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Structural Variations in the Composition of Land Funds at Regional Scales across Russia

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Abstract: In recent decades, Russia has experienced substantial transformations in agricultural land tenure. Post-Soviet reforms have shaped land distribution patterns but the impacts of these on agricultural use of land remain under-investigated. On a regional scale, there is still a knowledge gap in terms of knowing to what extent the variations in the compositions of agricultural land funds may be explained by changes in the acreage of other land categories. Using a case analysis of 82 of Russia's territories from 2010 to 2018, the authors attempted to study the structural variations by picturing the compositions of regional land funds and mapping agricultural land distributions based on ranking "land activity". Correlation analysis of centered log-ratio transformed compositional data revealed that in agriculture-oriented regions, the proportion of cropland was depressed by agriculture-to-urban and agriculture-to-industry land loss. In urbanized territories, the compositions of agricultural land funds were predominantly affected by changes in the acreage of industrial, transportation, and communication lands. In underpopulated territories in the north and far east of Russia, the acreages of cropland and perennial planting were strongly correlated with those of disturbed and barren lands. As the first attempt at such analysis in Russia, the conversion of cadastral classification data into land-rating values enabled the identification of region-to-region mismatches between the cadaster-based mapping and ranking-based distribution of agricultural lands.

Keywords: agricultural land; cropland; land category; land fund; territory; Russia

1. Introduction

Structural alterations in land use have been intrinsically associated with a growing demand for food [1,2]. Increasingly, contemporary processes of progressing urbanization and industrialization have been aggravating the conflicts between different functional land types [3]. As land systems represent a critical intersection between economic and ecological systems [4], land distribution patterns are becoming more vulnerable to a variety of environmental and social issues. Out of the one-fifth of the world's total land surface, which is potentially suitable for crop production, more than half is already actively cultivated [5]. Further agricultural expansion is hampered by natural and geographical factors [6], pervasive land-use change impacts [7], high economic costs [8], and infrastructure constraints [9]. At the same time, according to DeFries et al. [10], Ajani [11], and Lambin [12], agricultural production tends to face increasing competition for land with other types of land use. Over recent decades, many scholars and practitioners, including Platt [13], Briggs and Yurman [14], Vining et al. [15], and Sioen et al. [16], among others, have been reporting the irreversible removal of substantial areas of land previously used for agriculture to urban, industrial, infrastructure, and other types of use instead. Urbanization and industrialization intensify competition between agricultural and non-agricultural land-use practices [17]. Along with industrial development and urban sprawl, there are significant alterations of land use far beyond city limits that result in arable land loss [18].

Generally, at a regional scale, agricultural lands do not strictly compete with other categories for the same land areas due to the specific climate, soil, and topographical requirements for farming. However, in land-abundant and climate-diverse countries, the geographical distribution of agricultural land use tends to adjust to better match land quality [19]. Russia is aa good example of aa country that can be used to demonstrate this fact. Agriculture abandonment in vast northern and eastern areas has occurred in parallel with a concentration of intensive agriculture in fertile lands in the southern, western, and central regions of the country. In Russia, agricultural lands only represent 12.96% of the total national land fund (cropland at 7.16%, rangeland at 3.99%, hayfields at 1.40%, fallow at 0.28%, and perennial plantings at 0.11%). Per-territory concentrations of agricultural land vary from 75.32% in the Southern Federal District and 70.96% in the North Caucasian Federal District to only 4.05% in the Northwestern Federal District and 1.30% in the Far Eastern Federal District.

We clarified the definitions of the main terms used in this study as follows:

- District—A type of supraregional administrative division of Russia, which includes several territories based on a geographical principle (currently, eight federal districts exist).
- Land distribution—how lands of particular categories are spread out in a country, district, or territory.
- Land fund—the total of available land resources in a country, district, or territory.
- Land fund composition—a division of a land fund into land categories.
- Land use—the total of arrangements, activities, and inputs that people undertake in a certain land cover type.
- Territory—an umbrella term to designate various types of administrative divisions of the Russian Federation (oblasts, krais, republics, autonomous districts, and autonomous republics).

The disproportions of agricultural land distribution are, to some extent, caused by economic factors, not only geographic and natural conditions. Similar to most post-socialist countries, Russia has experienced dramatic changes in land ownership and land tenure since the early 1990s. Among the principal transformations, Lerman and Shagaida [20] have outlined the privatization of agricultural land, rights to agricultural land for individual landowners, and the removal of prohibitions on buying and selling land. The land market has responded positively to the liberalization with an increase in transactions between individual landowners [20]. However, the domination of shared and joint land ownership has weakened the role of the state in controlling land use [21] and has increased the fragmentation of public land property into many scattered units [22]. Almost twelve million land shares (certificates) were distributed between rural individuals and former employees of collective and state farms [23]. According to Trukhachev et al. [23], Lerman and Shagaida [20], Rozhkov [24], and Visser et al. [25], land reform in Russia has significantly contributed to structural variations in the composition of land funds. The proportion of agricultural land in the total land fund has been declining due to a loss of arable land, particularly in the vast areas of the Far Eastern Federal District and the Siberian Federal District [26]. From 1990 to 2000, the rate of land abandonment in Russia was above 30%, one of the highest among the economies in transition [27]. Milanova [28] reported a decrease in the cropped area for all crops during the 1990s due to the changes in land tenure and stagnation of the agricultural sector. A drastic decline in livestock production resulted in a reduction of hayfields and rangelands. Vast areas of arable land were abandoned due to land degradation. In some territories in the central, northern, and eastern parts of the country, humus content dropped by 50%. Prishchepov et al. [29] revealed the correlation between the spatial distribution of abandoned croplands and natural factors, such as inadequate precipitation and shorter growing periods, in both Siberia and eastern parts of the country. As many farms were situated in the boreal zone, some of the abandoned lands have experienced shrub and tree encroachment [30].

Many experts report an aggravated environmental degradation of agricultural lands due to over-exploitation [31,32]. The changes in land cover and land use in forest-steppe and steppe vegetation zones (agriculture-oriented territories of southern Russia, the European center, and southern parts of Ural and Siberia) have been driven by extensive farming. Milanova [28] and Milanova et al. [33] reported that up to 90% of lands in some territories were converted to crop production. However, where environmental concerns of land use are mentioned in either federal or regional legislation, they predominantly relate to reducing industrial emissions or waste disposal in urban and suburban areas, not to agricultural land use [34]. Over 40 million hectares of cropland is now abandoned in Russia, and another 58 million is eroded. Land degradation, along with desertification due to irrational land use, poses serious environmental, economic, and social threats in the long-term. Griewald et al. [34] argued that the land use context in Russia did not support a transition towards sustainable land management, i.e., a "use of land resources, including soils, water, animals, and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" [35]. The urban expansion causes shrinkage of arable and other categories of agricultural land [36], which are transferred to various non-agricultural types of land use. A considerable amount of agricultural land loss due to urbanization and industrialization takes place on fertile soil [37] and irrigated lands [38]. In return, the increase in agricultural land acreage occurs on soils that are lower in terms of their fertility. Prishchepov et al. [39], Brueckner [40], and Brown et al. [41] raised concern over the growing concentration of arable land in smaller and more fragmented locations in proximity to urban and industrialized areas. Erma et al. [42] reported many cases where residential settlements occupied agricultural land in southern and central parts of the country, which are known as the breadbasket regions of Russia.

