

Application of Basic and Modified Methods for Assessing the Land-Degradation Neutrality in the Context of Studying the Relationship between Degradation and Agricultural Production

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Abstract—This article is devoted to the theory and practice of applying the concept of land-degradation neutrality (LDN) to the conditions of the Belgorod oblast of the Russian Federation. Its basic version is considered, which is based on the analysis of three subindicators, where the assessment of land-degradation trends in the surveyed area involves the analysis of changes in the main indicator, which is the percentage of degraded land of the total area of the territory, and three subindicators of SDG 15.3.1, these being the changes in land productivity, the changes in land cover, and the dynamics of soil organic carbon reserves. As an adjustment to the basic approach of LDN, it is proposed to supplement it with the regional data on soil characteristics. The content of humus and nutrients, as well as pH, are soil properties that can be recommended as necessary for consideration in the evaluation model. These characteristics are largely related to soil fertility, on the one hand, and are most at risk of degradation changes during human exploitation of soils, on the other hand. Modification of the LDN methodology makes it possible not only to clarify the central (umbrella) indicator, but also to identify the relationship between the latter and the indicators of agricultural production, in particular, gross crop yields. Data analysis using the modified LDN method has shown that 64.8% of the region is degraded (which is almost two times higher than the values obtained by the basic LDN method), which leads to a significant loss of crop yield. The article proposes an algorithm for assessing the relationship between land degradation and gross crop yields based on correlation and regression analysis (spatial models).

Keywords: soil degradation, degradation indicators, degradation and food security

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INTRODUCTION

The problem of land degradation¹ is one of the most important challenges of the modern world. More than half of agricultural lands are currently more or less degraded (Nkonya et al., 2016). In view of the above, conservation of soil and land resources is a task of priority in the context of food security for global population and sustainable development in general.

The Economics of Land Degradation (ELD) Initiative provides a comprehensive understanding of land degradation as “the reduction in the economic value of ecosystem services and goods derived from land as a result of anthropogenic activities or natural biophysical evolution” (ELD Initiative..., 2013).

The approach elaborated as part of the ELD initiative is related to the approach that has been developed

in the recent decade on the basis of land-degradation neutrality (LDN) assessment (Tilahun et al., 2018). LDN is a condition whereby the quantity and quality of land resources required to maintain ecosystem functions and services and to enhance food security remain stable or increase at certain temporal and spatial scales and in certain ecosystems (Kust et al., 2017, 2018).

The essence of the LDN concept (at that time, it was referred to as “zero net land degradation”) was officially formulated for the first time by the United Nations Convention to Combat Desertification in 2011 (UNCCD, 2012). The LDN goal can be formulated as follows: to sustain and improve the reserves of natural capital and related ecosystem services for sustaining the future prosperity and security of humanity. Using the concept approaches, it is possible to execute some sustainable development goals (SDGs) associated with food security, environmental protection, and sustainable use of natural resources, as well as to increase resistance to global environmental changes.

¹ This paper deals with land degradation, in accordance with the concept of land-degradation neutrality, but not soil degradation. However, as regards agricultural lands, on which the present work is focused and where socioeconomic activity is associated with soil fertility, these two terms become extremely similar and in some cases can be taken as synonyms.

The *trends* of land degradation in a particular territory are assessed by analyzing the changes in the so-called “indicator parameters” within a certain period of time. The following basic indicator is recommended for monitoring the above trends at a global level: the proportion of degraded lands in the total area of the territory expressed as percentage and three subindicators of SDG 15.3.1: the changes in land productivity, the changes in land cover, and the dynamics of soil organic carbon reserves in a layer of 0–30 cm (Sims et al., 2017). These three subindicators are integrated in accordance with a single general rule: if a territory has been defined as potentially degraded with respect to any subindicator, it will be considered as potentially degraded.

The globally coordinated subindicators can be supplemented with national data taking into account the regional specificity of degradation processes.

The LDN concept is rather universal and applicable to the socioeconomic, natural, and climatic conditions of any country; to any type of degradation (natural or anthropogenic); and to any type of land use. Comparability of results is one of the most powerful features of this concept. It can be considered as an umbrella concept for all subsequent economic interpretations of the recorded degradation, including those in the context of the ELD initiative. It is postulated that the very mechanism for achieving neutrality is to balance the expected gains and losses in the land natural capital within the framework of unique land types through decision making in the field of land use and management (*Zemel'nye resursy: vsemirnyi obzor*, 2017).

It is a subtle point in the concept that ecosystem services are insufficiently analyzed using global proxy indicators; in fact, only one service is considered, which is associated with the above-ground plant biomass productivity of the ecosystem and assessed with respect to the NDVI index (Methodological Report on Defining..., 2017), while soil parameters are confined to carbon only.

Here, additional use of regional subindicators can be an important modification; as has been mentioned, the LDN methodology allows for it.

It is also significant that none of the subindicators considered, just like the integral indicator “proportion of degraded lands,” entails any economic interpretations. The loss of natural capital is not evaluated in monetary terms, which makes it mandatory to reassess degradation using an “external” methodology.

