Chapter 18
The Economics of Land Degradation in Russia

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Abstract The analysis of the costs for action versus inaction in addressing land degradation at national and sub-national (regional and district) levels in Russia showed that the total annual costs of land degradation due to land use and cover change only are about 189 billion USD in 2009 as compared with 2001, i.e. about 23.6 billion USD annually, or about 2 % of Russia's Gross Domestic Product (GDP) in 2010. These land use and land cover changes occurred in the area of 130 million ha. The area of arable lands decreased by 25 % during the period of the economic reforms between 1990 and 2009. The total economic value of ecosystem goods and services is estimated to equal about 3700 billion USD in Russia, exceeding the conventional GDP by 3 times. The costs of action against land degradation are lower than the costs of inaction in Russia by 5–6 times over a 30-year horizon. Almost 92 % of the costs of action are made up of the opportunity costs of action. The methodology of the economics of land degradation can be successfully applied in peculiar socioeconomic conditions of Russia, but the lack of harmonization of methods and indicators brings uncertainty to quantitative assessments.

Keywords Rostov region · Soil maps · Land use maps · Remote sensing data

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541

Introduction

Russia stretches over a large part of Eastern Europe and Northern Asia. The total area of Russia is more than 17 million km^2 (Rudneva 2001). The vastness of the territory of the country inevitably leads to a diversity of natural conditions that causes the development of multiple economic uses of land resources. Climatic conditions have direct and indirect impacts on biological components of natural landscapes and soil forming processes. In their turn, the biophysical conditions determine the shape of agricultural development of the territory, with various land-use systems and with different major degradation processes. Figure 18.1 illustrates the nine major and accompanying processes of degradation of arable lands in Russia.

The increasing degradation of land resources in many parts of Russia, manifested in numerous forms such as desertification, soil erosion, secondary salinization, waterlogging, and overgrazing, to name a few, considerably limits land productivity and the ability of land to provide ecosystem services (Table 18.1). Swamping and erosion result in the biggest affected areas. Salinization processes are most characteristic of the southern part of Volga Federal district (FD) (the Caspian depression, etc.). The major drivers of degradation include: climatic change, unsustainable agricultural practices, industrial and mining activities, expansion of crop production to fragile and marginal areas, inadequate maintenance of irrigation and drainage networks, and overgrazing.

Socioeconomic characteristics of the regions of Russia are extremely heterogeneous. The population in each region of Russia varies in density and per capita income. Actually in rural areas the income is 40 % of the average income in cities (Nefedova 2013). The regions differ in terms of transportation networks, access to
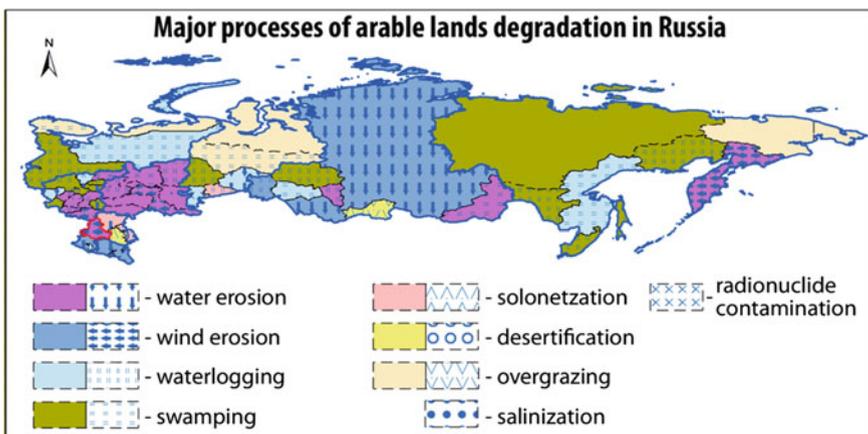

Fig. 18.1 Major processes of arable lands degradation in Russia with legend. Note: *Color*—the basic processes, *mark*—accompanying processes, *blue polygons*—borders of Federal districts, *red polygon*—boarder of Rostov region. *Source* Vandysheva and Gurov (2011). Reproduced with permission

Table 18.1 Major processes of arable lands degradation in Russia by federal districts (areas of basic and accompanying processes)

Federal districts	Units	Total area		Water erosion	Wind erosion	Waterlogging	Swamping	Solonetzation	Desertification	Overgrazing	Salinization	Radionuclide contamination
Type				Basic	Basic	Basic	Basic	Basic	Basic	Basic	Accompanying	Accompanying
Central	km²	647,694		313,318	–	85,956	248,420	–	–	–	–	–
	%	100		48.37	–	13.27	38.35	–	–	–	–	–
Northern-West	km²	1,862,379		–	–	1,021,812	518,855	–	–	321,712	–	–
	%	100		–	–	54.87	27.86	–	–	17.27	–	–
Southern	km²	420,876		100,967	75,485	7792	–	161,901	74,731	–	–	–
	%	100		23.99	17.94	1.85	–	38.47	17.76	–	–	–
North Caucasian	km²	170,439		7987	143,177	–	–	–	–	–	101,240	–
	%	100		4.69	84.00	–	–	–	–	–	9.76	–
Volga	km²	1,036,975		1,036,975	–	–	–	–	–	–	–	88,529
	%	100		100.00	–	–	–	–	–	–	–	4.87
Ural	km²	1,818,497		–	–	248,651	194,307	71,488	–	1,304,051	–	–
	%	100		–	–	13.67	10.69	3.93	–	71.71	–	–
Siberian	km²	5,144,953		527,617	3,956,585	177,756	314,391	–	168,604	–	–	–
	%	100		10.26	76.90	3.45	6.11	–	3.28	–	–	–
Far Eastern	km²	6,169,329		464,275	–	823,899	4,159,674	–	–	721,481	101,250	138,873
	%	100		7.53	–	13.35	67.43	–	–	11.69	0.59	0.80
Russia (total)	km²	17,271,142		2,451,334	4,175,426	2,365,966	5,435,797	233,431	243,356	2,347,345	–	50,331
	%	100		14.19	24.18	13.70	31.47	1.35	1.41	13.59	–	7.77

Source Based on Vandysheva and Gurov (2011)

infrastructure, and the provision of social services. All these differences affect the ways and extent of the economic use of lands, but are also conditioned by them.

The natural conditions and socio-economic factors determine the structure and the principles of land use in Russia. In the recent history in Russia, there was a rapid transition from state and collective farms formed under conditions of a planned centralized economy to private farms of various forms and sizes operating under market conditions. Such changes resulted in changes in land use, including of arable lands. Between 1990 and 2002, the economic reforms resulted in a drastic reduction in arable lands and cultivated areas. Since 2002, the area of arable lands in Russia has stabilized (Nefedova 2013). The State land records show that during the period from 1990 to 2001, the area of arable land has decreased by 8.5 million ha. During the period 2001–2006 the rate of land abandonment has decreased resulting in the decline of 1.9 million ha. In general for the period from 1990 to 2006 the area of arable land has decreased by 10.7 million ha (Federal State Statistics Service 2014a). Most of the abandoned lands were located in the regions with severe climate and poor soils; however, the biophysical conditions in the abandoned areas were not restrictive for agricultural production. Also, the reduction of the area of arable land was partly due to the formal transfer of the land from one category to another during the inventory undertaken by the legislation (Shoba et al. 2010). Following these reductions in the size of arable lands, the pressure on the fields remaining under use has increased, thus leading to more intensive use and creating conditions for the degradation of these most productive soils. Land degradation is a major challenge for the agriculture in the country, which is not properly addressed until now. We need deeper understanding of both the socioeconomic and biophysical drivers of land degradation in the Russian Federation. We have to estimate the cost of land degradation in Russia using a Total Economic Value (TEV) framework. The latter estimates tangible economic losses due to land degradation, such as the decline in the productivity of crops, together with the losses in non-market values of the ecosystem services, also essential for human and social well-being.

The aim of this study is to estimate the extent and the effect of land degradation on the agricultural economy of Russia. The research questions were:

1. What are the major drivers of land degradation in various zones of Russia with differing levels of socio-economic development, bioclimatic conditions, and resource potentials?
2. What is the total economic cost of land degradation in large (Federal district level) and small (region level) administrative-territorial units of Russia?
3. What is the value of potential benefits from sustainable land management in Russia?

Thus, the first section of this chapter analyses the degradation and improvement of the land resources on a national scale with an emphasis on the period of economic reforms from 1990 to 2009 in Russia, where the area of arable lands decreased by 25 %. We provide an estimation of the costs of the measures for controlling land degradation and then compare this cost with potential losses of land

value if no land protection or remediation action was taken. The main causes and drivers of these processes, both natural and socioeconomic, and the global consequences of these land use changes are discussed. The total economic costs of land degradation are estimated, including the losses in the value of non-marketed ecosystem services. The study also estimates the value of benefits from land improvement. Both land degradation costs and benefits from land improvement are estimated for the period of 2001–2009 at the Federal districts level in Russia.

The second section presents a case study of the state of agricultural production and land degradation in the Azov district of Rostov region in the southern part of European Russia. The analysis is done on the basis of accessible information on the socioeconomic characteristics of the district, the state of agricultural sector, maps and the reports on the land resources of the district. The latter group of data sources includes three land use maps of the district for 1990, 2000, and 2010, the map of the land planning of the district, and soil maps in both raster (scale 1:10,000) and vector formats (scales 1:50,000 and 1:300,000). Other available remote sensing data have also been used. Three maps showing land-use change for three time periods were developed: 1990–2000, 2000–2010 and 1990–2010. We estimate the total economic costs of land degradation, including the losses in the value of non-marketed ecosystem services. The study also estimated the value of benefits from land improvement. Both land degradation costs and benefits from land improvement were estimated for the periods of 1990–2000, 2000–2010 and 1990–2010.

Methodology

In this chapter a multiscale approach was used to estimate the economic effect of land degradation in Russia on the national, regional, and farm scale. The methodology used in the study follows the approaches proposed by von Braun et al. (2013) and Nkonya et al. (2014), and is based on the comparative evaluation of the cost of action and the cost of inaction. Following Nkonya et al. (2014), we calculated the costs of land degradation due to land-use and land-cover change (LUCC) through:

$$C_{LUCC} = \sum_{i}^{K} (\Delta a_1 * p_1 - \Delta a_1 * p_2) \tag{18.1}$$

where CLUCC = cost of land degradation due to LUCC; a_1 = land area of biome 1 being replaced by biome 2; P_1 and P_2 are the total economic value (TEV) of biomes 1 and 2, respectively.

By definition of land degradation, $P_1 > P_2$. In cases where $P_1 < P_2$, LUCC is not regarded as land degradation, but as land improvement (Nkonya et al. 2014).