With increased variability in the composition of land funds, a reliance on research in this area has become more critical. In a series of empirical studies, many authors, including Verburg et al. [43], Van Doorn and Bakker [44], Nainggolan et al. [45], and Diogo and Koomen [46], among others, have attempted to construct hypotheses about the relationship between proximate driving forces and agricultural land-use patterns. The problem is that the established hypotheses do not adequately explain the causality between land-use processes and the compositions of land funds at different regional scales. In transition economies, including Russia, where land reforms have dramatically changed the distribution of the land inventory in recent decades [42], variations in agricultural lands due to the pressure of non-agricultural land use have remained under-investigated. The composition of agricultural land funds has commonly been considered out of a non-agricultural context [47,48], instead of exploring the interactions between the proportions of agricultural, urban, infrastructure, and industrial lands. Most of the studies have applied a proportion of agricultural land in a land fund as a core territorial specification without further testing for alternative non-agricultural land use variables [4]. Therefore, in regional studies, a knowledge gap has emerged in terms of how the variations in the compositions of land funds may be tracked with an aim to optimize agricultural land use. A more explicit focus on the relationships between land categories is required to be able to explain and predict land system dynamics in diverse locations [49]. With this background, in the case of Russia, this study aimed to contribute to the body of knowledge on regional scale land uses by identifying structural variations in the compositions of territory land funds and revealing the interdependencies between the proportions of agricultural, on the one side, and urban, industrial, and other types of land on the other.

2. Materials and Methods

This study was a quantitative study that was performed based on the data obtained from land registers from 82 out of 85 of the administrative entities of Russia (further detailed in Section 2.6). Russian public statistics report thirteen land categories within land funds, including five agricultural and eight non-agricultural ones. As we aimed to study structural variations in the compositions of land funds by identifying the changes in the proportions of different lands, all thirteen land categories were considered here (the definitions are given in Section 2.1). The overarching methods adopted in this study included a ranking of the territories on the degree of agricultural land activity (see Sections 2.2 and 2.3), centered log-ratio transformation of compositional land share data to an unconstrained space (Section 2.4), and correlation analysis to reveal the variations in the proportion of land categories within the groups of territories (Section 2.5). In total, the study algorithm followed five stages (Table 1), which are further addressed in Sections 2.1–2.5 of the paper.

Table 1. Study flow algorithm.

Stage	Method	Section in the Paper for Methods	Results	Section in the Paper for Results
1	Merging of agricultural census data with operative land cadaster information.	Section 2.1	Establishment of an array of thirteen categories of agricultural (five variables) and non-agricultural (eight variables) land.	-
2	Computation of the shares of land categories in the land funds across Russia's territories.	Section 2.2	Map of the spatial distribution of agricultural lands in Russia per territories.	Section 3.1
3	Ranking of the shares of land categories in territory land funds.	Section 2.3	Rating scores and scales to measure the degree of agricultural land activity.	Section 3.2
4	Centered log-ratio transformation of compositional land shares data to an unconstrained space and correlation analysis of the obtained standard multivariate data.	Section 2.4	Four centered log-ratio-transformed correlation matrices based on the level of agricultural land activity.	Section 3.3
5	Computation of the coefficient of correlation variance.	Section 2.5	Identification of strong synergies between the variations of the proportions of agricultural and non-agricultural land categories in the land funds.	Section 3.3

Source: Authors' development.

2.1. Stage 1: Land Categories

As the structural features of land classification frameworks largely depend on the purpose of classification [50], various country specific approaches exist to categorize agriculture and other types of land. In Russia, Shagaida [51], Nosov [52], and Macht et al. [53] have contributed to the identification of various categories of agricultural lands. The majority of the studies, however, have paid inadequate attention to revealing variations in land fund compositions due to the specific needs for farming, residential construction, or industrial and infrastructure development in particular locations. For instance, Zhang et al. [3] applied an ecological-living-production classification system, to demonstrate the distribution of agricultural land across arable land, pastures, timberland, aquaculture land, and orchards, but they did not reveal the variations in the spatial concentration of particular land categories. Loshakov [54] developed an approach for the categorization of agricultural lands based on the productive qualities of soils but did not consider mismatches between agro-climatic zoning and land registers.

While the adjustments to land classification systems may be useful in achieving some specific technical, geographical, environmental, or economic goals, there are situations in which various existing approaches should be merged [55]. Many of the systems have a limitation in their ability to demonstrate the interrelationships between the categories of land cadasters for agricultural production. In general, classification concepts do not correctly emphasize per-category changes in the composition of a land fund. This is also one of the inherent vices of state statistics reporting on land fund structures in many countries. Notably, the Federal State Statistics Service of the Russian Federation (Rosstat) generalizes land into three broad categories (namely, agricultural, woodlands, and water reserve lands) [56]. Separate forms also report urban lands and lands for industrial, transportation, and communication infrastructure purposes; however, these forms exist at a national scale, not a regional scale. More detailed classification for five categories of agricultural land (croplands, hayfields, rangelands, perennial plantings, and fallows) is available in agricultural census report forms [57].

However, since the agricultural census is conducted decennially, intercategory variations cannot be effectively tracked on an annual basis.

One of the possible solutions to this discontinuity problem is to supplement census data with operative land cadaster information [58]. In Russia, the Federal Service for State Registration, Cadastre, and Cartography (Rosreestr) continually monitors land fund compositions per territories across seven categories of land, including agricultural land, residential land, industrial land, specially protected territories, woodlands, water fund lands, and reserve lands [59]. Among several classification schemes used by Rosreestr, one breaks agricultural lands into five categories, similar to Rosstat's decennial census, but instead on an annual basis. The usage of this data may allow the creation of a better time-sensitive model to represent changes in the proportion of land categories within different regions.

In this study, simple classifications determining the allocation of land between agriculture, urban, and nature were merged with more comprehensive ones, in which cadaster synergies could be detailed for a wider range of agricultural, industrial, urban and built-up, forest, and water reserve lands. The array included the categories of urban and infrastructure lands (obtained from separate sections of Rosstat's reports), as well as wetlands, disturbed lands, and barren lands (all reported by Rosreestr's alternative classification of utilized lands). In total, the authors' model merged thirteen land categories, including five agricultural ($L_{(1–5)}$) and eight non-agricultural ($L_{(6–13)}$) categories (Table 2). As reported by Rosstat [56,57] and Rosreestr [59], the categories were mutually exclusive and exhaustive. That is, each location within the T_j territory could be classified into one and only one L_i category.