Hence, it seems promising to supplement the assessment of an LDN estimate by estimation of the total economic value of ecosystem services, which will make it possible to most adequately assess the effects of land degradation on the environment. To assess the effects of land degradation on agricultural lands as an independent category, it is advisable to refer to statistical conjugation of this concept with gross crop yields.

The latter may become a basis for the integrated study of land degradation and food security. The present work is aimed at creating such a basis.

MATERIALS AND METHODS

An algorithm for assessing the relationship between land degradation and gross crop yields can be constructed, as has been mentioned, on LDN modification in terms of supplementing it with the regional soil data, as well as statistical analysis of the results obtained. The schematic diagram of the algorithm may consist of five steps.

Step 1 in this scheme includes assessment of land degradation dynamics on the basis of LDN calculations using global proxy indicators (hereinafter, the “basic method”) and comparison of the data obtained with the main degradation processes in the region under study.

In this case, LDN is calculated using the Trends. Earth software based on the Quantum GIS (QGIS). LDN is calculated in two stages. Initially, the calculations for each of the three subindicators are performed.

The calculation result for each subindicator is presented as a raster conveying information about the division of a surveyed territory into the categories of degraded lands, improved lands, lands without the recorded changes, and lands, for which there is no data. At the second stage, the final raster layer is formed on the basis of previous data on the subindicators also obtained with the involvement of Trends. Earth tools, with lands divided into the categories of “degraded,” “improved,” “unchanged,” and “no data.” The territory is classified as “degraded” if there is degradation in at least one subindicator.

In view of the fact that the present work is focused on arable lands, the next stage includes categorization of “arable land” using GIS tools. Then, based on the results of previous operations, the areas of arable lands assigned to the “degraded,” “unchanged,” “improved,” and “no data” categories are counted for the selected level of administrative division of the region of research and the LDN index, i.e., the difference between improved and degraded lands, is calculated.

Step 2 of the proposed algorithm includes the collection and analysis of regional data on soil characteristics for a number of rounds of agrochemical survey (the initial and final periods of agrochemical survey must coincide with the initial and final periods of study) and correction of the final LDN values using soil data (hereinafter, the “modified method”).

As has been shown previously, one of the peculiar features of the methodology under consideration is using only one soil characteristic—soil carbon reserves, which is calculated for the global tasks of application of the LDN method using model (not factual) data. For calculating LDN on the regional level, it is proposed to use, instead of the subindicator of changes in soil car-

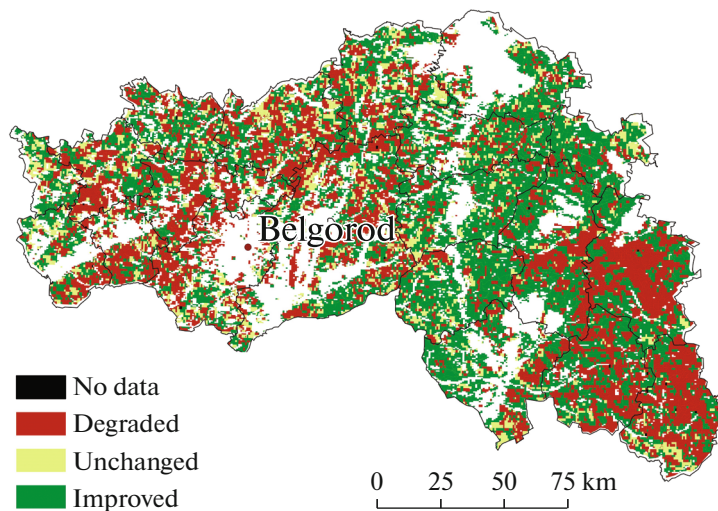


Fig. 1. Assessment of arable-land degradation in the Belgorod oblast by the basic LDN method.

bon reserves, the regional data on the changes in soil properties—the levels of organic matter,² phosphorus, potassium, and acidity—obtained by comparing the data from the two cycles of agrochemical survey and the intermediate results of LDN calculation by the classical method, i.e., the raster data on two subindicators: productivity dynamics and land cover change.

As it has been shown (Tsvetnov et al., 2020), this set of soil characteristics can be generally taken as sufficient for the analysis of soil degradation, because these properties largely run the risk of negative changes as a result of anthropogenic impacts on soils. The conclusions about the sufficiency of such set of soil characteristics can be also found in the works of experts from the Dokuchaev Soil Science Institute, in particular, Karmanov and Bulgakov (2003). In various individual cases, or in cases of in-depth research, e.g., with the analysis of a specific list of degradation processes (salinization, overwetting, etc.), this set of indicators can be modified and extended.

Note that switching from the “reserve” parameter to the “content” parameter seems to be appropriate in view of the reduction of total uncertainty in the analysis. The calculation of reserves requires an additional soil characteristic: the actual bulk density correlated with the actual data on the content of organic matter and nutritional elements for the entire region of research, and such data are very rarely available. When using the averaged values of densities at a given depth, the change in the “content” will be the only significant variable characterizing the change in reserves.

