefits from the current and new (“restored”) type of land use, data of the Ministry of Agriculture of the Russian Federation on agricultural organizations of Russia in 2015 [1] were used, converted using a deflator into comparable costs of 2020.

DISCUSSION

As we stated earlier, *received damages* (Table 1) make up the cost of work on the restoration of degraded territories. In fact, the damage caused to

agricultural lands of all the studied regions was due to the low level of agrotechnical measures carried out there, mainly due to the insufficient application of organic and mineral fertilizers and liming of acidic soils, for example, in Kaliningrad oblast and plastering of alkaline soils in Volgograd oblast. Such a situation, in general, indicates the unsustainable nature of land use in the regions, when agricultural activity leads to the depletion of agricultural landscapes.

When interpreting the results of calculation of the *LDN indicator* (Table 2), a special approach is required that consists in the analysis of the *dynamics* of indicators of degradation/improvement for the period from 2000 to 2015 (for Penza oblast, from 2000 to 2010). The year 2000 and, accordingly, the state of land for this period was taken as the starting point, which, among other things, implies the possibility of a rather low share of degraded land in the context of LDN indicators against the background of the historically high actual development of degradation processes.

Therefore, it was necessary to recommend the introduction of measures that, on the one hand, would contribute to the improvement of the *historical situation* in the area of land cover degradation and, on the other hand, would lead to a change of the *modern attitude* to land use in the considered regions.

In this regard, the following measures can be proposed for the studied subjects of the Russian Federation:

1. the introduction of adaptive landscape agriculture (including the creation of a system of forest belts), which is basically a set of measures aimed at preserving and expanding the reproduction of soil fertility [6];

Table 3. Evaluation of the effectiveness of “action” and “inaction” against land degradation in Volgograd, Belgorod, Kaliningrad, and Penza oblasts

Variables	Volgograd oblast	Belgorod oblast	Kaliningrad oblast	Penza oblast
Cost of “expensive” land, rub./ha	34603	87908	133519	31 194
Cost of laying “expensive” land, rub./ha	25 176	56490	118301	111 774
Cost of annual maintenance of “expensive” land, rub./ha	7122	19988	73824	24 167
Cost of “action” for a period of 20 years, rub.	719986503244	524966146701	91 188 594 859	3 100 100 101 014
Cost of “inaction” for a period of 20 years, rub.	1070842245866	567 500 122 378	45954009292	606836401463
Ratio of cost of “inaction” to cost of “action”	1.49	1.08	0.50	0.20
Ratio of cost of “action” to cost of “inaction,” %	67	93	198	511
Cost of “cheap” land (revenue from 1 ha of agricultural land), rub./ha	9427	31 418	63 350	21 812
Area of degraded land, ha	5446410	1 286 374	76925	7 597 237

2. introduction of environmentally oriented forms of management in practices (for example, organic farming), including through the replacement of traditional forms of agriculture in part of the territory of a particular region; and

3. implementation of incentive measures for sustainable land use. These measures can be both fairly loyal measures, such as organizing seminars and training programs and informing the population and agricultural producers, and relatively tough measures such as the introduction of an additional tax burden on those owners who have worsened the condition of their lands over a certain reporting period.

In calculations of *the ratio of the cost of “inaction” to the cost of “action” in relation to the restoration of degraded lands* only productive services (i.e., crop production) were taken into account. Briefly summarizing the results (Table 3), it is obvious that the indicator of the cost of restoring ELD according von Braun is, as a rule, cost-effective (the ratio of the cost of “inaction” to the cost of “action” is higher than 1) with fairly large investments in the restoration of land resources. This is due to the fact that, in general, the cost of cultivated land (revenue per 1 ha) fluctuates depending on the region, and, with the cost of damage in the same range, the model does not fix the difference in changes in land quality and, therefore the profitability of the land restoration project “goes negative.” Conversely, when the cost of restoration (damage) is higher than the value of the land (the productivity of land in the form of revenue per 1 ha), then the ELD model captures the profitability of the

project. In this case, such a situation is noted for the lands of Volgograd and Belgorod oblasts: here the project for the restoration of degraded lands is profitable (Table 3). In the case of Kaliningrad and Penza oblasts, the ratio of the cost of “inaction” to the cost of “action”; e.g., the amount of damage is lower than the amount of revenue from 1 ha of agricultural land and the value is less than 1. Therefore, the complex of reclamation works is not effective from either an environmental or an economic point of view.

The results obtained using the methodology of von Braun (Table 3), on the one hand, are based to a certain extent on the methodology for calculating the damage from soil and land degradation (here, the cost of damage is used in the calculations), on the other hand, they conflict with the LDN results for these regions. Thus, Volgograd oblast had the lowest land-degradation neutrality value of all regions (the indicators of land condition were the most deteriorated, see Table 2); however it “provides” a favorable forecast for the success of the implementation of remediation activities.

This pattern probably should be explained as follows: the rapid intensification of degradation processes in the agricultural lands of the region causes an urgent need for “action”—a set of necessary reclamation measures. Naturally, to increase the investment attractiveness of reclamation projects and the introduction of sustainable farming technologies, long-term agricultural policy measures are needed to increase the future incomes of agricultural producers. Otherwise, work on withdrawing land from circulation

for the reduction of the use of unproductive lands are required.

Thus, in the course of integrating the algorithms for calculating damage and summing up the current type of land use to the reference one (Russian methodology) and calculating the efficiency of the land-degradation economy using “action–inaction” assessment, it was possible to combine Russian assessment methodology with foreign ones to a certain extent.

CONCLUSIONS

For a number of regions of the Russian Federation (Volgograd, Belgorod, Kaliningrad, and Penza oblasts), a basic integrated scheme for the environmental and economic assessment of land degradation was developed and tested, which includes the use of several methodological approaches: a) calculation of the amount of damage/harm, which allows assessing the present degradation; b) determination of land-degradation neutrality, which reflects the development of degradation processes in dynamics; and c) assessment of the ratio of the cost of “inaction” to the cost of “action” according to relation to the restoration of degraded lands, showing the prospects for current land use and predicting the profitability of land restoration projects. The originality of the developed scheme is determined by the possibility of simultaneous detailed analysis of degradation processes in soils and lands in retrospect and at the present time, as well as their prediction in the future. It is likely that the further development of this synthesis of approaches to the environmental and economic assessment of land should be carried out within the framework of the harmonization of the ecosystem and socioeconomic components.

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COMPLIANCE WITH ETHICAL STANDARDS

This article does not contain any studies involving animals or human beings performed by any of the authors.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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