The cost of taking action against land degradation due to LUCC is given by:

$$CTA_i = A_i \frac{1}{\rho^t} \left\{ z_i + \sum_{t=1}^{T} (x_i + p_j x_j) \right\} \qquad (18.2)$$

where CTA_i = cost of restoring high value biome i; ρ^t = discount factor of land user; A_i = area of high value biome i that was replaced by low value biome j; z_i = cost of establishing high value biome I; x_i = maintenance cost of high value biome i until it reaches maturity; x_j = productivity of low value biome j per ha; p_j = price of low value biome j per unit (e.g. ton); t = time in years and T = planning horizon of taking action against land degradation. The term $p_j x_j$ represents the opportunity cost of foregoing production of the low value biome j being replaced.

The cost of inaction will be the sum of annual losses due to land degradation:

$$CI_i = \sum_{t=1}^{T} C_{LUCC} \qquad (18.3)$$

where CI_i = cost of not taking action against degradation of biome i. Given that the benefit of restoring degraded land goes beyond the maturity period of biome i, we have to use the planning horizon of the land user. Poor farmers tend to have a shorter planning horizon while better off farmers tend to have a longer planning horizon (Pannell et al. 2014). The planning horizon also depends on the type of investment. For example, tree planting requires a longer planning horizon than annual cropland management. We will assume a 30 year planning horizon for the afforestation program to redress deforestation and loss of woodlands and shrublands. We will use a 6 year planning horizon for grassland and croplands—majority of which are annual crops. As Nkonya et al. (2013) notes, land users will take action against land degradation if $CTA_i < CI_i$.

Data and Materials

First Level Analysis—8 Federal Districts of Russian Federation

Moderate Resolution Imaging Spectroradiometer (MODIS) remotely sensed datasets on land cover were used to identify the shifts in the land use and land cover in the region between 2001 and 2009 at the level of Federal districts of the Russian Federation. These included forests, grassland, cropland, shrublands (including woodlands), urban areas, barren lands, and water bodies. The MODIS land cover dataset is groundtruthed and quality controlled (Friedl et al. 2010), with overall accuracy of land use classification at 75 %. Following this analysis of the land-use and land-cover change, total economic values were assigned to each land use using the data from TEEB (The Economics of Ecosystems and Biodiversity) (van der Ploeg and de Groot 2010), using the benefit transfer approach.

Table 18.2 Data used for the evaluation of the land degradation at the district level (Azov district of Rostov region of Russian Federation)

Data	Year	Spatial resolution, m	Links
Base data			
Landsat 5 TM	1990	30	usgs.gov
Landsat 7 ETM+	2000	15	usgs.gov
IRS	2007	6	Commercial data
Navteq maps		0.6	navteq.com
Panchromatic images		From 1 to 2	http://gptl.ru/
References purposes data			
Landsat 2	1975, 1976	60	usgs.gov
Landsat 3	1979	60	usgs.gov
Landsat 5	1984, 1986 and 2011	30	usgs.gov
Landsat 7	1999	15	usgs.gov
Spot	2010	2.5	Commercial data
Interpretation of soil and land cover data			
TDM		30 and 90	
SRTM		90	maps-for-free.com
SRTM (alternative palette)		90	maps-for-free.com
ASTER DEM		30–70	maps-for-free.com

Source The authors

Second Level Analysis—Azov District (Rostov Region, Southern FD of Russian Federation)

The following data sources and materials have been used for the evaluation of land degradation at the district level (Table 18.2).

A Review of the State and Current Tendencies in Russian Agriculture

The size of agricultural lands in Russia is similar to Brazil and Canada. Since the late 1980s, the rural population of Russia declined sharply from almost 60 to 20 million people by 2010 (Federal State Statistics Service 2014b). Official statistics of Russia show that the density of rural population is about 2.2 persons/km^2, the area of arable land is 122 million ha (about 23 % of the land fund of Russia). The area of arable land per rural person is 3.2 ha, and the share of the population employed in agriculture and forestry is 15.6 % (Federal State Statistics Service 2014a). It should be noted that the value for the average

Table 18.3 Some characteristics of rural lands and agriculture of Federal districts of Russia and European countries with respectively similar bioclimatic conditions

Federal districts of Russia and European countries	Rural population density, person/km^2	Area of arable lands, million ha	Share of arable lands in the territory (%)	Availability of arable lands, ha/person	Share of employment in agriculture of rural population (%)
Northern FD	1.4	2.4	1.6	1.2	18.9
Finland	5.8	2.3	6.7	1.1	6.0
Central FD	11.0	20.1	32.0	2.9	18.7
Poland	45.6	12.5	38.6	0.8	15.8
Southern FD	16.7	20.4	35.0	2.1	16.7
France	26.0	18.5	33.6	1.3	5.4

Source Based on Nefedova (2013)

availability of cropland per one rural inhabitant is deceptive, because of the uneven development of the territory. In the share of employment in agriculture (15.6 %) Russia is comparable with other developing countries (Nefedova 2013).

Since the territory of Russia developed unevenly, it is more informative to compare other countries with macro-regions of Russia, such as the federal districts (there are eight of them as of 2014), with similar agro-climatic conditions. For example, we can compare the Northern, Central, and Southern Federal districts with the countries of Northern, Central and Southern Europe, respectively (Table 18.3). The comparison shows that at a much lower population density (1.4, 11.0, 16.7 persons/km^2, in the Northern, Central, and Southern Federal districts, respectively) and higher availability of land (1.2, 2.9, 2.1 ha/person, respectively), the Russian regions stand out with the higher employment in agriculture (18.9, 18.7, 16.7 %, respectively) than in the European countries with similar bioclimatic conditions (Nefedova 2013).

The claim that Russia has a lot of land should be considered as a relative one. The areas with optimal heat and moisture for agriculture in Russia occupy 14 % of the territory that is inhabited by 58 % of the rural population. Only in 1 % of the territory of the country there is a combination of sufficient heat with satisfactory humidity.[1]

The yield of the main crops in Russia is not high compared to other countries with rainfed agricultural production, and only Kazakhstan and Australia are surpassed by Russia. It means that the productivity of the Russian lands is not high and the gross volume of production is obtained through enormous use of land resources (Federal State Statistics Service 2014c). The yield of grain crops in Russia is far behind that of most Western countries. The average yield of grain crop is within 2100–2300 kg/ha, while in the US it is above 6500 kg/ha.

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[1]Considering that for the majority of crops the sum of active temperatures (above 10 °C) should exceed 2500 °C, and the ratio of annual precipitation to potential evaporation should be over 0.75 (Shoba et al. 2010).

Table 18.4 The percentage of livestock for different categories of land tenure

Russia and Federal districts	Agricultural organizations (%)		Households (%)		Farms (%)	
	1990s	2000s	1990s	2000s	1990s	2000s
Russia	69.8	54.8	28.7	42.0	1.4	3.2
Central	81.5	73.8	17.8	24.7	0.7	1.5
Northern-West	78.4	73.5	20.2	23.4	1.4	3.1
Southern	66.9	44.3	30.6	49.5	2.5	6.2
North Caucasian	36.9	16.9	58.6	75.8	4.5	7.3
Volga	70.9	58.4	28.2	39.1	0.9	2.5
Ural	63.0	50.3	35.3	47.2	1.7	2.5
Siberian	62.6	48.8	35.5	48.6	1.9	2.6
Far Eastern	53.9	27.3	40.4	60.4	5.7	12.3

Mean values for 1990s and 2000s by the end of each year, the share of livestock to all categories
Source Based on Federal State Statistics Service (2014a)

Table 18.4 shows the structure of livestock for different categories of land tenure: agricultural organizations, households and farms. The share of livestock in agricultural organizations decreases in 2000s compared with other market players (households and farms). These results can be explained by the fact that since the reforms of the 1990s the demonopolization of the agricultural sector has occurred.

Since the 1990s the application of water for irrigation, fertilizers, and other ameliorative facilities for intensification of land productivity in Russia has decreased in most Federal districts. These results can be explained by several facts. Overall, there was a reorganization of the agricultural organizations. Many unprofitable farms were closed and many lands were abandoned due to unfavorable performance. At the same time, due to lack of funding, the landlords began to invest less money in fertilizer and water for irrigation.

Russia is far behind Europe in the density of paved roads. The total road density is below 50 km/1000 km^2. The western part of Russia has a relatively high density of paved roads, but density falls gradually or abruptly from about 600 km/1000 km^2 in the Moscow region to about 60 km/1000 km^2 in the Novosibirsk region (the equivalent distance between Mexico and Canada). This gradient is similar to the yield of crops and many other agricultural indicators (Nefedova 2013).

Agricultural production remains an important factor of regional development in Russia. Its share in gross domestic product in 2010 on average was 8 %, but in many regions, such as the Belgorod and Orel regions, agricultural production was about 30 % of the gross regional product (GRP). In the southern region of the Russian Plain it was from 20 to 30 % (Federal State Statistics Service 2014a). Unlike Western countries, where the agro-industrial complex (AIC) is dominated by manufacturing and services associated with the processing of agricultural raw material (feedstock), marketing, and supply and maintenance of agricultural production, in Russia it is dominated by raw agricultural products.