² In this work, the term “soil organic matter” is used. The information about its content in soil was taken from (Lukin, 2016), where it is indicated that the content of soil organic carbon was determined by the method of Tyurin in accordance with GOST (State Standard) 26213-91 and, then, converted into organic-matter content.

These operations lead us to **step 3** of the presented algorithm: calculation of the proportion of degraded lands based on the modified DLN method.

For this purpose, the areas of land of each category are calculated, as well as the percentage of lands degraded with respect to each subindicator of total research area for the region of survey in general, in addition to for the units of municipal division.

Let us once again emphasize that this estimation is the calculation of *degradation dynamics (over a certain period)*, but not its absolute values. For the regions where the analysis of degradation dynamics is insufficient (e.g., for the countries of Central Asia, where degradation can cover more than 80% of the territory), it is necessary to calculate the proportion of degraded lands in the context of *absolute values* of degradation based on the analysis of erosional processes, desertification, salinization, etc., as well as the comparison of factual soil parameters with the standards (if there are any) (Frid et al., 2010).

Step 4 of the algorithm under consideration includes collection of data on crop production costs: total, as well as (if any) the costs of mineral and organic fertilizers, plant-protection products, and labor remuneration separately. It is also extremely important to collect data on application of mineral and organic fertilizers; it is especially relevant in the absence of data on expenditures, because it will to some extent make it possible to trace the relationship with the cost of capital in crop production.

These data are necessary for constructing the regression models of dependence between the gross yields in crop production and the proportion of degraded lands (**step 5** of the algorithm). It is supposed that agricultural crop production involves the following factors: labor (data on labor remuneration), capital (data on the total cost in crop production/data on the

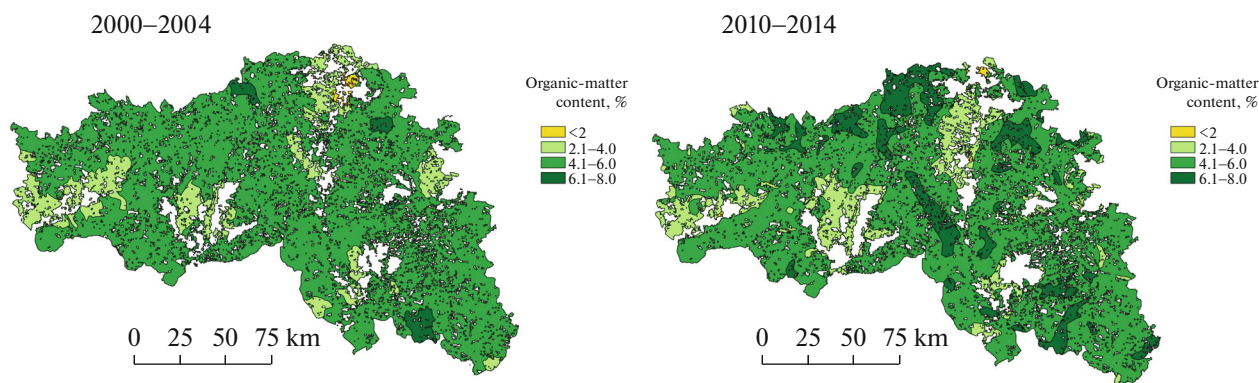


Fig. 2. Cartograms of organic-matter content in arable soils of the Belgorod oblast according to the results of agrochemical surveys of 2000–2004 and 2010–2014 (Lukin, 2008, 2016).

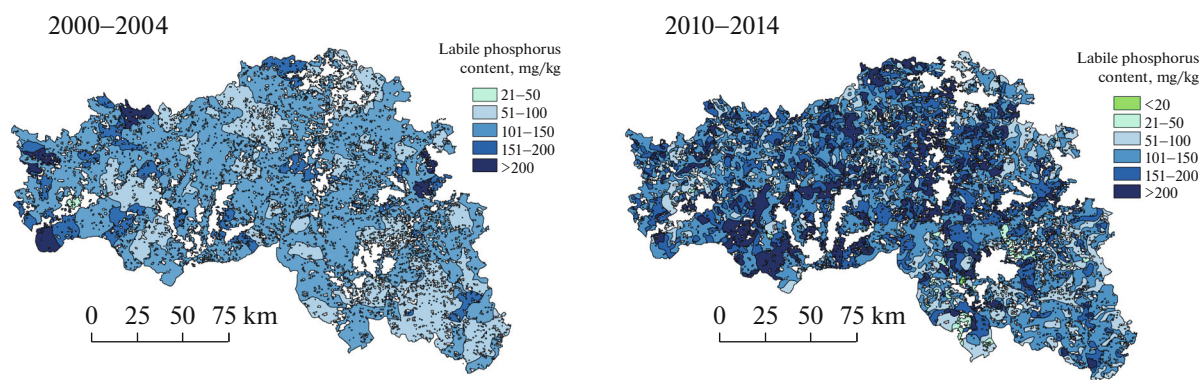


Fig. 3. Cartograms of labile phosphorus content in arable soils of the Belgorod oblast according to the results of agrochemical surveys of 2000–2004 and 2010–2014 (Lukin, 2008, 2016).

cost of organic fertilizers, plant-protection products/data on application of mineral and organic fertilizers in physical weight per ha) and land (the proportion of degraded lands, soil characteristics). As part of the last factor, it is also important to consider climatic

characteristics such as temperature and precipitation; however, for fractional administrative division of the surveyed region, such data are published very rarely.