Table 2. Land categories in the study.

Codes	Land Categories	Definitions
L_1	Croplands	Land systematically cultivated for crop production, including perennial grasses, clean fallow, and land under greenhouses.
L_2	Fallows	Land previously used as cropland but left unseeded for more than one year and not included in clean fallow.
L_3	Perennial plantings	Land under homogeneous stands of arboreal plants, bushes, and herbaceous plants used for the production of horticultural, technical, and medical products.
L_4	Hayfields	Fields where herbaceous plants are systematically grown for hay.
L_5	Rangelands	Land systematically and predominantly used for livestock grazing, including lands appropriate for livestock grazing but not used as hayfields or fallow.
L_6	Woodlands	Land that is mostly covered with woods or dense growths of trees and shrubs.
L_7	Forest ranges	Forest plantings on military lands, urban lands, and lands of rural settlements.
L_8	Water reserve lands	Land covered by surface water in water bodies (seas, lakes, ponds, water storage reservoirs) and land under waterworks and other facilities located within water bodies.
L_9	Residential and industrial lands	Areas of intensive use in cities, towns, and villages with much of the land covered by residential and industrial structures (those occupied by residential real estates, administrative buildings, shopping centers, industrial and commercial complexes), including in the locations isolated from urban areas.
L_{10}	Lands under transportation and communication infrastructure	Land under railways and highways, right-of-ways, cuttings in forests, livestock alleyways, and other routes of communication, as well as areas involved in processing, treatment, and transportation of water, gas, oil, and electricity.
L_{11}	Wetlands	Swampy or marshy areas saturated with moisture where the water table is at, near, or above the surface of the soil all year or for varying periods during the year, including during the growing season.
L_{12}	Disturbed lands	Land from which vegetation, topsoil, or overburden is removed or other damage is made as a result of economic and other human activities or natural processes and which is not reclaimed under the reclamation plan.
L_{13}	Barren lands	Land of limited ability to support life and incapable of producing crops or any useful vegetation.

Source: Authors' development based on Rosstat [56,57] and Rosreestr [59].

2.2. Stage 2: Composition of Land Funds

As the keynote idea is to reveal the variations in the compositions of the land funds across diverse territories, a kind of assessment scale should be applied. There have been many attempts to find a reliable approach for the conversion of cadastral classification data into land-rating values. Land classification systems based on rankings have been in use since the 1980s when Wright et al. [60] and Cocks et al. [61] first applied simple additive linear models of factor weights to the evaluation of land utility for crop production. In the realm of building a relevant ranking framework, one of the major challenges is determining how to align categorization (public statistics) with functional scales. In agriculture, variations between the proportions of lands are hard to identify [62] and thus cannot be effectively linked with territory fragmentations of agricultural production [63]. The immediacy of the problem was convincingly demonstrated by Grčman et al. [64], who found the difference between land-rating values based on precise calculations and those based on official information (specifically, for agricultural land with lower production potential).

Another challenge is that the ranking systems are not comparable and, therefore, inapplicable across a variety of agricultural and non-agricultural lands [65,66], and even across croplands, fallows, and pastures [67,68]. There have been attempts to overcome this problem by finding an integral parameter that would allow the adjustment of agricultural- and non-agricultural-oriented ranking systems to be comparable. In terms of land fund compositions, one of the most promising foundations of ranking is the contribution of a land category to the total land acreage per territory [69] (Equation (1)). The applicability of this parameter for building category-based land assessment frameworks was successfully tested by Mazurkin and Mihailova [70], Buckett [71], Artamonova et al. [72], Stupen et al. [73], Shishkina et al. [74], and Yerseitova et al. [75].

$$A_{jLi} = \frac{S_{jLi}}{S_j} \tag{1}$$

where A_{jLi} = share of land category L_i in the land fund in territory T_j; S_{jLi} = area of L_i in territory T_j; S_j = total land acreage of territory T_j.

The shares of the $L_{(1–13)}$ land categories in the land funds were computed across $T_{(1–82)}$ territories (Appendix B, Tables A9–A16).

2.3. Stage 3: Agricultural Land Activity

Further, the A_{jLi} values are ranked across the arrays of L_i land categories and T_j territories to calculate a parameter of land activity. Agricultural land activity is a degree of orientation of a land fund composition toward an agricultural type of land use. It is an indicator of how a proportion of $L_{(1–5)}$ to $L_{(6–13)}$ serves the purpose of agricultural production in particular geographic and economic conditions at a regional scale. Land activity is a score of a T_j territory, obtained based on the proportions of various land categories within a land fund. Higher contributions of $L_{(1–5)}$ to total acreage result in higher agricultural land activity scores. The activity-rank correspondence is straightforward, where the higher is A_{jLi} value, the higher is R_{ji} score. A high rank demonstrates an orientation of land fund composition towards agricultural specialization. Since the prevalence of non-agricultural lands is considered as a spatial constraint for the allocation of agricultural land uses, higher proportions of $L_{(6–13)}$ within a land fund result in lower agricultural land activity scores. For these land categories, the activity-rank relationship is inverse, where the higher is A_{jLi} value, the lower is the R_{ji} score. For j territories included in the study, the R interval was $[0; j-1]$. In our model, as $A_{jL(1–5)}$ tended to 1, R tended to $(j-1)$, while as $A_{jL(6–13)}$ tended to 1, R tended to 0.

Then, we assessed the significance of derived estimates. R_{ji} scores were used to identify the quartiles of A_{jLi} (Figure 1). The $[\sum R_{jmin}; \sum R_{jmax}]$ interval was divided into the quartiles by finding the n multiplier, where $n = \frac{\sum R_{jmax} - \sum R_{jmin}}{4}$.

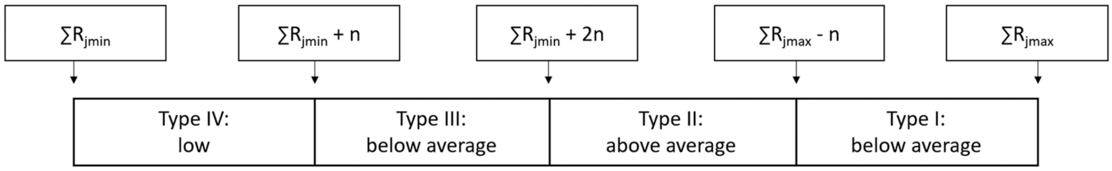

Figure 1. Scale to classify T_j territories on the degree of agricultural land activity. Source: Authors' development.

The quartile-based approach was used by Mazurkin [69] for the ranking of territories based on absolute values of land activity parameters. It also agrees with Kotykova et al. [76] and Zhildikbaeva et al. [77], who compared the deviations of land category estimates from their highest level on a territory-by-territory basis. In this study, such a method for the classification of rankings allowed consideration of the information in the percentage areas measured for each L_i in each T_j.