Table 18.5 Application of water for irrigation, fertilizers, and other ameliorative facilities for intensification of land productivity in Russia (the mean values for 1990s and 2000s)

Russia and its Federal districts	Water for irrigation, million m³		Mineral fertilizers, kg/ha		Organic fertilizers, kg/ha		Lime application, 1000 ha		Phosphate application, 1000 ha	
	90s	00s	90s	00s	90s	00s	90s	00s	90s	00s
Russia	11,562	9,413	52.6	26.4	2500	0.9	493.0	362.8	91.4	40.9
Central	705	272	90.3	42.8	3700	1.2	79.5	101.2	22.0	18.2
Northern-West	90	37	90.4	30.9	6700	2.5	8.8	15.3	0.3	1.1
Southern	4899	4464	51.1	37.9	2000	0.8	263.4	0.2	4.6	0.0
North Caucasian	3373	3617	64.0	33.2	1700	1.1	0.0	0.3	0.0	0.0
Volga	1440	436	49.0	23.9	2500	1.0	126.2	240.6	47.3	15.8
Ural	137	54	35.5	15.5	1900	0.6	7.7	2.8	15.7	3.3
Siberian	821	433	21.5	6.3	1200	0.5	5.5	0.8	0.1	0.0
Far Eastern	98	101	52.8	19.8	1800	0.2	2.0	1.8	1.5	2.5

Source Based on Federal State Statistics Service (2014a)

Table 18.6 Socio-economic characteristics of Russia

Federal districts	Area, 1000 km²	GRP per capita, RUB		Population, 1000 ppl		Poverty (%)		Investment per capita, RUB		Employment in agriculture, in %		Density of roads, km/1000 km²		Density of railways, km/10000 km²	
Period		90s	00s	90s	00s	90s	00s	90s	00s	90s	00s	90s	00s	90s	00s
Central	650.2	14505.2	153571.2	38119.3	38171.5	35.7	15.6	1982.9	25257.6	9.7	8.7	167.2	193.8	269.6	263.1
Northern-West	1687	13497.1	120532.3	15058.7	13795.2	32.2	14.2	1681.3	33433.1	6.2	7	36.4	41.2	77.6	77.3
Southern	420.9	8544.5	67237.7	14895.1	13884.2	38.2	19.2	1183.1	19718.9	20.4	18.6	97.2	110.8	162.7	160
North Caucasian	170.4	3578.7	38583.8	8138	9023.8	54	20.2	1080.2	11011.4	21.3	20.8	174.3	199.6	131.6	128.3
Volga	1037	12447.4	87178.3	31933	30569.5	37.8	17.3	1769.7	20445.1	14.8	13.5	105.4	128	146	143.2
Ural	1818.5	23513.2	211311.1	12678.6	12183.5	30.9	13.6	4562	54152.8	8.8	7.6	17	20.7	48	47.6
Siberian	5145	13258.6	91954	21023	19607.3	41.6	18.6	1670.5	18873.3	13.1	12.5	16.2	18.7	29.8	28.9
Far Eastern	6169.3	16073.8	120303	7746.8	6507.6	42.9	21.1	2058.3	38357.9	9.5	9.5	4.9	5.6	13.4	13
Total	17098.3	20785.9	138764.2	148172.6	143742.6	29	14.9	1971.9	25796.3	14.7	11.5	28	33.1	50.6	50

Source Based on Federal State Statistics Service (2014b)

The average annual salary in the agricultural sector in 2010 was 3500 USD with the average indicators in all the sectors of economy 6970 USD. In 1989 the wage in this industry reached the national average wage, so with this in mind we have to admit that agriculture and rural areas have greatly suffered (Federal State Statistics Service 2014a). Other socio-economic characteristics of Russia are shown in Table 18.6. The important outcomes of the reforms are: (1) double decrease in percentage of population living under the poverty level; (2) the increase of investments per capita; (3) slight increase in road density. The negative outcomes are: (1) decrease of population; (2) decrease of share of employments in agriculture, which, at the same time, could have a positive impact if the modernization of agricultural industry occurs.

Some experts (Nefedova 2013) distinguish 5 zones with different types of land development in Russia: 1—low level of land reclamation and land without reclamation in the North and East of the country (47 % of the total area of Russia): this group is characterized by small centers of agriculture, low population density, seasonal population migration, weak access to information, and traditional economy of indigenous peoples; 2—Forest area with mining of mineral resources, sparse (a few percent of territory) settlements and agriculture (22 % of the Russia's territory): characterized by suburban agriculture, a small part of rural population, poor access to information, and the crisis of agricultural enterprises; 3—Forest agricultural area (13 % of the area of Russia and 30 % of the rural population): characterized by a developed industry, a big heterogeneity of land reclamation (from suburbs to the periphery), low density of rural population, and the decline of agriculture; 4—Mostly agricultural area (12 % of the area of Russia and 58 % of the rural population) characterized by good land reclamation, with problems of over-plowed soils and aridity of some territories. These problems can be resolved within the framework of sustainable (rational) natural resource management; 5—Mountain pastoral area (6 % of the area of Russia, 8 % of the rural population) (Table 18.5).

In Russia 70 % of the territory is characterized by sparse population, complexity of management and natural conditions, and sparse networks of paved roads.

Soil Resources

Soil resources are basic for sustainable agricultural production. To a great extent soils determine the agricultural practices and application of fertilizers. The Chernozem zone is the main base of grain production in Russia. Within this zone there are 85–90 % of lands that are under cultivation. Though it occupies about 12 % of the country's area, more than 50 % of arable lands of Russia are concentrated here (Shoba et al. 2010). More than half of the arable lands of the country is represented by the Chernozem zone, 15 % are represented by the Albeluvisol/Phaeozem zone, and the extension of the Kastanozem zone is more than 10 % (Ministry of Natural Resources and Environment of the Russian Federation 2013).

The Reforms of 1990s

The agricultural sector was faced with several challenges at the very beginning: dramatic reduction of State support; the rudimentary state of market relations; the struggle for ownership; lack of coordination of government entities; the impact of the international market; the imperfection of the law and ignorance of the law; and the lack of feedback between society and the State.

The reforms have resulted in several changes: the elimination of state monopoly on land (more than 85 % of lands were transferred to the ownership of individuals); the creation of an administrative land market (prices were established depending on the quality and location of the plot, with annual indexation); the population had the opportunity to purchase and sell land; and the account of unclaimed land and their transfer to municipal ownership was simplified.

According to the Federal State Statistics Service (2014a) the share of loss-making enterprises reached a maximum in 1998 and amounted up to 88 % of the total. In 2010 unprofitable enterprises were only 28 % of large and medium-sized agricultural organizations. The share of all loss-making enterprises in the Russian Federation is 30 %. The decrease in the share of unprofitable enterprises was not only due to their coping with the crisis, but also due to the closure of non-viable ones. Employment in enterprises has also dropped from 8.3 million in 1990 to 2 million in 2010. Average acreage of enterprises decreased from 2.9 to 2.3 thousand ha. Catastrophic changes have occurred with an average number of cattle, which decreased from 1800 heads in 1990 to 130 heads in 2010.

As stated earlier, a lot of land became unused, which led, on the one hand to a significant reduction of degradation processes in agricultural areas, but, on the other hand, on those lands that remained agricultural (usually the most fertile lands), the intensification of production was observed.

A Review of the State and Tendencies of Land Degradation in Russia

Land degradation can be classified into physical, chemical, and biological types. These types do not necessarily occur individually; spiral feedbacks between processes are often present (Katyal and Vlek 2000). Physical land degradation refers to erosion; changes in the soil physical structure, such as compaction or crusting and waterlogging. Chemical degradation, on the other hand, includes leaching, salinization, acidification, nutrient imbalances, and fertility depletion, soil organic carbon loss. Biological degradation includes rangeland degradation, deforestation, and loss in biodiversity, involving loss of soil organic matter or of flora and fauna populations or species in the soil (Scherr 1999).

Causes of land degradation are classified into proximate and underlying. Proximate causes of land degradation are those that have a direct effect on the

terrestrial ecosystem. The proximate causes are further divided into biophysical proximate causes (natural) and unsustainable land management practices (anthropogenic). The underlying causes of land degradation are those that indirectly affect the proximate causes of land degradation (von Braun et al. 2013).

The negative processes related to development of land degradation have reached alarming proportions at the beginning of 2000s in the Russian Federation. More than 20 types of land degradation processes can be identified, which lead to a deterioration in the quality of land, reversible and irreversible transfers of land from one category to another. In arable land, most degradation is caused by the development of processes of erosion and deflation, secondary salinization, reduction of humus, phosphorus and potassium content, and adverse values of pH. The reversible transfer of lands from one category to another is related to the covering with shrubs and woodland, the flooding of the floodplain meadows by water in reservoirs and clogging by the stones. Long-term and irreversible losses of arable land is due to factors such as the contamination by radioactive substances, the extraction of minerals, development of gully systems, subsidence effects associated with waterlogging of soil, and construction of residential and industrial buildings on lands suitable for farming (Kashtanov 2001; Dobrovolski 2002).

The Federal program "Preservation and restoration of soil fertility of agricultural lands and agricultural landscapes as a national treasure of Russia in 2006–2010 and for the period till 2013" established indicators for restoration and rehabilitation of agricultural lands for 2010. These target indicators were exceeded by 2010; however, the rate of rehabilitation of degraded agricultural land is insufficient in comparison to the scale of land degradation in Russia. The area protected from water erosion, inundation and flooding, wind erosion and desertification constituted approximately 0.4 % of lands of Russia. The decrease in the degree of acidity of the soil was approximately 0.6 %, which equates to 0.06 % of the amelioration of solonetzic soils of all agricultural lands (Ministry of Agriculture 2011).

According to estimates at the present time, the total expected yield of eroded and deflated arable land is about 25 % less than of areas not affected by erosion. It means that the loss is 400 kg per ha in the equivalent for grain, and for the entire country it is about 14 billion kg, even taking into account the actual low crop yields and low productivity of natural grasslands. The shortage of products from degraded grasslands is about 100 kg per ha of hay, which gives 1400 million kg loss for the total area of the country (Ministry of Natural Resources and Environment of the Russian Federation 2013).

Erosion is evident in areas with hilly terrain. About 20 % of agricultural lands in Russia are on slopes steeper than 20 %. Under these conditions, water flow, resulting from intensive snowmelt or precipitation of heavy rainfalls, lead to the development of gully erosion. The total area of the gullies is 2.4 million ha (0.14 % of the total land area of the Russian Federation). The main part of the gullies are located on agricultural lands (0.6 million ha), forest (1.1 million ha) and protected environmental lands. Every year the area of ravines grows with devastating speed up to 180–200 thousand ha. The growth of gullies leads to the complete withdrawal of productive land or transforms it into other categories such as pasture or unused

land. The land area affected by gully erosion is 2.5–3 times larger than the area of the gullies, because of the difficulties for operation of agricultural machinery. Due to production conditions they have low productivity and are eventually transformed into low productive grazing lands. The annual loss of production from these lands is estimated at 1200 million kg of grain (Ministry of Natural Resources and Environment of the Russian Federation 2013).

Soil compaction leads to the loss of tillage performance by up to 5–10 %. Costs for fertilizer increase approximately by 1.5 times, as low-degraded lands require higher doses of fertilizers by 10 %, medium-degraded by 30 % and high-degraded 1.5–2 times (Gordeeva and Romanenko 2008). On heavily compacted soils yield reduction reaches 50 %. Low-compacted soils occupy 17 million ha; medium-compacted—69 million ha, and high-compacted—49 million ha of arable lands. Loss of fertility is 5–10, 20–30 and 50–60 %, respectively. Humus content is decreasing, the environmental condition of the soil is deteriorating, and more recently, the stability of the soils is decreasing. Humus storage in Chernozems is reduced annually by 0.62 t/ha over the last 15–25 years. Losses from the presence of acidic soils are 15–16 billion kg of agricultural products in terms of grain per year (Gordeeva and Romanenko 2008) (Table 18.7).

As it was mentioned above, it is more useful to take into analysis the macro-regions of Russia, such as the federal districts, because they are more homogenous in climatic conditions, economic development, and land-use practices. We have taken into consideration eight Federal districts—Central, North-Western, Southern, North Caucasian, Volga, Ural, Siberian, and Far Eastern.