The collected data are a basis for constructing a spatial regression model, where the *dependent* variable

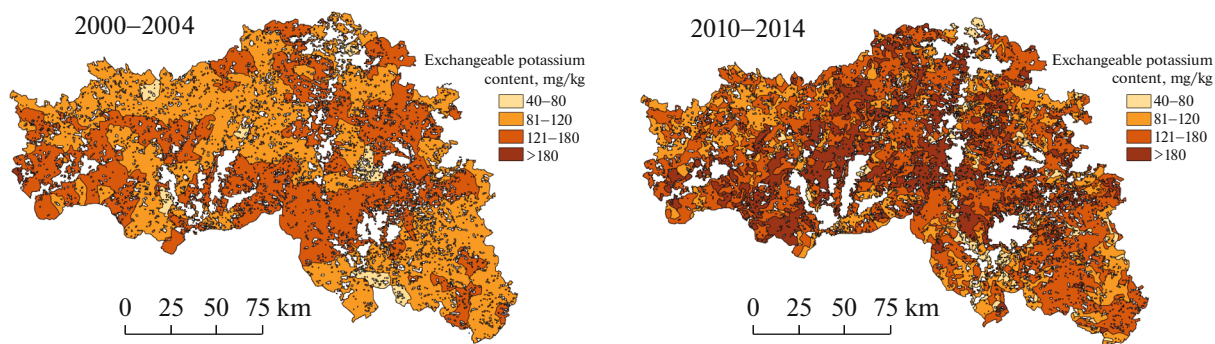


Fig. 4. Cartograms of exchangeable potassium content in arable soils of the Belgorod oblast according to the results of agrochemical surveys of 2000–2004 and 2010–2014 (Lukin, 2008, 2016).

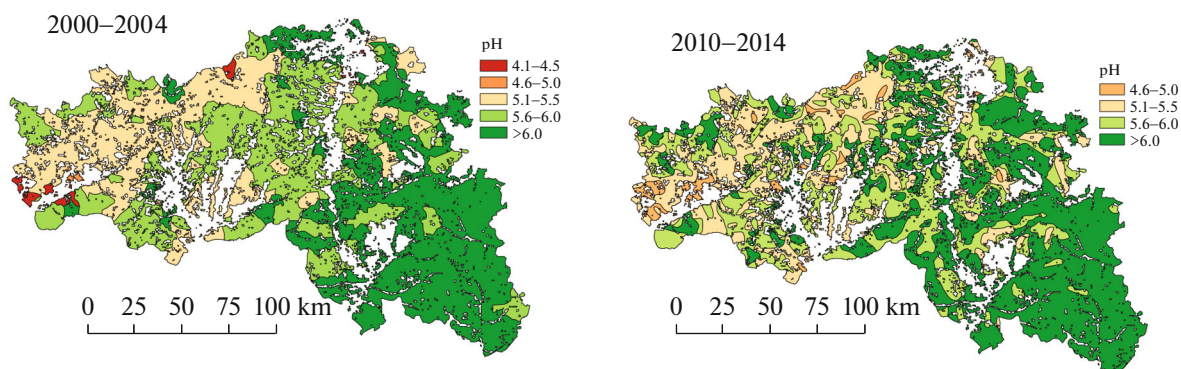


Fig. 5. Cartograms of acidity in arable soils of the Belgorod oblast according to the results of agrochemical surveys of 2000–2004 and 2010–2014 (Lukin, 2008, 2016).

is the gross yields of agricultural crops in the region of research and the *possible* independent variables are all other variables listed above (the proportion of degraded lands calculated by the basic and modified methods, the proportion of eroded lands, the amount of mineral fertilizers applied, the content of soil organic matter, exchangeable potassium, labile phosphorus, soil acidity, and plant production costs (total and by category)).

It would be reasonable to convert the gross yields of agricultural crops at farms of all categories into the grain equivalent in order to operate not with the numerous indices of gross yields for each particular crop, but with the integral index of gross yields.

The concluding stage of the algorithm is *step 6*, with the formulation of proposals for persons making decisions on minimization of the effects of degradation processes on production of the major crops.

The proposed algorithm has been tested on agricultural lands of the most important agrarian region of Russia: the Belgorod oblast, which is part of the Central Black Earth Economic Region (CBEER).