2.4. Stage 4: Revealing Structural Variations of Agricultural and Non-Agricultural Land Categories

Since the early years of Russia's land reform, structural variations in the compositions of land funds have progressed in response to socioeconomic and anthropogenic processes. To identify these variations between various land categories across four types of territories, this study employed factor analysis. It enables the transformation of land fund data into meaningful information [43,78] and revelation of variations in the structure of the use of territory land funds. According to Alcamo et al. [79] and Lavalle et al. [80], the integration of proximate and underlying factors may capture both the spatial distribution and the variety of land categories claimed for different land-based activities. The employment of factor analysis tools at a regional scale by Bakker et al. [81], Van Doorn and Bakker [44], and Hatna and Bakker [82] demonstrates the appropriateness of the method for cross-territory comparisons.

Among numerous factor analysis approaches, correlation analysis is one of the most suitable approaches to reveal variations in land fund compositions [83,84]. Since the A_{jLi} data are compositional, i.e., they add up to a constant value of 1 or 100% of a land fund, they need a special treatment prior to correlation analysis [85]. Aitchison [86] named land fund compositions among the typical datasets associated with challenging problems in compositional data analysis. In a compositional vector that consists of several parts summing up to a constant, the relevant information is contained only in the ratios between these parts [87] (Equation (2)).

$$x = (x_1, \ldots, x_D)^t,\ x_i > 0,\ i = 1, \ldots, D,\ \sum_{i=1}^{D} x_i = k \tag{2}$$

where D = number of compositions, and k = a positive constant value, i.e., the sum of D compositions.

If correlation analysis is applied directly to the A_{jLi} data, this can give misleading results [88] and form undesirable properties, like scale dependence [89]. The best way to analyze data with constant sum constraints is by first transforming them into an unconstrained space [88], where standard data analysis tools can then be employed [90]. Several log-ratio transformations have been introduced by Aitchison [89,91], Pawlowsky-Glahn et al. [87,90], Filzmoser and Hron [85], Long and Wang [92], and Van den Boogaart and Tolosana-Delgado [93]. Commonly used methods include using the additive log-ratio (alr), isometric log-ratio (ilr), and centered log-ratio (clr). Additive log-ratio transformation is based on log-ratios to a single reference variable. It is the simplest way to transform compositional data. However, it does not preserve distances between variables; i.e., it is not isometric [85]. Isometric log-ratio transformation is built on the choice of an orthonormal basis and thus solves the isometry problem. However, according to Egozcue et al. [94] and Egozcue and Pawlowsky-Glahn [95], base compositional parts are only related to isometric log-ratio transformed variables through non-linear functions. In our case, this meant that the computed correlations between the proportions of land categories could not be interpreted in the sense of the A_{jLi} data.

For this study, we employed centered log-ratio transformation (Equation (3)). Distinct from the additive log-ratio method, the centered log-ratio method is based on the geometric mean of all variables. It allows for the selection of a ratio variable to be avoided [85]. In contrast with the isometric log-ratio method, the centered log-ratio method simplifies the interpretation of the transformed variables because one could think of them in terms of the original variables [85,96].

$$y = [y_1, \ldots, y_D] = \left[\ln \frac{x_1}{\sqrt[D]{\prod_{i=1}^{D} x_i}}, \ldots, \ln \frac{x_D}{\sqrt[D]{\prod_{i=1}^{D} x_i}}\right] \quad (3)$$

where $x = A_{jLi}$ share of land category L_i in the land fund in territory T_j; y = transformed A_{jLi} compositions ATR_{jLi}; D = number of compositions, i.e., L_i land categories.

The A_{jLi} compositions were transformed into ATR_{jLi} data across all T_j territories using CoDaPack. This open-access software is one of the easiest-to-use applications that is commonly employed for compositional data transformation (for instance, see Thió-Henestrosa and Martín-Fernández [97], Egozcue and Pawlowsky-Glahn [98], and Muriithi [99]). The centered log-ratio-transformed data that were obtained were standard multivariate data that enabled us to use correlation analysis. Correlation matrices were built separately for the four groups of territories earlier ranked by the type of agricultural land activity. Correlation analysis was carried out here using the Excel Data Analysis ToolPak.

2.5. Stage 5: Significance of Correlations

When conducting correlation analysis for land systems, most scholars have faced a challenge similar to what we outlined earlier concerning ranking scales, namely, determining the significance of synergies between variables. Among various methods, the coefficient of correlation variance seems to be the most appropriate for dealing with interdependent multitudes of land categories [69,70] (Equation (4)).

$$C_{cv} = \frac{\sum ATR_{jLi}}{ATR_{max} \times N_L \times N_T} \quad (4)$$

where C_{cv} = coefficient of correlation variance; $\sum ATR_{jLi}$ = sum of transformed A_{jLi} values of L_i land categories in T_j territories in the group; ATR_{max} = the highest value of ATR_{jLi} in the group; N_L = number of land categories in the array; N_T = number of territories in the array.

The C_{cv} value was applied across four correlation matrices (types of land activity) to remove weak interdependencies and reveal strong synergies between the proportions of the $L_{(1–5)}$ and $L_{(6–13)}$ land categories in a land fund.

2.6. Territories and Data

Russia is a federation comprised of 85 administrative entities, or territories, as defined in the Section 1. Our study included 82 of them (mapped in Figures 2 and 3). The three municipal areas of Moscow, Saint Petersburg, and Sevastopol were excluded from the array as they are areas in which the proportion of agricultural land in the territory land fund is of negligible importance. For each territory, land cadaster data were derived from the annual reports from Rosreestr [59] and Rosstat [56,57] during 2010–2018. In Russia, these data are reported across thirteen land categories in thousand hectares. Appendix A summarizes the data of the total acreages of the territories included in the study, along with the acreages of the thirteen land categories. The study was built on the mean acreages of $L_{(1–13)}$ land categories during 2010–2018 (Appendix A, Tables A1–A8). The proportions of the $L_{(1–13)}$ land categories in regional land funds across $T_{(1–82)}$ territories are provided as percentages in Appendix B, Tables A9–A16. The variations in the proportions are provided as differences between 2010 and 2018 in Appendix B, Tables A9–A16. The consideration of the Republic of Crimea as a part of the array was determined by the current position of the territory as being de-facto controlled by Russia. In no way, these results reflect the authors' attitude to the international status of the area. For the Republic of Crimea, we used the mean data of the land acreage and land categories' proportions from 2015–2018.