Following Nkonya et al. (2011) we compare the changes in NDVI between 1981 and 2006 and some key biophysical and socioeconomic variables, such as precipitation, population density, government effectiveness, agricultural intensification, and Gross Domestic Product (GDP) (Figs. 18.2, 18.3, 18.4 and 18.5). Since such relationships could differ across the country, we disaggregate the analysis across the eight Federal districts of Russia. The analysis showed a positive correlation between changes in key biophysical and socioeconomic variables with NDVI in most of the Federal districts of Russia. The exceptions are the FD with large and more heterogeneous territory such as Siberian and Far Eastern FDs. The most positive results were in the Chernozem Agro-ecological zone—the southern part of Russia.

Table 18.7 Dynamics of agrochemicals application and land improvement in Russia (on average)

| Indicators	1991–1995	2003–2007
Application of organic fertilizers, billion kg (kg/ha)	150.1 (1700)	51.8 (900)
Supply of mineral fertilizers, billion kg	4.5	1.5
Application of mineral fertilizers, kg/ha	35	28
Melioration of acidic soils, thousand ha	2733	314
Application of phosphorous fertilizers, thousand ha	1021	39.1
Melioration of Solonetz, thousand ha	66.2	3.2
Processing of Solonetz, thousand ha	84	10.1

Source Gordeeva and Romanenko (2008)
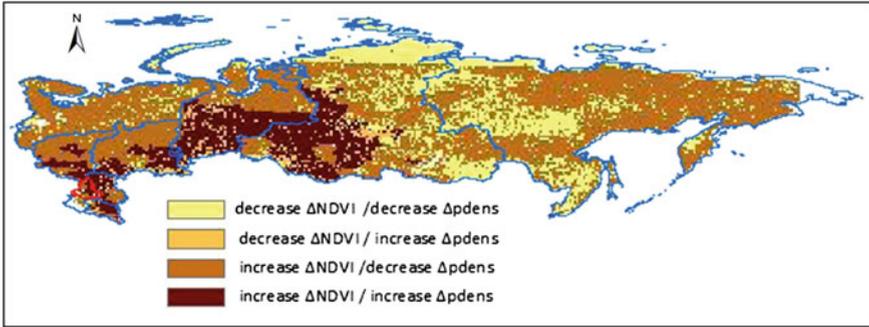
Fig. 18.2 Relationship between change in NDVI and population density. *Source* Based on Nkonya et al. (2011)
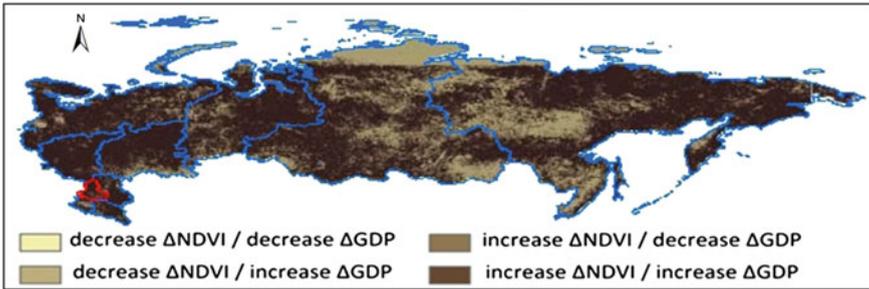

Fig. 18.3 Relationship between GDP and NDVI. *Source* Based on Nkonya et al. (2011)
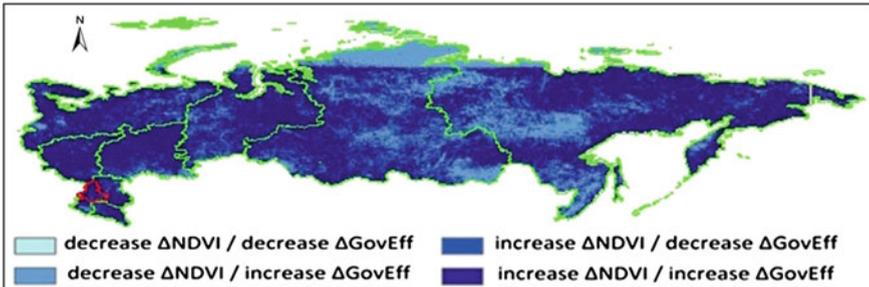

Fig. 18.4 Relationship between government effectiveness and NDVI. *Source* Based on Nkonya et al. (2011)

Le et al. (2014) used 7 broad land use/cover classes (see Fig. 18.6) aggregated from 23 classes of the Globcover 2005–2006 data (Bicheron et al. 2008). Figure 18.6 shows the main land-cover/land-use changes compared to long term NDVI (1982–2006). The NDVI layer corrects for AF (atmospheric fertilization),
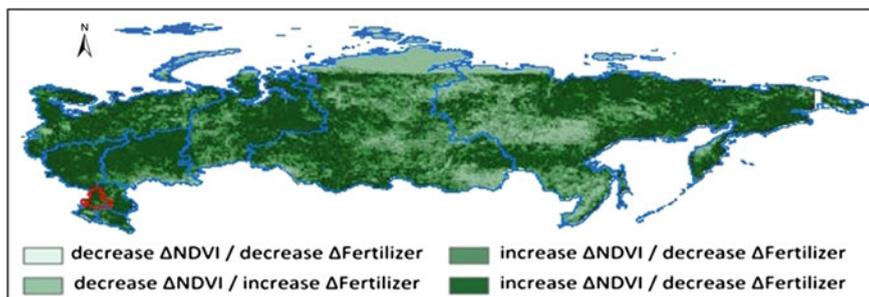
Fig. 18.5 Relationship between fertilizer application and NDVI. *Source* Based on Nkonya et al. (2011)
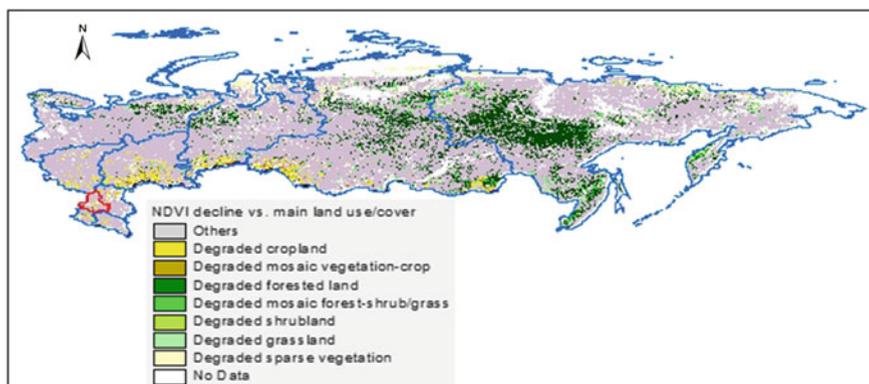

Fig. 18.6 Areas of long-term (1982–2006) NDVI decline (with correction of RF and AF effects and masking saturated NDVI zones) versus main land cover/use types of the Russian Federation. *Source* Based on Le et al. (2014). Note: *Blue color*—boundaries of Federal districts, *red color*— boundaries of Rostov region. "*Others*" means not degraded areas

areas with a high positive correlation with RF (rainfall), and saturated areas of NDVI (see Chap. 5). The related statistics for Russia are shown in Table 18.8. Figure 18.6 shows that land degradation hotspots in Russia are mainly on forested areas, croplands and areas with sparse vegetation. These are areas affected by forest fires (Sakha Republic, Krasnoyarskiy territory, etc.) and crop land degradation (Saratov, Omsk, Tyumen, Kurgan regions, etc.), due to processes such as salinization, degradation of irrigated lands, and desertification. In the case study of the Rostov region, we can also see the manifestation of cropland degradation processes.

Table 18.8 shows that close to 20 % or more (except shrub-land) of each main land cover/use types were affected by degradation processes. Croplands, especially in the southern part of Russia, where the agricultural industry is more risky due to drought, wind erosion, and problems with moral obsolescence of the irrigation system, have the biggest percentage of degradation in Russia (27 %).

Table 18.8 Value for Areas of long-term (1982–2006) NDVI decline (with correction of RF and AF effects and masking saturated NDVI zones) versus main land cover/use types of the Russian Federation in km^2 and in percentages for the corresponding land cover

NDVI decline versus main land use/cover	Value (km^2)	Percentage (%)
Degraded cropland	562,048	27
Degraded mosaic vegetation-crop	183,296	27
Degraded forest land	4,074,176	24
Degraded mosaic forest land	482,944	22
Degraded shrub-land	116,416	6
Degraded grassland	162,176	17
Degraded sparse vegetation	1,401,792	19
Total	6,982,848	43

Source Le et al. (2014)

Identification of Land Degradation Trends and Hotpots in Federal Districts of Russia

Our analysis shows that Russia at the Federal district level has been experiencing dynamic land-use and land-cover changes (LUCC) over the last decade (2001–2009). Tables 18.9 and 18.10 present these changes over the period of 2001 and 2009, using the data from the Moderate Resolution Imaging Spectroradiometer (MODIS) remotely sensed datasets. We can see that the largest areas of croplands are in Siberian and Volga FD (Fig. 18.7). But the bioclimatic conditions of these FDs are far from the optimum. Arable lands of the Volga FD are affected by salinization and water erosion and of the Siberian FD are affected by erosion and desertification.