Table 1. Proportion of degraded arable lands (of total area of arable land) with respect to subindicators. Modified method of LDN

Subindicator	Proportion of degraded land, %
Changes in productivity	38.2
Land cover dynamics	0.3
Changes in soil properties (organic-matter content)	6.1
Changes in soil properties (labile phosphorus content)	18.5
Changes in soil properties (exchangeable potassium content)	11.4
Changes in soil properties (pH (KCl))	15.7

In the total land area of the region (2713.4 thousand ha), agricultural lands are 78.7%, forest lands are 8.9%, water surface is 1.8%, and other lands are 10.6% (*Belgorodskaya oblast' v tsifrakh...*, 2016). The main active agents of agricultural production here are agroholdings, i.e., large structures capable of economically efficient production (Kiryushin, 2015), which, however, are far from always environmentally responsible.

Black soils represented by typical, leached, and ordinary subtypes occupy 77.1% (about 2090.8 thousand ha) of the total territory of the region, making up 90% of all arable lands (Lukin, 2016). Processes of arable-soil degradation, such as erosion, dehumification, and nutrient losses (agricultural depletion, acidification), are widespread in the region. At the same time, the territory of the Belgorod oblast is the most eroded of all CBEER regions. According to the data of 2011, the area of eroded soils was 53.6% of the area of the whole region.

RESULTS

Step 1 of the “algorithm” involves calculations by the *basic* method of LDN. Analysis was performed for the period from 2000 to 2015³; the productivity-change subindicator was calculated using the UNCCD data set; the category of arable lands was identified on the basis of MCD12Q1 (MODIS Land Cover Type) (Friedl and Sulla-Menashe, 2019) for the last year (2015) of survey (spatial resolution is 500 m; the land classification used is the IGBP-International Geosphere–Biosphere Programme).

The calculations have shown that about 38% of arable lands in the Belgorod oblast degraded from 2000 to 2015 (Fig. 1), improved territories make up 48.2%, and unchanged lands make up 13.3%. The final LDN index is 8.5%, indicating the nominal achievement of a neutral balance.

³ All calculations were connected to 2015 in view of the fact that we have obtained data on expenditures for this year.

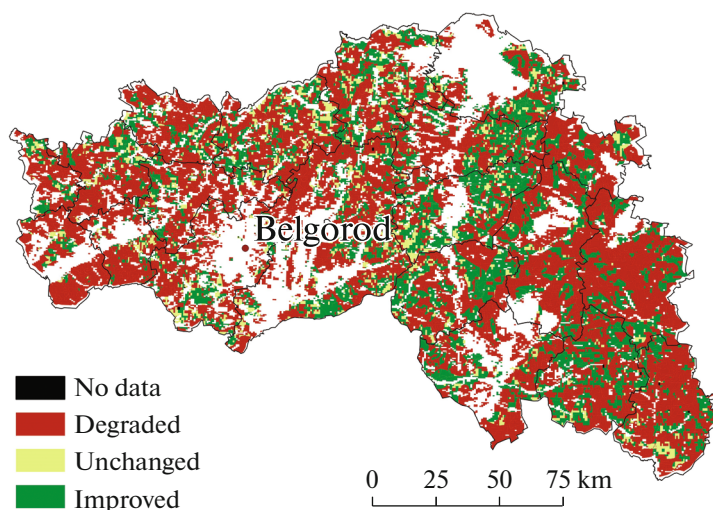


Fig. 6. Assessment of arable-land degradation in the Belgorod oblast by the modified LDN method.

Due to inclusion of the regional data on soil parameters collected at the Belgorod Center for Agrochemical Service (step 2 of the algorithm) in the methodology, it was possible to significantly correct the result. The subindicator of the dynamics of organic carbon reserves was replaced by the indicator of the dynamics of factual content of soil organic matter: the modified method (Fig. 2). The data on the changes in the content of labile phosphorus (Fig. 3) and exchangeable potassium (Fig. 4), as well as acidity (Fig. 5), were used here as additional indicators.

Visual analysis of the cartograms shows improvement with respect to each of the analyzed parameters. The calculations have shown that the “degraded land” category does not prevail with respect to any of the parameters under consideration (Table 1). However, the superposition of cartograms of the changes in soil characteristics on each other demonstrates a different pattern. As it has been mentioned above, according to the *basic* method of LDN, if there is degradation by at least one parameter, then the entire pixel on the cartogram is marked as “degradation.”

Introduction of regional soil data into the basic method has shown that the proportion of degraded lands increases almost twofold—up to 64.8% (Fig. 6)—and the final LDN index becomes negative (−30.4%) (Table 2).

We should separately address the issue of accounting for the problem of erosion, which is rather significant in the Belgorod oblast. The erosion rate can be integrated into the basic method of LDN if there are data on the dynamics of this parameter within a survey period. Inasmuch as only static data are available, we have studied erosion as a separate parameter of degradation. Archival materials for the Belgorod oblast of 2000–2010 have been collected. According to V.D. Solovichenko, almost 54% of arable lands in the Belgorod oblast are eroded. At the same time, erosion has developed to the

maximum in the eastern and southeastern districts, where the proportion of eroded lands is up to 66% in the Valuysky district (Fig. 7, Table 3) (Uvarov and Solovichenko, 2010).