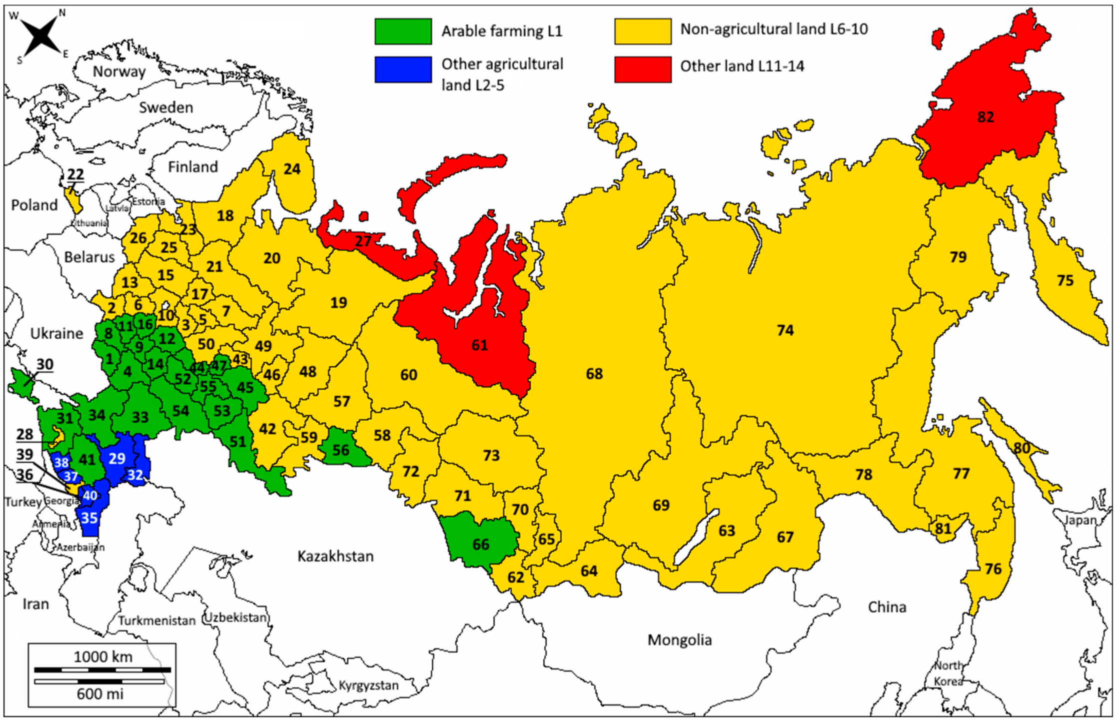

Figure 2. Spatial distribution of agricultural lands in Russia. Note: 1 = Belgorod; 2 = Bryansk; 3 = Vladimir; 4 = Voronezh; 5 = Ivanovo; 6 = Kaluga; 7 = Kostroma; 8 = Kursk; 9 = Lipetsk; 10 = Moscow Oblast; 11 = Orel; 12 = Ryazan; 13 = Smolensk; 14 = Tambov; 15 = Tver; 16 = Tula; 17 = Yaroslavl; 18 = Karelia; 19 = Komi; 20 = Arkhangelsk; 21 = Vologda; 22 = Kaliningrad; 23 = Leningrad; 24 = Murmansk; 25 = Novgorod; 26 = Pskov; 27 = Nenets; 28 = Adygeya; 29 = Kalmykia; 30 = Crimea; 31 = Krasnodar; 32 = Astrakhan; 33 = Volgograd; 34 = Rostov; 35 = Dagestan; 36 = Ingushetia; 37 = Kabardino-Balkaria; 38 = Karachaevo-Cherkessia; 39 = North Osetia-Alania; 40 = Chechnya; 41 = Stavropol; 42 = Bashkortostan; 43 = Mari El; 44 = Mordovia; 45 = Tatarstan; 46 = Udmurtia; 47 = Chuvashia; 48 = Perm; 49 = Kirov; 50 = Nizhny Novgorod; 51 = Orenburg; 52 = Penza; 53 = Samara; 54 = Saratov; 55 = Ulyanovsk; 56 = Kurgan; 57 = Sverdlovsk; 58 = Tyumen; 59 = Chelyabinsk; 60 = Khanty-Mansi; 61 = Yamal-Nenets; 62 = Altay Republic; 63 = Buryatia; 64 = Tyva; 65 = Khakasia; 66 = Altay; 67 = Zabaikalsk; 68 = Krasnoyarsk; 69 = Irkutsk; 70 = Kemerovo; 71 = Novosibirsk; 72 = Omsk; 73 = Tomsk; 74 = Sakha Yakutia; 75 = Kamchatka; 76 = Primorye; 77 = Khabarovsk; 78 = Amur; 79 = Magadan; 80 = Sakhalin; 81 = Jewish AO; 82 = Chukotka. The Republic of Crimea was included in the study due to its current position as a territory under the de-facto control of Russia. This in no way reflects the authors' attitude to the international status of the area. Source: Authors' development.