Table 18.10 shows that Siberian, Far Eastern, and Ural FDs lost vast areas of grassland (66 million ha) and shrublands (55 million ha), which were almost totally converted into forestland (Fig. 18.8). The total addition to forests over the last

Table 18.9 Land use/cover classification in Federal districts of Russia in 2001, in million ha

Federal districts	Cropland	Forest	Grassland	Shrublands	Urban	Water	Barren
Central	31.1	25.8	5.7	1.6	0.6	0.4	0.0
Southern	22.8	2.4	14.0	1.6	0.7	0.4	0.1
Northwestern	3.4	83.5	8.4	58.0	8.1	0.1	5.3
Far Eastern	10.8	147.0	59.8	388.0	6.3	0.3	2.6
Siberian	50.2	188.0	43.5	213.8	9.0	0.6	4.3
Ural	12.9	47.3	10.2	96.7	5.2	0.1	0.2
Volga	53.8	38.7	6.2	3.2	1.4	0.3	0.0
North Caucasian	7.9	1.8	4.9	1.5	0.1	0.3	0.3
Total	193	535	153	765	32	3	13

Source Calculated using MODIS data

Table 18.10 Land use/cover change in Federal districts of Russia in 2009 relative to 2001, in million ha

Federal districts	Cropland	Forest	Grassland	Shrublands	Urban	Water	Barren
Central	0	4	−3	−1	0	0	0
Southern	−2	0	2	−1	0	0	0
Northwestern	−1	8	1	−7	−2	0	1
Far Eastern	1	44	−40	−3	−2	0	0
Siberian	−1	49	−22	−27	−1	0	3
Ural	3	14	−4	−13	0	0	0
Volga	−4	6	0	−2	0	0	0
North Caucasian	0	0	0	0	0	0	0
Total	−4	125	−66	−55	−6	0	4

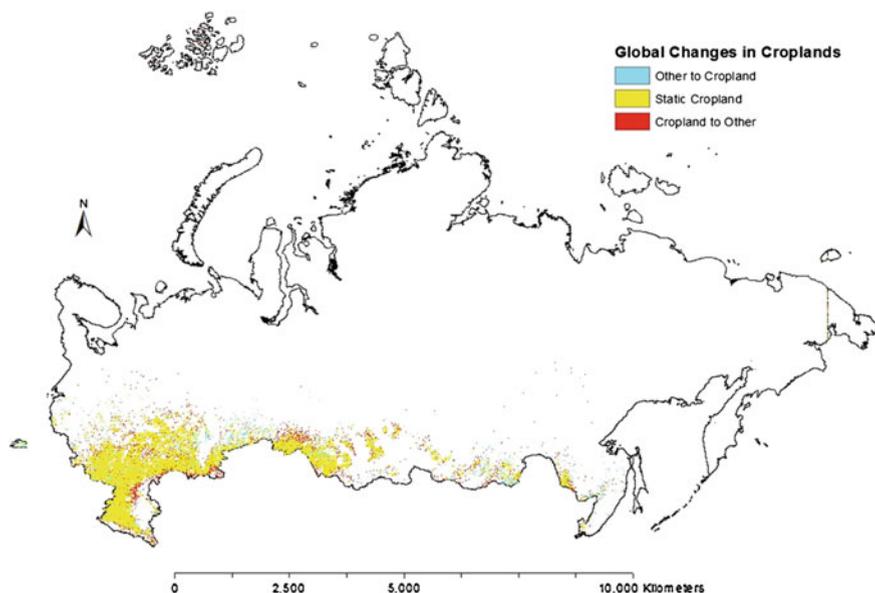*Source* Calculated using MODIS data

Fig. 18.7 Global changes in croplands in Russia in 2009 relative to 2001. *Source* Based on MODIS data

period was 125 million ha. This conversion can be explained by land abandonment and reduction of the number of cattle over the last twenty years. The reduction of croplands still takes place in most of the territory. In some respects, this may be a beneficial change since ecological functions provided by forests are larger than grasslands and shrublands. Another positive impact is that Russia did not have a desiccation of the water bodies. The increase of barren lands by 4 million ha can be
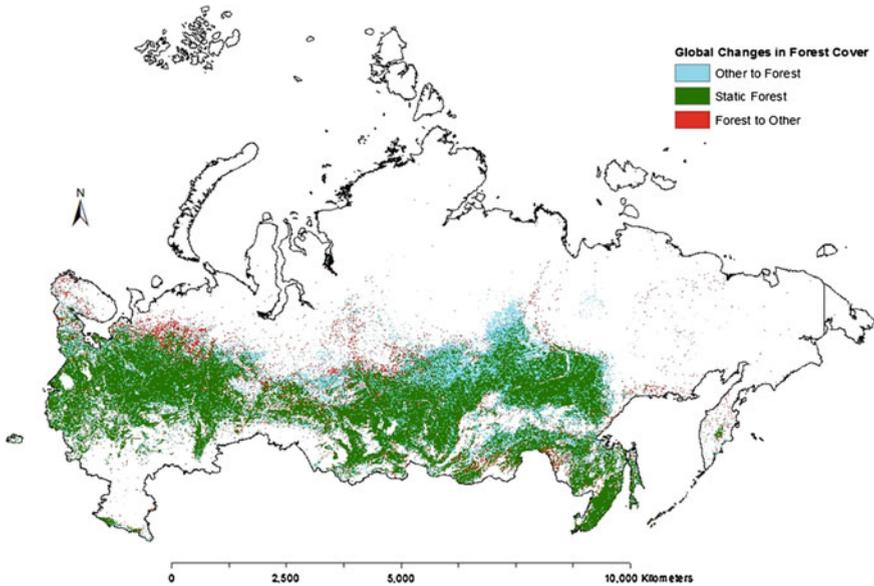
Fig. 18.8 Global changes in forest cover in Russia in 2009 relative to 2001. *Source* Based on MODIS data

explained by intensive developing of mineral resources, industrial construction, and manifestation of degradation processes in the southern part of the country such as desertification and salinization.

Economic Impacts of Land Degradation

We have calculated the costs of land degradation in Russia using the approach described in detail in the methodological chapter of this book. The results show that the total costs of land degradation due to land-use change only (i.e. without the costs of land degradation due to lower soil and land productivity within the same land use), are about 189 billion USD during the period of 2001–2009 (Table 18.11), i.e. about 23.6 billion USD annually, or about 2 % of Russia's Gross Domestic Product (GDP) in 2010. Most of these costs, about two thirds, are related to land-cover change in Siberian and Far Eastern districts. Land degradation costs per capita also vary among Federal districts: the highest in Far Eastern (1460 USD annually) and lowest in Southern, Central and Volga (18, 20 and 21 USD annually, respectively).

The Total Economic Value of ecosystem goods and services is estimated to equal about 3700 billion USD in Russia, exceeding the GDP by 3 times. The relative value of ecosystems per capita depends on the territory, land use/cover characteristics, and 0. In this regard, the Far Eastern district with its huge territory,

Table 18.11 The costs of land degradation in Federal districts of Russia through land-use change, including TEV values

Federal district	Costs of land degradation (2001–2009)	Annual costs of land degradation, in billion USD	Annual cost of land degradation per capita, in USD	GDPin 2010, current billion USD	Land degradation as a share of GDP (%), annually
Central	6	0.8	20	434	0.2
Southern	2	0.3	18	75	0.4
Northwestern	17	2.1	154	127	1.7
Far Eastern	76	9.5	1460	68	14.0
Siberian	61	7.6	389	133	5.7
Ural	18	2.3	185	165	1.4
Volga	5	0.6	21	184	0.3
North Caucasian	3	0.4	42	29	1.4
Total	189	23.6	164	1216	1.9

Source Calculated by authors using initial data from Nkonya et al. (2014), based on LUCC during the period of 2001–2009

most of it under higher valued shrublands, forest lands, and grasslands, and relatively smaller population, has the highest per capita value of ecosystems in Russia. Whereas, for example the Central district, with the biggest population in the region and almost half of its territory consisting of croplands, has one of the lowest value of ecosystems. From another perspective, in the Far Eastern district the share of GDP of the Total Economic Value is just 5 %, this number is 334 % in the Central district and between 90 % and 97 % in the Southern, Volga and North Caucasian districts. This implies that population pressure on ecosystems is much higher in these four districts (Table 18.12).

Table 18.12 Total Economic Value (TEV) of Land Ecosystems and GDP in Federal districts of Russia, billion USD

Federal district	TEV 2001	TEV 2009	GDP in 2009	Value of ecosystems per capita, in USD	GDP/TEV (%)
Central	129	130	434	3406	334
Southern	76	80	75	5762	94
Northwestern	441	439	127	31,823	29
Far Eastern	1300	1290	68	198,229	5
Siberian	1150	1180	133	60,182	11
Ural	381	394	165	32,339	42
Volga	199	208	184	6804	88
North Caucasian	30	30	29	3325	97
Total	3700	3750	1216	26,088	32

Source Calculated by authors using initial data from Nkonya et al. (2014)

Cost of Actions

The results of the analysis of the costs of action, following the methodology presented earlier, are given in Table 18.13. The results show that the costs of action against land degradation are lower than the costs of inaction in Russia by 5–6 times over the 30 year horizon, meaning that each dollar spent on addressing land degradation is likely to have about 5–6 dollars of returns. The costs of action were found to equal about 702 billion USD over the 30-year horizon (Fig. 18.9), whereas if nothing is done, the resulting losses may equal almost 3663 billion USD during the same period. Almost 92 % of the costs of action are made up of the opportunity costs of action. This is one of the key barriers for actions against land degradation, as the costs are tangible and may need to be borne by landusers, as well as regional and federal budgets, however, the benefits of action are not fully internalized by landusers and often not even locally, as they represent global benefits from additional ecosystem services enjoyed by the whole world. At the same time, it is also true that these restored ecosystem services and goods would benefit first and foremost the people living in these degraded areas and Russian society as whole.

Figure 18.10 showed the map with several layers: costs of action over the 30-year horizon in US dollars shown per hectare and land degradation hotspots. For example, we will look at the European part of Russia. This region should show the most accurate results because of the data used and benefit transfer approach. Three categories of lands might be distinguished: the first category—the degraded lands with high costs of actions; the second category—the improved lands with low costs of actions; and third category—cross-matches of the first and second categories. The cost of action of this category is from 2 to 11 thousand US dollars per ha. The areas are mostly concentrated in the southern part of Russia: the dig cluster consists of Astrakhan, Volgograd, Saratov, Orenburg regions. These regions are affected by soil salinity and alkalinity problems; the other cluster consists of Caucasia regions, which are affected by moderate and serve water erosion; the third cluster is Chernozem zone, where there is an intensive agricultural activity (the lands basically change into croplands); and last cluster is northern part (mainly Komi Republic)—the area of rivers and swamps. The degraded area is situated in the basin of Pechora and Usa rivers. We link these results with hydrological conditions and type of rivers dietary habits—mainly snow, which is not stable from year to year. It was shown that different sources come to the same results, so we can talk about land degradation in these regions with a big share of confidence. The cost of action of the second category is from 0.1 to 2 thousand US dollars per ha. The area is mainly the northern border of Central Chernozem zone, where many croplands, due to different reasons, which were described in the first part of the chapter, were changed to other categories (Fig. 18.7) and so land improvements occurred. It should be also taken into account that this area is less eroded and not affected by salinity and alkalinity as was the case in the southern part of Russia. The third category needs additional analyses on land degradation and improvement.