The final estimates of degradation by districts of the region are given in Table 3.

DISCUSSION

As has been mentioned, the findings can be used to study the relationship between degradation and agricultural production. The correlation and regression analysis of relationships between the gross yields of agricultural crops at farms of all categories, in the grain equivalent for 2015, and the resulting proportion of degraded lands was performed for this purpose.

Gross yields served as a dependent variable (Y), and the proportion of degraded lands was an independent variable. The latter was analyzed in two variants: calculated by the basic and modified methods of LDN. One more parameter of degradation, which, as has been mentioned, can be used separately, was the proportion of eroded lands taken from literature sources.

Quite a broad set of factors, both soil factors proper and economic factors, were also involved in the analysis as independent variables. They were selected with regard to considerations about the existence of production factors: labor, land, and capital, as well as the official statistics.

Soil characteristics:

- labile phosphorus (P_2O_5) content in soil, $mg\ kg^{-1}$;
- exchangeable potassium (K_2O) content in soil, $mg\ kg^{-1}$;
- organic matter content in soil, %;
- soil acidity, pH (KCl).

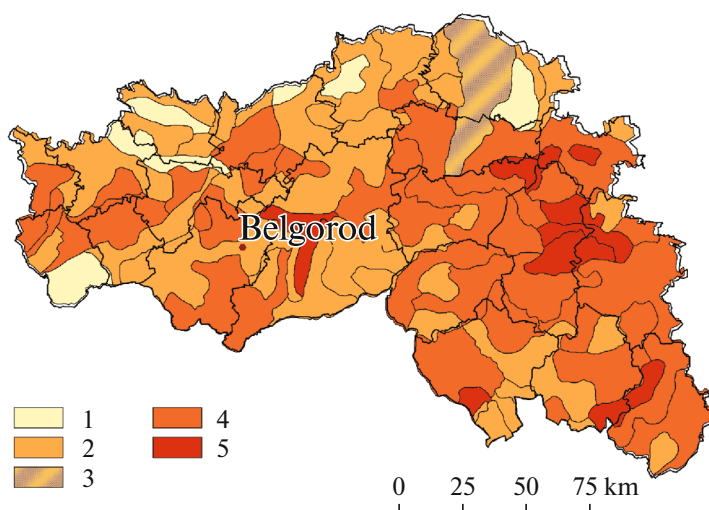


Fig. 7. Erosion of soil in the Belgorod oblast. (1) Weak washout, (2) medium washout, (3) deflated, (4) strong washout, and (5) very strong washout (Uvarov and Solovichenko, 2010).

Economic characteristics:

- total costs in plant production, a total of 2015, rub, and separately
- labor costs in plant production for 2015, rub;
- costs of chemical products (estimated), rub.

Application of mineral fertilizers (per 100% of nutrients) for crops in agricultural organizations (2015), cwt.

Climatic characteristics were not taken into account in view of the impossibility of obtaining detailed regional statistics. The latter is published mainly at the regional level.

Correlation analysis has shown that the dependent variable largely correlates with three parameters: the application of mineral fertilizers, the proportion of degraded lands calculated by the modified methods, and organic matter. There was no recorded relationship with the proportion of degraded lands obtained by the basic method of LDN. It seems to be highly significant in light of the present work and shows the fundamental importance of the modified method under consideration, because it is precisely the method that allows such relationship to be detected.

Emissions were excluded from further analysis (Novooskolsky, Krasnensky, and Krasnoyarskiy districts); separately, we note that the Gubkinsky and Starooskolsky districts were not included in analysis due to the absence of official data on most of the variables. The data are not published by statistical agencies, because there are fewer than three farms in each of these districts. Multicollinearity was analyzed, and regression was calculated. The calculations showed that the analysis should be confined to the two independent variables: the factor of soil organic-matter content was excluded, because the model coefficients proved to be insignificant. As a result, we analyzed the relationship between the gross yields of crops at the farms of all categories (in the grain equivalent), i.e., dependent variable Y , and the application of mineral fertilizers (per 100% of nutrients) for crops at agricultural organizations (2015), cwt, i.e., variable X_1 . Variable X_2 was the proportion of degraded lands calculated by the modified method.