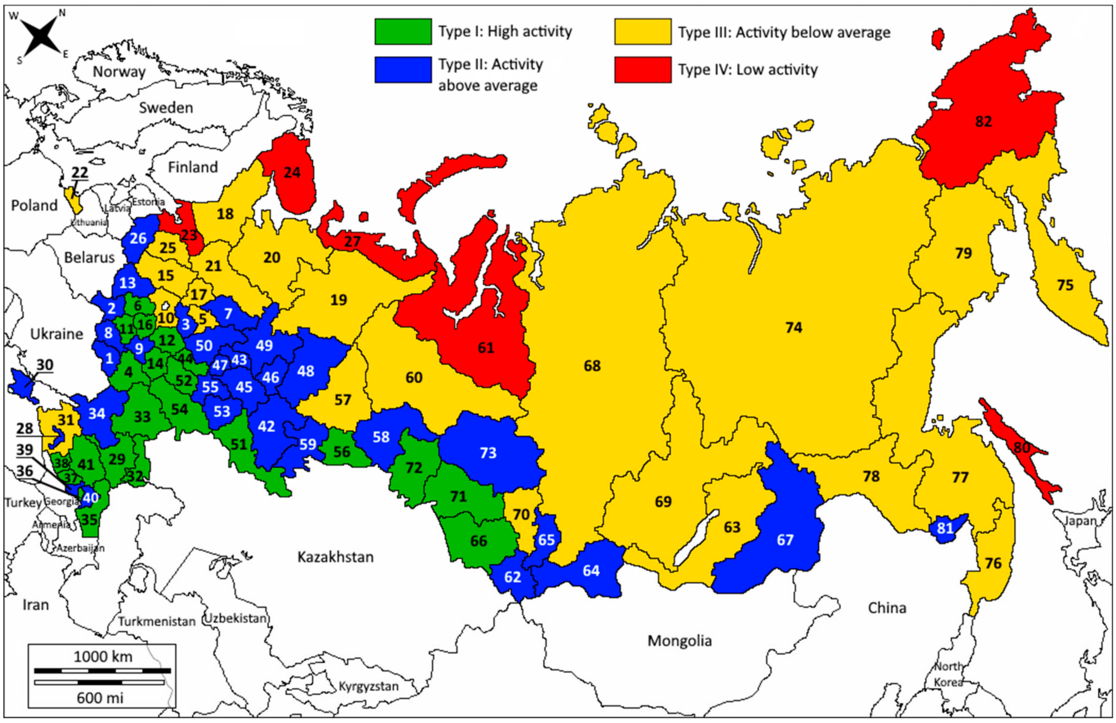

Figure 3. Russian territories: types of agricultural land activity. Note: 1 = Belgorod; 2 = Bryansk; 3 = Vladimir; 4 = Voronezh; 5 = Ivanovo; 6 = Kaluga; 7 = Kostroma; 8 = Kursk; 9 = Lipetsk; 10 = Moscow Oblast; 11 = Orel; 12 = Ryazan; 13 = Smolensk; 14 = Tambov; 15 = Tver; 16 = Tula; 17 = Yaroslavl; 18 = Karelia; 19 = Komi; 20 = Arkhangelsk; 21 = Vologda; 22 = Kaliningrad; 23 = Leningrad; 24 = Murmansk; 25 = Novgorod; 26 = Pskov; 27 = Nenets; 28 = Adygeya; 29 = Kalmykia; 30 = Crimea; 31 = Krasnodar; 32 = Astrakhan; 33 = Volgograd; 34 = Rostov; 35 = Dagestan; 36 = Ingushetia; 37 = Kabardino-Balkaria; 38 = Karachaevo-Cherkessia; 39 = North Osetia-Alania; 40 = Chechnya; 41 = Stavropol; 42 = Bashkortostan; 43 = Mari El; 44 = Mordovia; 45 = Tatarstan; 46 = Udmurtia; 47 = Chuvashia; 48 = Perm; 49 = Kirov; 50 = Nizhny Novgorod; 51 = Orenburg; 52 = Penza; 53 = Samara; 54 = Saratov; 55 = Ulyanovsk; 56 = Kurgan; 57 = Sverdlovsk; 58 = Tyumen; 59 = Chelyabinsk; 60 = Khanty-Mansi; 61 = Yamal-Nenets; 62 = Altay Republic; 63 = Buryatia; 64 = Tyva; 65 = Khakasia; 66 = Altay; 67 = Zabaikalsk; 68 = Krasnoyarsk; 69 = Irkutsk; 70 = Kemerovo; 71 = Novosibirsk; 72 = Omsk; 73 = Tomsk; 74 = Sakha Yakutia; 75 = Kamchatka; 76 = Primorye; 77 = Khabarovsk; 78 = Amur; 79 = Magadan; 80 = Sakhalin; 81 = Jewish AO; 82 = Chukotka. The Republic of Crimea was included in the study due to its current position as a territory under the de-facto control of Russia. This in no way reflects the authors' attitude to the international status of the area. Source: Authors' development.

3. Results

3.1. Composition of Land Funds

The analysis of land cadaster data across Russia's T_j territories (Appendix B, Tables A9–A16) allowed the discovery of a distinct regularity in the spatial distribution of agricultural lands. In southern and central parts of the country (green belt between 45° and 55° north latitude), croplands prevailed in the composition of the land funds (Figure 2). In the mountainous areas of North Caucasus, the blue belt comprised the territories where rangelands and other agricultural lands predominated. In most of the northern and eastern regions, the land funds were comprised of non-agricultural lands with a minor proportion of cropland.

3.2. Agricultural Land Activity

The ranking of Russia's territories on a parameter of agricultural land activity resulted in higher scores for the southern and central parts of the country than for Siberia and the Far East (Appendix C, Tables A17–A24). Concurrently, some less apparent findings were yielded (Appendix D, Table A25).

First, in the Southern Federal District, an agricultural granary for the country, the land fund composition was less agriculture-oriented compared to the Central and Volga districts and some territories of Siberia. Specifically, for Krasnodar and Rostov, two green belt territories with a considerable proportion of cropland in the structure of the land fund, the $\sum\overline{R_{ji}}$ values were well below the district average. In some territories in the south and center, high ranks of cropland and rangeland were negated by low ranks for barren lands, water reserve lands, residential, industrial, and infrastructure lands.

Second, in the Siberian Federal District, the $\sum\overline{R_{ji}}$ values nearly reached those values of the central and southern districts due to the high scores of hayfields in Omsk and Novosibirsk. The green belt by Altay was rated high for the proportion of cropland and other agricultural lands in the composition of the land fund.

Third, the yellow and red belts in the Far East feature the least agriculture-oriented macroregion in Russia. In Chukotka, Magadan, and Sakhalin, where woodlands and wetlands dominate the composition of the land fund, the agricultural land categories were ranked the lowest among the 82 territories examined here. However, in Primorye, Khabarovsk, Amur, and Jewish Autonomous Oblast, fallows, hayfields, and rangelands received high scores.

Following the obtained ranks, four R_j intervals were identified, each of which included T_j territories according to the degrees of agricultural land activity. The grouping reproduced the earlier revealed belt-like distribution of agricultural land, but with a modified configuration instead (Figure 3).

Generally, while the green belt shrank and shifted eastward, the blue one expanded and spread north of the 55° latitude mark. In some of the previously yellow belt territories of the Northwestern, Central, and Volga districts, perennial plantings and hayfields were ranked high enough to include those regions as type II regions. In Siberia, the green belt included Omsk and Novosibirsk due to the high rank of hayfields and the low rank of disturbed and barren lands. The blue belt stretched from Ural (Tyumen and Chelyabinsk) to Siberia (Tomsk, Khakasia, Tyva, and the Altay Republic) and farther to the Far East (Zabaikalsk and the Jewish Autonomous Oblast). In the south, the substantial activity of residential, industrial, transportation, communication, and disturbed lands downgraded Krasnodar to type III and Rostov and Crimea to type II. Ingushetia, Kabardino-Balkaria, Karachaevo-Cherkessia, and Dagestan, on the contrary, broke forth to the green belt due to high scores of perennial plantings and rangeland and low activity of wetlands, disturbed lands, and water reserve lands.

3.3. Correlation Analysis

In type I territories, the variations in the compositions of agricultural lands correlated with the changes in the acreage of non-agricultural land for infrastructure, primarily transportation and communication (the strongest correlation with cropland, perennial plantings, and hayfields) (Table 3). Strong correlations were also revealed between the proportions of croplands and fallows, on one side, and those of woodland and barren land on the other. The share of rangeland in the land fund was strongly correlated with that of barren land.

Table 3. Correlation matrix for type I territories.