Table 18.13 Costs of action versus inaction in Federal districts of Russia, in billion USD

Federal districts	Costs of land degradation (2001–2009)	Of which, the costs of provisional ecosystem services	Cost of action (6 years)	Cost of action (30 years)	Opportunity cost of action	Cost of inaction (6 years)	Cost of inaction (30 years)	Proportion of cost of action/inaction (30 years) (%)
Central	6	2	14	14	13	43	93	14
Southern	2	0	5	5	5	15	32	16
Northwestern	17	16	81	82	75	161	348	22
Far Eastern	76	60	279	283	263	720	1558	17
Siberian	61	44	217	220	201	530	1147	18
Ural	18	12	77	77	71	164	355	20
Volga	5	2	14	14	12	39	85	15
North Caucasian	3	1	7	7	6	21	46	14
Total	189	136	694	702	647	1693	3663	18

Source Calculated by authors using initial data from Nkonya et al. (2014)
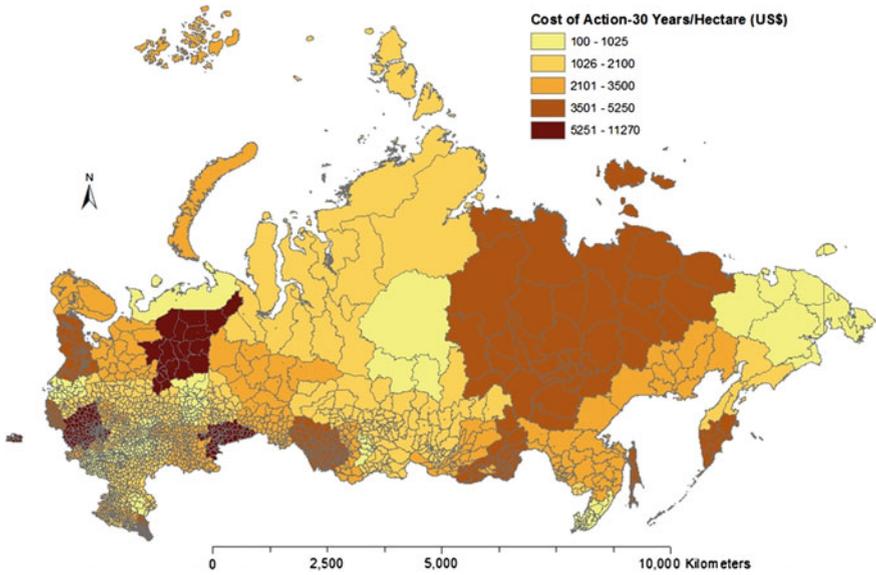
Fig. 18.9 Costs of action over the 30-year horizon in US dollars shown per hectare. *Source* Image was prepared by authors using initial data from Nkonya et al. (2014)
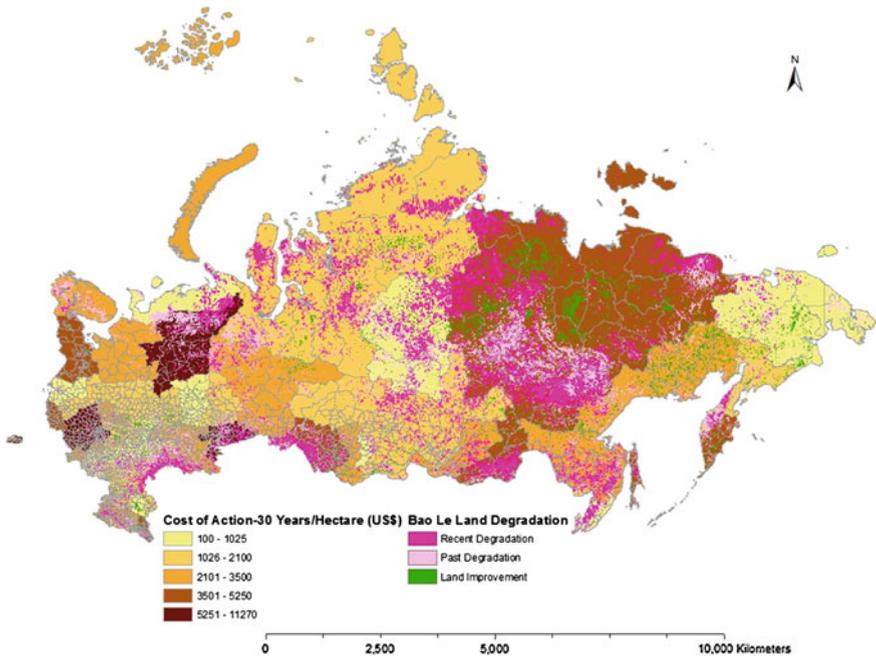

Fig. 18.10 Costs of action over the 30-year horizon in USD shown per hectare with land degradation hotspots. *Source* Image was prepared by authors using initial data from Nkonya et al. (2014) and Le et al. (2014)

Fig. 18.11 Map of the subjects of Russian Federation. *Source* https://commons.wikimedia.org/wiki/File%3ARostov_in_Russia.svg. Note: *Red color*—Rostov region, *light-green color* marked with *arrowhead*—Azov district

A Detailed Study of the Issues Related to Agriculture and Land Degradation in the Azov District of the Rostov Region

The Azov district is a very favorable economic and geographical area of the Rostov region. Transportation infrastructure, skilled manpower, and lack of social tensions has historically defined the area as one of the largest centers of diversified industries, developed agriculture, science, and culture in the Southern part of Russia (Fig. 18.11).

General Information About the Azov District of the Rostov Region

The Azov district is located in the South-Western part of the Rostov region. The total area of the district is 286.2 thousand ha. The Azov district has the largest population in the area. According to statistics, the population of the district is 90,642 people (Federal State Statistics Service 2014b). The demographic situation in the region continues to be adverse due to the natural decrease of population. Migration remains the main source of replenishment of the population. The agricultural lands occupy up to 73.9 % of the total area of the district, and the arable lands constitute 85.7 % of the agricultural land. The agricultural specialization of the Azov district is crop production, though livestock production also present.

The main crops grown in the area are: winter wheat, spring barley, sunflower, corn, annual and perennial herbs, vegetables, and fruits. Agricultural production in the area is based on 26 large and medium-sized farms, 108 small farms, 107 individual entrepreneurs, 62 horticultural and 5 suburban associations, and a total of 33,892 households. The share of the State sector in the total number of registered entities is 5.9 %, and of private individuals is 94.1 % (Federal State Statistics Service 2014a, b, c). The structure of agricultural land use is: 210.4 thousand ha of agricultural land, including 182.5 thousand ha of arable land, 4.0 thousand ha of hayfields, 21.1 thousand ha of pasture, and 1.5 thousand ha of perennial plants. More than 25 % of the agricultural undertakings in the region have a positive profit margin. The gross grain harvest in 2010 was 353,300 thousand kg, with the average yield of 3900 kg/ha. The volatility of the yields of crops depends not only on fluctuations in the weather, but also from insufficient application of fertilizers and violation of farming system methods. At the same period of time in the seed-growing farms the yield was 4350 kg/ha. This fact indicates the presence of some reserves to improve crop yields in the district. However, there are issues related to losses of water, nutrients and carbon storage, and degradation processes.

Large losses of water are found during the process of transporting of up to 40 % (instead of the projected 22 %) on water supply networks. Mostly from irrigation channels due to their physical and moral wear and tear. Burning stubble in the fields of agricultural enterprises is unauthorized but yet takes place in almost all territories of the region. Intensive development of negative processes and phenomena, such as water and wind erosion, loss of humus, waterlogging, salinity, alkalinity, soil pollution with toxic substances continues to take place. The region is affected by erosion, on more than 35 % of agricultural land. For combating erosion, it has been planned to plant windbreaks and to stabilize gullies by planting trees however only 10–20 % of the planned work has been performed. Desertification is the most important environmental and socio-economic problem of the region (Ministry of Natural Resources and Environment of the Russian Federation 2013). Natural soil fertility has to be maintained by application of fertilizers: organic and nitrogen fertilizers are applied in almost sufficient doses, while phosphate and potash fertilization is not enough (Table 18.14).

In spite of the fact that the Azov district is in a zone of strong wind erosion and moderate water erosion, there is not enough attention aimed at the conservation of crops and lands from erosion on farms. The development of the erosion processes is

Table 18.14 Mean application of fertilizers (for 5 years) and qualitative assessment of deviation from norm (regarding the data from experimental farms, which was adopted as a norm)

Fertilizer application	Mean for 5 years, kg/ha	Variation from norm
Organic	2900	Almost enough
Nitrogen	28.2	Almost enough
Phosphate	18.4	Not enough
Potash	2.4	Not enough

Source Based on Federal State Statistics Service (2014a)

insufficiently monitored in the region. Old soil survey materials do not reflect the processes of wind erosion. There are no ongoing works on reclamation of saline soils, while there are about 24,967 ha of soils with various degree of salinization in the district. The formation of saline soils in the district mainly occurs because of improper or excessive irrigation. Such phenomena occur in areas with shallow saline groundwater or saline deposits. Many farms do not comply with the recommendations (Ministry of Agriculture of Russian SFSR 1978).

The climate of the Azov district is moderately continental with the average amplitude of temperatures 28.1 °C and the ratio of annual precipitation to potential evaporation of 0.7–0.8. According to the agro-climatic zoning of the Rostov region, the Azov district belongs to the dry zone. In general, the climatic conditions are quite favorable for the development of agricultural production, but some climate features such as drought, strong winds and strong fluctuations in other climatic indexes over the years, require a strict adherence of agricultural technology for the accumulation and preservation of moisture in the soil and protection of soil from wind and water erosion. In general, flat topography creates favorable conditions for soil management, plant care, and harvesting.

The Azov district belongs to the soil province of Ciscaucasia Chernozems. The main features of the district's soil cover are homogeneity caused by flat steppe conditions, as well as deep topsoil (humus accumulative horizon) and the accumulation of a large number of shallow carbonate salts. Also hydromorphic Chernozems, Luvisols, and wetlands soils with various degree of salinization are formed in this district territory. Ministry of Agriculture of Russian SFSR (1978) shows that in the Azov district 214,149 ha or 70.6 % of its territory is formed by Chernozems, among which 15,198 ha or 5 % of the soils are exposed to water erosion, and 23,074 ha or 7.6 % are exposed to wind erosion. Within the district there are 2657 ha of nitric soils, 2346 ha of sodic soils, 18,505 ha of saline soils (mostly floodplain), and 16.775 ha of wetland soils.

Soil data analysis shows that in the district's soil cover, potentially rich soils predominate. A high percentage of saline (6.1 %) and wetland (7.7 %) soils occur in the floodplains. The presence of eroded soils in watersheds indicates that after their improvement (melioration) and cultivation, there are additional opportunities for further development of agriculture and animal husbandry at the expense of not yet productive and sometimes unproductive land use. It is important to emphasize the necessity of sustainable use of cultivated soils and maintenance of their fertility.