The regression analysis based on these data yielded the dependence in the form of (1):

$$Y = 4669358.12 + 18.25X_1 - 40461.88X_2. \quad (1)$$

Table 2. Results of calculation by the modified method of land-degradation neutrality for the territory of the Belgorod oblast over the period of 2000–2015

Category	Land area by categories, km ²	Proportions of samples by categories, %	LDN index, %
No data	6.6	0.0	–30.4
Degraded	13001.2	64.8	
Unchanged	173.9	0.9	
Improved	6896.9	34.3	

Table 3. Proportion of degraded/eroded arable lands of the Belgorod oblast by district

District of Belgorod oblast	Proportion of degraded lands LDN 2000–2015 (basic method), %	Proportion of degraded lands, LDN 2000–2015 (modified method), %	Proportion of eroded soils (total), %*
Alekseyevsky	53.6	74.6	64.2
Belgorodsky	49.0	66.8	37.4
Borisovsky	54.7	81.0	26.5
Valuysky	27.4	69.4	66.0
Veydelevsky	46.5	56.1	53.1
Volokonovsky	16.4	54.5	46.1
Grayvoronsky	36.6	86.0	22.8
Gubkinsky	32.3	56.5	42.1
Ivnyansky	35.6	71.5	23.2
Korochansky	47.5	73.3	62.6
Krasnensky	19.4	73.9	57.5
Krasnogvardeysky	37.2	71.0	64.9
Krasnoyarsky	20.8	68.1	25.0
Novooskolsky	17.5	39.9	48.9
Prokhorovsky	45.0	58.4	35.1
Rakityansky	47.5	71.8	28.6
Rovensky	61.0	72.9	56.5
Starooskolsky	20.9	49.2	39.6
Chernyansky	23.3	58.8	53.2
Shebekinsky	39.2	58.1	39.4
Yakovlevsky	55.5	71.9	45.4

* According to (Lukin, 2016).

Regression statistics analysis (Table 4) shows that about 63% of changes in the dependent variable (the gross yields of crops in the grain equivalent) can be accounted for by the two selected variables. Calculations show that the regression model is generally significant, on par with the model constant and the coefficients at X1 and X2 (Tables 4, 5).

The findings, as well as the analysis of observed and predicted values of the dependent variable, show that the model is satisfactory in general and has the mean error at a level of 13%.

At a 1% increase in the proportion of degraded lands, gross crop yields at the farms of all categories (in the grain equivalent) decrease by 40461.88 cwt on the average. Thus, it can be supposed that agricultural losses in the Belgorod oblast, where the proportion of degraded lands by districts is 67% on the average, make up about 271.1 thousand t in the grain equivalent.

Hence, it is possible to estimate the reference point for the scale of monetary losses. There is no direct cost factor for the grain equivalent, and, therefore, the sought-reference point will be calculated using the annual prices established by agricultural producers for

cereals and leguminous crops. In Russia, on average for 2015 (the survey was carried out in this period), this value was 8684 rub/t according to the Rosstat data.

Thus, in terms of money, land degradation in the Belgorod oblast from 2000 to 2015 resulted in the loss of 2.35 billion rubles.

CONCLUSIONS

1. The methodology for assessing the relationship between land degradation and gross crop yields can be constructed on the basis of the currently developed concept of land-degradation neutrality, which has already become an umbrella concept for the Econom-

Table 4. Regression statistics

Multiple R	0.83
R-squared	0.68
Normalized R-squared	0.63
Standard error	440641.56
Observations	16

F = 14.02; $F_{crit} = 3.8$ ($\alpha = 0.05$); significance of F = 0.0006.

Table 5. Data on coefficients of the regression model

	Coefficient	Standard error	t-Statistic	P Value	Lower 95%	Upper 95%
Y-Intersection	4669358.1	1302672.61	3.58	0.0033	1855105.05	7483611
X1	18.25	7.80	2.34	0.0359	1.39	35.10
X2	-40461.88	14954.46	-2.71	0.0180	-72769.02	-8154.74

$t_{crit} = 2.16$ ($\alpha = 0.05$).

ics of Land Degradation Initiative and estimates the dynamics of degradation processes in a region under study, i.e., characterizes the sustainability of management on arable lands in the latter. It has been proposed to supplement the basic method of LDN by the regional data on soil characteristics. It is recommended that the following soil properties should be accounted for in the evaluation model: the content of organic matter and nutrients, as well as pH, because these characteristics are largely related to soil fertility, on the one hand, and are most at risk of degradative changes during soil exploitation by human beings, on the other hand. The relationship between land degradation and gross crop yields can be assessed on the basis of correlation and regression analysis (spatial models).

2. Data analysis by the modified method of LDN including regional soil characteristics has shown a 64.8% degradation in the region, i.e., almost twice as high as the values obtained by the basic method of LDN.

3. A model has been constructed to detect quantitative relationships between the gross crop yields at the farms of all categories (in the grain equivalent for 2015) and the proportion of degraded lands, where dependent variable Y was the gross crop yields at the farms of all categories in the grain equivalent and independent variables were the application of mineral fertilizers per 100% of nutrients for the crops in agricultural organizations (2015), cwt (X1), and the proportion of degraded lands calculated by the modified method (X2). The relationships with the analogous index calculated by the basic method of LDN have not been detected, i.e., the modified method of LDN not only provides a more accurate value of the proportion of degraded lands but also the relationship between the latter and separate indicators of food security. Regression analysis based on these data yielded the following dependence:

$$Y = 4669358.12 + 18.25X1 - 40461.88X2.$$

The 1% increase in the proportion of degraded lands is accompanied by a decrease in gross crop yields at the farms of all categories (in the grain equivalent) by 40461.88 cwt on the average. It can be supposed that agricultural losses in the Belgorod oblast, where the proportion of degraded lands is 67% on the average by districts, amount to about 271.1 thousand t. Thus, in monetary terms, land degradation in the Belgorod

oblast from 2000 to 2015 leads to potential losses of 2.35 billion rubles yr^{-1} .