Regressands	Regressors											
	ATR$_{L1}$	**ATR$_{L2}$**	**ATR$_{L3}$**	**ATR$_{L4}$**	**ATR$_{L5}$**	**ATR$_{L6}$**	**ATR$_{L7}$**	**ATR$_{L8}$**	**ATR$_{L9}$**	**ATR$_{L10}$**	**ATR$_{L11}$**	**ATR$_{L12}$**
ATR$_{L2}$	0.5317											
ATR$_{L3}$	0.6206	**0.7844**										
ATR$_{L4}$	0.4195	0.2973	**0.7109**									
ATR$_{L5}$	0.6619	0.6836	0.3088	0.6619								
ATR$_{L6}$	0.5854	**0.8127**	0.3917	0.1485	0.5193							
ATR$_{L7}$	**0.8863**	**0.7340**	0.6226	0.6993	0.4286	0.3275						
ATR$_{L8}$	0.4001	0.4872	0.4345	**0.7226**	0.6719	0.5015	0.4812					
ATR$_{L9}$	**0.8925**	0.5100	0.7001	0.6133	**0.7483**	0.4990	0.6291	**0.7255**				
ATR$_{L10}$	**0.9691**	0.5902	**0.9583**	**0.9121**	0.4128	0.3802	**0.8016**	0.3476	0.2196			
ATR$_{L11}$	**0.7779**	0.2014	0.4296	**0.7724**	0.1944	**0.8403**	0.2974	**0.7402**	0.3209	**0.7947**		
ATR$_{L12}$	0.1803	**0.7098**	0.5044	0.1725	0.4592	0.6274	0.3076	0.1577	**0.8182**	0.2619	0.5044	
ATR$_{L13}$	0.3956	**0.7317**	0.3712	0.4594	**0.8215**	0.6619	0.4764	0.1810	0.4464	0.3118	0.6275	0.2999

Note: ATR_{Li} = centered log-ratio-transformed data: ATR_{L1} = cropland; ATR_{L2} = fallow; ATR_{L3} = perennial plantings; ATR_{L4} = hayfields; ATR_{L5} = rangeland; ATR_{L6} = woodlands; ATR_{L7} = forest range; ATR_{L8} = water reserve lands; ATR_{L9} = residential and industrial lands; ATR_{L10} = lands under transportation and communication infrastructure; ATR_{L11} = wetlands; ATR_{L12} = disturbed lands; ATR_{L13} = barren; bold denotes a strong correlation, $C_{ATRli} > C_{cv}$ (0.7022 for type I territories). Source: Authors' development.

Similar to type I, in the type II group, a strong correlation was found between the shares of cropland and perennial plantings and those of lands for transportation and communication infrastructure (Table 4). Besides, since the blue belt predominantly was comprised of densely populated territories, there was a correlation between the shares of croplands and residential lands. In many type II territories, the contribution of woodlands and other forest ranges to the structure of the land fund was essential. This fact might explain the high correlation between the composition of agricultural lands and woodlands. In the south, where the climate and soil favor the development of horticulture and viniculture (i.e., in Crimea, Adygeya, and Rostov), C_{cv} emphasized a strong correlation between the proportions of perennial plantings and croplands within the agricultural land categories.

Table 4. Correlation matrix for type II territories.

Regressands	Regressors											
	ATR$_{L1}$	**ATR$_{L2}$**	**ATR$_{L3}$**	**ATR$_{L4}$**	**ATR$_{L5}$**	**ATR$_{L6}$**	**ATR$_{L7}$**	**ATR$_{L8}$**	**ATR$_{L9}$**	**ATR$_{L10}$**	**ATR$_{L11}$**	**ATR$_{L12}$**
ATR$_{L2}$	0.3291											
ATR$_{L3}$	**0.6719**	0.4417										
ATR$_{L4}$	0.5213	**0.8013**	0.5016									
ATR$_{L5}$	0.2706	0.3814	0.1928	0.4836								
ATR$_{L6}$	**0.8804**	**0.7512**	**0.7793**	0.3391	**0.8284**							
ATR$_{L7}$	0.4817	0.5788	0.4801	**0.6481**	0.2662	0.4571						
ATR$_{L8}$	0.2940	**0.6941**	0.5592	0.5702	0.1827	0.2719	**0.7027**					
ATR$_{L9}$	**0.7592**	0.4290	**0.7728**	0.4817	0.5011	0.0458	0.2664	0.5822				
ATR$_{L10}$	**0.8918**	0.2811	**0.9102**	0.1482	**0.7661**	0.3443	0.1988	0.5591	**0.6619**			
ATR$_{L11}$	0.1157	0.1792	0.2866	**0.7205**	**0.8003**	0.4509	0.4295	0.3619	**0.7268**	0.1384		
ATR$_{L12}$	**0.6834**	0.3810	0.3017	0.0133	0.4506	**0.7318**	**0.6040**	0.0744	**0.8112**	**0.6714**	0.2857	
ATR$_{L13}$	0.2375	0.027	**0.5993**	0.2915	**0.6266**	0.5011	0.1302	0.2599	0.2004	0.2777	0.5296	0.4018

Note: ATR_{Li} = centered log-ratio-transformed data: ATR_{L1} = cropland; ATR_{L2} = fallow; ATR_{L3} = perennial plantings; ATR_{L4} = hayfields; ATR_{L5} = rangeland; ATR_{L6} = woodlands; ATR_{L7} = forest range; ATR_{L8} = water reserve lands; ATR_{L9} = residential and industrial lands; ATR_{L10} = lands under transportation and communication infrastructure; ATR_{L11} = wetlands; ATR_{L12} = disturbed lands; ATR_{L13} = barren; bold denotes a strong correlation, $C_{ATRli} > C_{cv}$ (0.5904 for type II territories). Source: Authors' development.

The yellow belt included three types of territories, namely, northern territories, Siberia, and the Far East, occupying over half of the territory of Russia, but only representing 12.3% of its agricultural land, where the land use was primarily rangeland. The variations in the acreage of rangelands strongly correlated with those of woodlands, other forest ranges, and wetlands (Table 5). The northern locus included the territories of Russia's northwest, the Ural region, and central Russia (i.e., north of Moscow). In these highly industrialized but less populated territories, we revealed strong correlations between the proportions of croplands and barren land, as well as between those of perennial plantings and disturbed lands. In the south, the yellow belt included Krasnodar, the principal breadbasket territory of Russia. The share of cropland in the composition of Krasnodar's land fund was 52.8%. Krasnodar is also one of Russia's most densely populated regions and is the most popular resort area. The analysis demonstrated high correlations between the proportions of cropland and perennial plantings, on one side, and the shares of residential and industrial lands and lands under transportation and communication infrastructure on the other.

Table 5. Correlation matrix for type III territories.