In accordance with the old system having been used in the Soviet Union, the agricultural lands of a farm are divided into agroindustrial groups. The last report of Ministry of Agriculture of Russian SFSR (1978) said that all soil types that are allocated in the Azov district are combined in 25 land management groups by taking into account their genesis, physic-chemical properties, water-air regime, geology, relief, etc. The first group included the best arable soils with no limitations for producing zonal crops. In the case of the Pobeda farm the soils of the 1st agroindustrial group included Chernozems and Gleyic Chernozems, and the recommended crops were winter wheat, corn, barley, millet, beans, and sunflower (Ministry of Agriculture of Russian SFSR 1978). It was recommended to cultivate

sugar beet, and upland vegetable cultures in depressions. The complex of agrotechnical measures had to be directed on moisture accumulation in soil. Other groups included areas with weak development of wind and water erosional processes. They are also suitable to cultivate general crops. The complex of agrotechnical measures had to be directed on prevention of further erosion and moisture containment. The worst soils were included in the other agroindustrial groups: each of the groups had certain limitations in soil use and required special measures for soil protection. For example, sodification, salinity and severe erosion. It is not completely clear, if these recommendations are still followed at the Azov farms.

Identification of the Causes and Extent of Land Degradation in the Azov District of the Rostov Region

The Choice of the Model Object

The Southern Federal district is the most intensive agricultural region of the Russian Federation. The level of tilled lands in this region exceeds 80 %. Obviously, land-use change studies require spatially distributed research, which is time-consuming, even on the level of data collection. The compromise was to study one administrative district, the Azov district of the Rostov region (Fig. 18.12). The time interval for the study (1990–2010) was identified by the availability and accuracy of the data used. Multi-temporal maps were made to assess the variability of land use in the area (Bryzzhev and Ruhovich 2013).

Figure 18.13 shows the plots where at least once during the analyzed period (1990–2010) the agricultural processing was not performed, was difficult, or did not give the intended outcome (harvest).

The total studied area is 292,478 ha. Agricultural lands, i.e. lands that were processed at any given time (arable land, including irrigated areas, garden areas, etc.), take up 193,261 ha (66 %) of the resulting data. The territory was subjected to different land-use changes. From 1990 to 2000, 10,355 ha (5.35 %) had changed, from 2000 to 2010, 5450 ha (3.5 %) changed. Bryzzhev and Ruhovich (2013) showed that despite the relative homogeneity of the district in climatic, geological, and topographical terms, for 20 years (from 1990 to 2010), more than 8 % of the territory ware affected by land-use change.

The main trends of land-use changes are:

- The withdrawal of lands from agricultural use to under buildings—2584 ha. This process is controlled exclusively by the administration of the Azov district. Most often it does not depend on soil characteristics, so sometimes the best soils were removed from agricultural land.
- Agricultural activity, which was not previously active (fallow)—1535 ha.
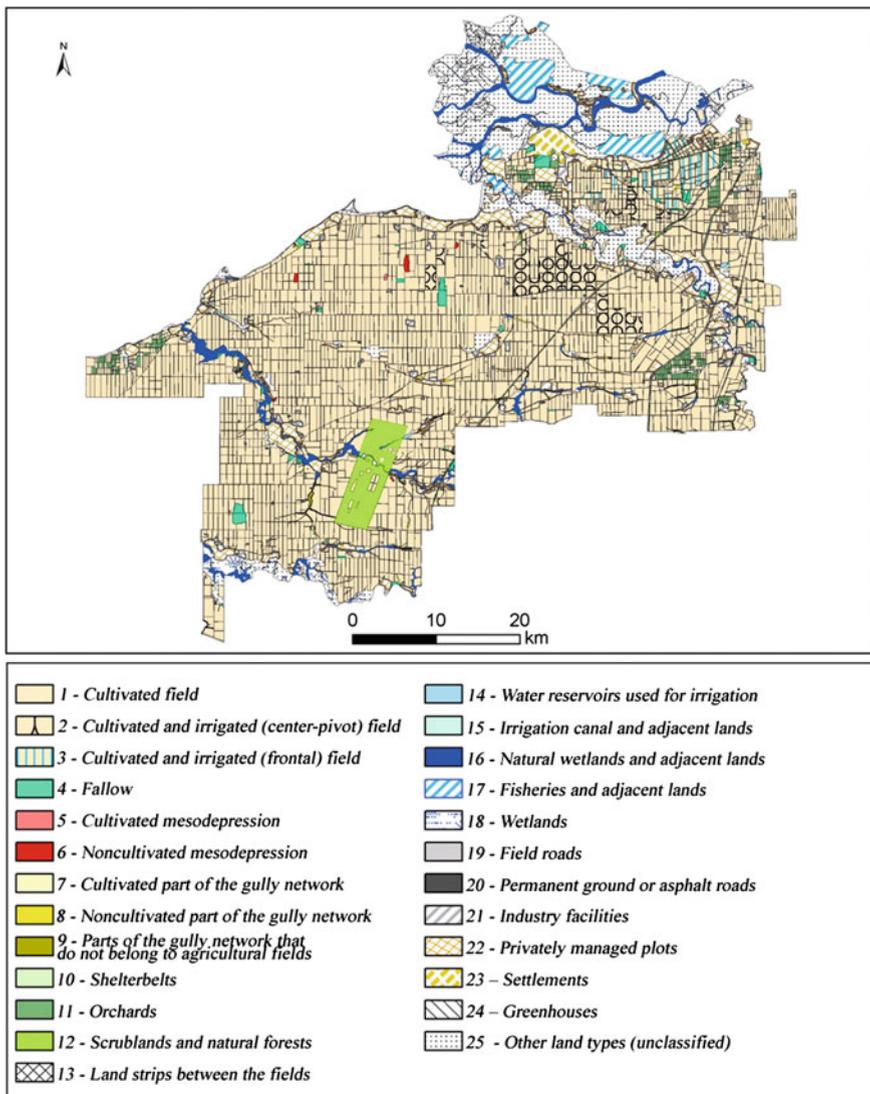
Fig. 18.12 Map of land use of the Azov district of the Rostov region. *Source* The authors

- Termination of agricultural fields (deposits)—1210 ha. Processes related to the improvement/degradation of soil characteristics, as a result of climate change, land improvement, melioration, etc.
- The irrigation (of various types) of previously rain-fed agricultural fields— 4136 ha. Irrigation was introduced on agricultural fields, mainly occupying automorphic areas.
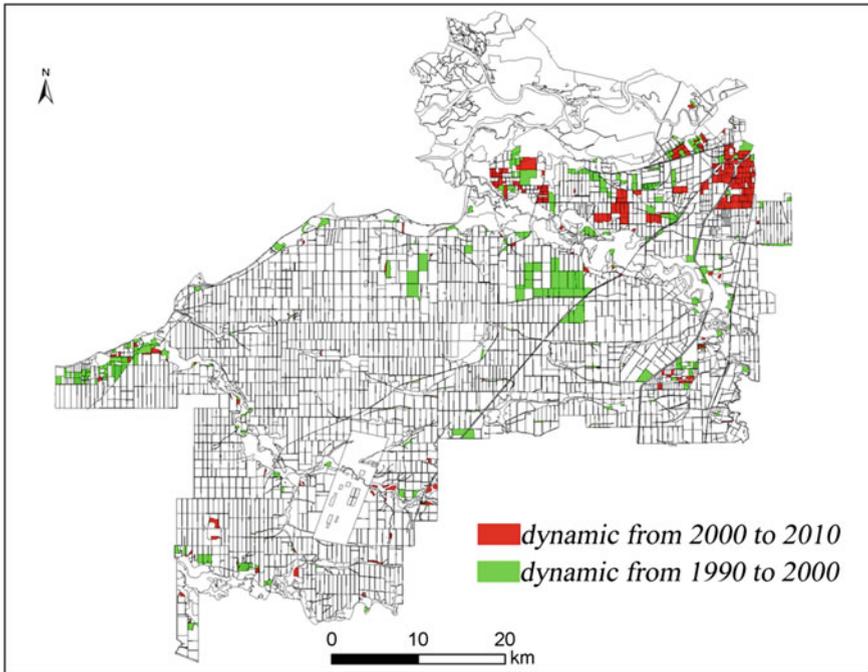
Fig. 18.13 Map of land use change on plots of the Azov district of Rostov region (1990–2000 and 2000–2010). *Source* The authors. *Note* The *colors* refer to any land-use change occurring between each date

- The development of a gully network—738 ha. The process leading to the increase in the area occupied by eroded soils. This is a process that is difficult to reverse, it is necessary to conduct special anti-erosion measures.

One of the leading negative soil processes of the district is the process of soil salinization. Moreover, this process was exacerbated mainly due to improper planning of agricultural lands. The establishment of agricultural fields in the majority of cases is conducted by planting forest belts and roads along the fields. As a result saline soils were involved in tillage lands. The area of the saline soils occupies about 11 % of the total area of the Azov district, but it occupies about 2 % of arable land, i.e. there is not a specific need to use these lands for agriculture. But saline soils exist as fragments of many fields due to the rectangular cut of the fields bordered by forest belts and roads. Moreover forest belts and roads violate the original hydrological regime of the landscape, leading to the gradual spread of saline soils or increase of the degree of salinization. Agriculture in saline soils is unsustainable. Table 18.15 shows that the share of the shift to other land uses of non-saline soils was 7.2 %, but the same for saline soils was 17.3 % (2.4 times higher for the period of 20 years (Ruhovich et al. in press). It should be noted that the land-use changes of non-saline soils was mostly from building construction, the

Table 18.15 Dynamics of the territory of the Azov district, Rostov region including non-saline and saline soils

Soils	Total area (ha)	Agricultural area (ha)	Area of dynamics 1990–2000 (ha)	Dynamics 1990–2000 (%)	Area of dynamics 2000–2010 (ha)	Dynamics 2000–2010 (%)
Total	292,478	193,261	10,355	5.36	5450	2.82
Non-saline	260,812	189,295	9838	5.20	5271	2.78
Saline	31,666	3966	517	13.02	179	4.53

Source The authors

uprooting of orchards, etc. and in saline soils the changes were only due to the absence of harvest, due to salt regime. In addition, saline soils often hinder the passage of agricultural machinery, which leads to the fragmentation of fields and serves as a source of weeds.

The Evaluation of the Potential Cost of Land Degradation

Our analysis shows that the Azov district has been experiencing dynamic land-use and land-cover changes over the last two decades: in 2000 relative to 1990 and in 2010 relative to 2000 (Table 18.16).

Table 18.16 shows that Azov district totally lost areas of shrublands (4122 ha), which were converted mainly into croplands and urban territories. The total increase in croplands over the last period 2000–2010 was 2908 ha. This conversion can be explained by liquidation of orchard areas over the last ten years. The reduction of croplands in 2000 relative to 1990 can be explained by termination of processing of agricultural fields with subsequent construction of household out-buildings (including roads) or residential housings. The increase of grasslands by 235 ha, as it was mentioned before, can be explained by termination of processing of agricultural fields due to erosion or degradation of soil agronomy quality.