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

- Belgorodskaya oblast' v tsifrakh. 2016: Kratkii statisticheskiy sb.* (Belgorod oblast in Figures 2016. Brief Statistical Collection), Belgorod, 2016.
- Economics of Land Degradation and Improvement. A Global Assessment for Sustainable Development*, Nkonya, E., Mirzabaev, A., and Braun, J.V., Eds., Cham: Springer, 2016.
- ELD Initiative. The Rewards of Investing in Sustainable Land Management. Interim Report for the Economics of Land Degradation Initiative: A Global Strategy for Sustainable Land Management. 2013. https://www.eld-initiative.org/fileadmin/pdf/ELD_interim_report_2015_web.pdf. Accessed April 14, 2020.
- Frid, A.S., Kuznetsova, I.V., Koroleva, I.E., et al., *Zonal'no-provintsial'nye normativy izmenenii agrokhimicheskikh, fiziko-khimicheskikh i fizicheskikh pokazatelei osnovnykh pakhotnykh pochv evropeiskoi territorii Rossii pri antropogennykh vozdeistviyakh* (Zonal-Province Measuring Norms for Agroclimate, Physicochemical, and Physical Indexes of the Main Arable Soils in Russia under Anthropogenic Loading), Moscow, 2010.
- Friedl, M. and Sulla-Menashe, D., *MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006*. NASA EOSDIS Land Processes DAAC, 2019.
- Karmanov, I.I. and Bulgakov, D.S., The way to create index-calculating method for agriculture land value on the base of soil ecology, in *Rol' pochv v biosfere* (Soil Role in the Biosphere), issue 3: *Otsenka i uchety pochvennykh resursov* (Soil Resources: Estimation and Considering), Moscow, Tula, 2003.
- Kiryushin, V.I., Afterwards of radical economical liberalism and aims of new agrarian policy, *Innovatsii*, 2015, no. 1.
- Kust, G.S., Andreeva, O.V., and Cowie, A., Land degradation neutrality: concept development, practical applications and assessment, *J. Environ. Manag.*, 2016, vol. 195, part 1. <https://doi.org/10.1016/j.jenvman.2016.10.043>
- Kust, G.S., Andreeva, O.V., and Lobkovskii, V.A., Neutral balance of land degradation is the newest approach to solution making in the field of land management and land policy, *Probl. Postsov. Prostranstva*, 2018, vol. 5,

- no. 4.
<https://doi.org/10.24975/2313-8920-2018-5-4-369-389>
- Lukin, S.V., *Agroekologicheskoe sostoyanie pochv Belgorodskoi oblasti* (Soils Agroecological State in Belgorod oblast), Belgorod, 2008.
- Lukin, S.V., *Agroekologicheskoe sostoyanie i produktivnost' pochv Belgorodskoi oblasti* (Soils Agroecological State and Productivity in Belgorod oblast), Belgorod, 2016.
- Methodological Report on Defining National Voluntary Problems Referring to Neutral Land Degradation Balance by Using Index System of United Nations Convention to Combat Desertification, 2017.
- Sims, N.C., Green, C., Newnham, G.J., et al., *Good Practice Guidance. SDG Indicator 15.3.1. Proportion of Land That Is Degraded over Total Land Area*, 2017.
- Tilahun, M., Singh, A., Kumar, P., et al., *The Economics of Land Degradation Neutrality in Asia: Empirical Analyses and Policy Implications for the Sustainable Development Goals*, 2018. https://www.eld-initiative.org/fileadmin/pdf/Asia_Report_EN.pdf. Accessed April 16, 2020.
- Tsvetnov, E.V., Tsvetnova, O.B., Makarov, O.A., et al., Problems of assessing the land degradation neutrality at the regional level of the Russian Federation, *Zemledelie*, 2020, no. 2.
<https://doi.org/10.24411/0044-3913-2020-10201>
- UNCCD. *Zero Net Land Degradation—A Sustainable Development Goal for Rio+20: To Secure the Contribution of Our Planet? Land and Soil to Sustainable Development, Including Food Security and Poverty Eradication*, Bonn, 2012.
- Uvarov, G.I. and Solovichenko, V.D., *Degradatsiya i okhrana pochv Belgorodskoi oblasti* (Soils Degradation and Protection in Belgorod oblast), Belgorod, 2010.
- Zemel'nye resursy: vsemirnyi obzor (Land Resources: World Wide Review)*, Bonn: United Nations Convention to Combat Desertification, 2017.

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