The time period of 2000–2010 was chosen for economics of land degradation analysis due to the availability and accuracy of the data used. Our analysis shows that Azov district has been experiencing dynamic land use and land cover changes (LUCC) over the 2000s.

Table 18.16 Land use/cover change in the Azov district of the Rostov region in 2000 relative to 1990, in 2010 relative to 2000 and total change, ha

Period	Cropland	Forest	Grassland	Shrublands	Urban	Water	Barren
2000–1990	−1566.59	3.79	233.80	−1200.79	2529.79	0	0
2010–2000	2908.19	−2.66	1.05	−2921.60	15.02	0	0
Total	1341.60	1.13	234.85	−4122.39	2544.81	0	0

Source Using land-use monitoring datasets

Table 18.17 The costs of land degradation in the Azov district of the Rostov region of Russia through land use change in 2010 relative to 2000

Annual cost of land degradation in 2010 as compared with 2000, in million USD	Annual cost of land degradation per capita including the value lost ecosystem services, in USD	Total agricultural production (TAP) in 2010, current million USD	Land degradation as a share of TAP (%), annually
0.3	3.6	242.5	0.1

Source Authors calculations using data of ROSSTAT, World Bank and initial data from Nkonya et al. (2014)

Table 18.18 Total Economic Value (TEV) of Land Ecosystems and TAP in Azov district of Rostov region of Russia, million USD

TEV 2000	TEV 2010	Total agricultural production (TAP) in 2010	Value of ecosystems per capita, in USD	TAP/TEV
505	503	242.5	52.5	48.1 %

Source Authors calculations using data of ROSSTAT, World Bank and initial data from Nkonya et al. (2014)

We have calculated the cost of land degradation in the region using the approach described in detail in the methodological chapter of this book. The results in Table 18.17 show that annual cost of degradation on the sample period due to land use change only, i.e. without the costs of land degradation due to soil-ecological conditions and productivity within the same land use, are 0.3 in 2010 as compared with 2000, in million USD. The land use shift happened because of favorable conditions for growing crops in Azov region.

The Russian attitude to ecosystem value is rather low—52.5 USD per capita,[2] which is ten times lower than in the developed countries. The total economic value of ecosystem goods and services is estimated to equal about 503 million USD in Azov district, doubling the TAP. The TAP/TEV estimation 48.1 % for Azov district shows us that there's much else to do in economic activities besides agriculture (Table 18.18).

Cost of Actions

Cost of action and inaction, presented in Table 18.19. The results show that the cost of action against land degradation in the Azov district will be 12.65 million dollars in a 6 year time period. For example the planned volume of financial support for the

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[2]Estimation taken from TEEB website.

Table 18.19 Costs of action vs inaction in Azov district of Rostov region of Russia, in million USD

District	TAP in 2010	Annual TEV cost of land degradation in 2010 as compared with 2000, in million USD	Cost of action (6 years)	Cost of action (30 years)	Cost of inaction (6 years)	Cost of inaction (30 years)	Ratio of cost of action/inaction in 30 years (%)	Ratio (USD)
Azov	242.5	0.3	12.65	23.53	13.37	25.08	94	1.07

Source Authors calculations using data of ROSSTAT, World Bank and initial data from Nkonya et al. (2014)

Russian Federal program for Melioration in 2014–2020 is 4012 million USD.[3] The ratio of cost of action/inaction in a 30 years period is 94 %: 23.53–25.08 million USD, respectively. In other words every invested dollar against land degradation in this area will give back 1.07 dollars. We have to take this result as being critical, because the TEV used for these calculations are suitable for Russia as a whole, but in the Azov district more precise values might be different.

Conclusions

The vastness of the territory of the Russian Federation inevitably leads to a diversity of natural conditions that causes the development of multiple approaches to the economic use of land resources. Climatic conditions have a direct and indirect impact on biological components of natural landscapes and soil forming processes. In their turn the biophysical conditions determine the shape of agricultural development of the territory, with various land-use systems and with different major degradation processes. The major drivers of degradation include climatic change, unsustainable agricultural practices, industrial and mining activities, expansion of crop production to fragile and marginal areas, inadequate maintenance of irrigation and drainage networks, and overgrazing.

The calculations show that the total land use/cover dynamic changes are about 130 million ha, and the total annual costs of land degradation due to land-use change only, i.e. without the costs of land degradation due to soil-ecological conditions and productivity within the same land use, are about 189 billion USD for the period of 2001–2009. i.e. 23.6 billion USD annually. The total economic value of ecosystem goods and services is estimated to equal about 3700 billion USD in Russia, exceeding the GDP by 3 times. The costs of action against land degradation are lower than the costs of inaction in Russia by 5–6 times over the 30 year horizon, meaning that each dollar spent on addressing land degradation is likely to have about 5–6 dollars of returns. In our opinion this is a significant economic justification to favor rational agricultural and sustainable land use practices and also actions against degradation. Almost 92 % of the costs of action are made up of the opportunity costs of action. On the other hand, at the level of Azov district, Rostov province, we have found that the cost of action against land degradation is 1.07 times higher than cost of inaction.

We recommend raising awareness on the ELD in Russia for improving the effectiveness of agricultural production, however we have to mention that the average TEV used in these calculations should be corrected in future work, with reference to Russian local surveys and data.

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[3]Ratio RUB to USD equal to 0.022.

References

Bicheron, P., Defourny, P., Brockmann, C., Schouten, L., Vancutsem, C., Huc, M., et al. (2008). GLOBCOVER: products description and validation report. http://due.esrin.esa.int/globcover/LandCover_V2.2/GLOBCOVER_Products_Description_Validation_Report_I2.1.pdf. ESA Globcover Project, led by MEDIAS-France/POSTEL.

Bryzzhev, A. V., & Ruhovich, D. I. (2013). Organization of retrospective monitoring soil and land cover of Azov district of Rostov region. *Eurasian Soil Science., 11*, 1294–1315.

Dobrovolski, G. V. (Ed.). (2002). *Soil degradation and preservation*. Moscow: Moscow University publishing house. (in Russian).

Federal State Statistics Service. (2014a). Official statistics. Entrepreneurship. Agriculture, hunting and forestry. http://www.gks.ru/. (in Russian).

Federal State Statistics Service. (2014b). Official statistics. Publications. Catalogue of publications. Demographic Yearbook of Russia. http://www.gks.ru/. (in Russian).

Federal State Statistics Service. (2014c). Official statistics. Publications. Catalogue of publications. Russia and foreign countries. http://www.gks.ru/. (in Russian).

Friedl, M. A., Sulla-Menashe, D., Tan, B., Schneider, A., Ramankutty, N., Sibley, A., & Huang, X. (2010). MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets. *Remote Sensing of Environment, 114*, 168–182.

Gordeeva, A. V., & Romanenko, G.A. (Eds.). (2008). *Issues of degradation and productivity restoration of agricultural lands in Russia*. Moscow: Rosinformagroteh. (in Russian).

Kashtanov, A. N. (2001). Concept of sustainable development of agriculture of Russia in XXI century. *Pochvovedenie, 3*, 263–265. (in Russian).

Katyal, J. C., & Vlek, P. L. (2000). *Desertification: Concept, causes, and amelioration*. Bonn, Germany: Center for Development Research.

Le, Q. B., Nkonya, E., & Mirzabaev, A. (2014). *Biomass productivity-based mapping of global land degradation hotspots*. ZEF—Discussion Papers on Development Policy No. 193, 1-57.

Ministry of Agriculture of Russian Federation. (2011). *Report on the state and use of agricultural lands*. Moscow: FGBNU Rosinformagroteh. (in Russian).

Ministry of Agriculture of Russian SFSR. (1978). *Soils of Azov district of Rostov region and their land-use*. Roszemproekt, Yujgiprozem: Rostov-na-Donu. (in Russian).

Ministry of Natural Resources and Environment of the Russian Federation. (2013). Government report "On state and on environment protection in Russian Federation in 2012". http://www.mnr.gov.ru. (in Russian).

Nefedova, T. G. (2013). *Ten topical issues about rural Russia: A geographer's viewpoint*. Moscow: LENAND. (in Russian).

Nkonya, E., Anderson, W., Kato, E., Koo, J., Mirzabaev, A., von Braun, J., & Meyer, S. (2014). Global cost of land degradation. In E. Nkonya, A. Mirzabaev & J. von Braun (Eds.), *Economics of land degradation and improvement*. Netherlands: Springer.

Nkonya, E., Gerber, N., Baumgartner, P., von Braun, J., De Pinto, A., Graw, V., et al. (2011). *The economics of land degradation—towards an integrated global assessment*. Germany: Peter Lang.

Nkonya, E., von Braun, J., Mirzabaev, A., Bao Le, Q., Kwon, H. Y., & Kirui, O. (2013). *Economics of land degradation initiative: Methods and approach for global and national assessments*. ZEF-Discussion Papers on Development Policy No. 183.

Pannell, D. J., Llewellyn, R. S., & Corbeels, M. (2014). The farm-level economics of conservation agriculture for resource-poor farmers. *Agriculture, Ecosystems and Environment, 187*, 52–64.

Rudneva, E. N. (2001). Soil map content and principals of soil cover mapping. In *Soil cover and land resources of Russian Federation* (pp. 4–98). Moscow. (in Russian).

Ruhovich, D. I., Simakova, M. S., & Bryzzhev, A. V. (in press). Influence of saline soils on the variability of land-use types.

Scherr, S. (1999). *Soil degradation: A threat to developing-country food security by 2020, food, agriculture and the environment*. Washington, D.C., USA: International Food Policy Research Institute.

Shoba, S. A., Alyabina, I. O., Kolesnikova, V. M., Molchanov, E. N., Rojkov, V. A., Stolbovoi, V. S., et al. (2010). *Soil resources of Russia. Soil-geographic data base*. Moscow: GEOS. (in Russian).

Van der Ploeg, S., & de Groot, R. S. (2010). The TEEB valuation database—a searchable database of 1310 estimates of monetary values of ecosystem services. Foundation for Sustainable Development, Wageningen, The Netherlands.

Vandysheva, N. M., & Gurov, A. F. (2011). Predominant negative processes on agricultural lands. In S. A. Shoba (Ed.), *National atlas of soils in Russian federation* (pp. 266–267). Moscow, Astrel: ACT. (in Russian).

von Braun, J., Gerber, N., Mirzabaev, A., & Nkonya, E. (2013). *The economics of land degradation*. ZEF Working paper 109. Bonn, Germany.