Regressands	Regressors											
	$\mathbf{ATR_{L1}}$	$\mathbf{ATR_{L2}}$	$\mathbf{ATR_{L3}}$	$\mathbf{ATR_{L4}}$	$\mathbf{ATR_{L5}}$	$\mathbf{ATR_{L6}}$	$\mathbf{ATR_{L7}}$	$\mathbf{ATR_{L8}}$	$\mathbf{ATR_{L9}}$	$\mathbf{ATR_{L10}}$	$\mathbf{ATR_{L11}}$	$\mathbf{ATR_{L12}}$
ATR_{L2}	0.5638											
ATR_{L3}	**0.8819**	0.4291										
ATR_{L4}	**0.8025**	0.4010	**0.8211**									
ATR_{L5}	0.2811	0.6388	**0.9157**	0.5037								
ATR_{L6}	**0.9012**	0.5917	**0.8924**	0.4545	**0.7684**							
ATR_{L7}	0.4709	**0.7559**	0.6713	**0.7553**	**0.8315**	0.2819						
ATR_{L8}	0.6880	0.7000	0.5004	0.3819	**0.7700**	0.4196	0.3358					
ATR_{L9}	**0.8544**	0.3093	**0.8120**	0.6594	0.5428	**0.7920**	0.3902	0.4971				
ATR_{L10}	**0.7923**	0.4458	**0.7538**	0.2888	0.4111	**0.8328**	0.7010	0.6947	**0.7748**			
ATR_{L11}	0.7001	0.6219	0.4816	0.1329	**0.8148**	0.1887	0.6409	0.5068	**0.8591**	0.2509		
ATR_{L12}	0.5493	**0.7704**	0.3309	**0.8617**	0.1499	0.2796	**0.8419**	0.3991	0.4404	**0.7803**	0.3012	
ATR_{L13}	**0.8057**	0.1295	**0.7772**	0.6026	0.2891	0.4905	0.3948	0.4819	**0.9062**	**0.7696**	0.0180	**0.8016**

Note: ATR_{Li} = centered log-ratio-transformed data: ATR_{L1} = cropland; ATR_{L2} = fallow; ATR_{L3} = perennial plantings; ATR_{L4} = hayfields; ATR_{L5} = rangeland; ATR_{L6} = woodlands; ATR_{L7} = forest range; ATR_{L8} = water reserve lands; ATR_{L9} = residential and industrial lands; ATR_{L10} = lands under transportation and communication infrastructure; ATR_{L11} = wetlands; ATR_{L12} = disturbed lands; ATR_{L13} = barren; bold denotes a strong correlation, $C_{ATRli} > C_{cv}$ (0.7458 for type III territories). Source: Authors' development.

Type IV comprised the territories with the lowest activity of agricultural lands. The scarcity of agricultural lands represented intercategory variations in the composition of the agricultural land fund. The strongest correlations were identified between various categories of agricultural lands, specifically, cropland and hayfields, on one side, and perennial plantings and rangeland on the other (Table 6). The composition of the agricultural land fund was also affected by the proportions of barren land (in Chukotka and Nenets), woodlands (in Leningrad and Murmansk), wetlands (in Murmansk), and water reserve lands (in Yamal-Nenets).

Table 6. Correlation matrix for type IV territories.

Regressands	Regressors											
	$\mathbf{ATR_{L1}}$	$\mathbf{ATR_{L2}}$	$\mathbf{ATR_{L3}}$	$\mathbf{ATR_{L4}}$	$\mathbf{ATR_{L5}}$	$\mathbf{ATR_{L6}}$	$\mathbf{ATR_{L7}}$	$\mathbf{ATR_{L8}}$	$\mathbf{ATR_{L9}}$	$\mathbf{ATR_{L10}}$	$\mathbf{ATR_{L11}}$	$\mathbf{ATR_{L12}}$
ATR_{L2}	0.4018											
ATR_{L3}	**0.7301**	0.3884										
ATR_{L4}	0.3899	0.3892	**0.8496**									
ATR_{L5}	**0.6933**	0.2594	**0.7915**	**0.8101**								
ATR_{L6}	**0.6705**	0.3217	0.4024	0.1788	0.2894							
ATR_{L7}	**0.8111**	**0.7910**	0.3881	0.2519	0.3221	**0.7518**						
ATR_{L8}	0.3595	0.6159	0.2053	0.3706	0.1553	0.2995	0.4085					
ATR_{L9}	0.4276	**0.6757**	0.5829	0.4881	**0.7391**	0.2709	**0.7047**	**0.6586**				
ATR_{L10}	0.6083	0.4792	**0.7294**	0.3201	0.3899	0.3892	0.3999	0.5993	0.3788			
ATR_{L11}	0.4291	**0.7032**	0.5022	0.2718	0.0377	0.4920	0.4793	0.2819	0.3003	0.2709		
ATR_{L12}	0.1829	0.0377	0.4603	**0.6883**	**0.7418**	0.3207	**0.6991**	0.1842	**0.6309**	0.5346	0.1442	
ATR_{L13}	**0.6693**	0.4871	**0.7918**	0.5593	0.1294	**0.7622**	0.0412	0.3909	0.1899	**0.6511**	0.2895	0.1566

Note: ATR_{Li} = centered log-ratio-transformed data: ATR_{L1} = cropland; ATR_{L2} = fallow; ATR_{L3} = perennial plantings; ATR_{L4} = hayfields; ATR_{L5} = rangeland; ATR_{L6} = woodlands; ATR_{L7} = forest range; ATR_{L8} = water reserve lands; ATR_{L9} = residential and industrial lands; ATR_{L10} = lands under transportation and communication infrastructure; ATR_{L11} = wetlands; ATR_{L12} = disturbed lands; ATR_{L13} = barren; bold denotes a strong correlation, $C_{ATRli} > C_{cv}$ (0.6293 for type IV territories). Source: Authors' development.

4. Discussion

The results, as expected, demonstrated that the compositions of the land funds in Russia vary across territories. Echoing Bichler et al. [100], Chu [101], Smith et al. [102], and Bakker et al. [103], we found that the distribution of agricultural lands is largely affected by natural factors, while agricultural lands are spread unevenly across the country. At a regional scale, belt-type concentrations of cropland suggest an agriculture-focused land distribution pattern in the southern and central areas of Russia. This is consistent with the observations of Rounsevell et al. [104] and White and Engelen [105,106], who revealed that agricultural land use tends to become concentrated in locations, reflecting the influence of natural factors and neighboring land distribution patterns. Nevertheless, in particular territories, the proportion of agricultural lands in the land funds do not match the type of agricultural land activity.

Emulating earlier studies by Mazurkin and Mihailova [70], Shishkina et al. [74], Mazurkin [69], and Buckett [71], we revealed that the application of a land activity parameter could result in creating a picture of land distribution patterns that are different from that which might be expected from the knowledge of the proportions of individual land categories. Therefore, land distribution change maps are not sufficient to capture specific finer-scale variations in the compositions of land funds at a regional scale. In Russia, land tenure and demand for land have been the principal economic proxies to map agricultural land distribution. According to Shagaida [107], the demand for agricultural land varies significantly across Russia's territories, depending on the degree of land consolidation. In the course of land reform, the previously dominant state farms have transformed the organizational form of their land use but still have persisted as the backbone of the agricultural sector [34,108]. In the embryonic land market in the 1990–2000s, the establishment of new land tenure patterns had not involved immediate changes in the distribution of land from big ex-Soviet agricultural enterprises to individual owners [107]. Since land certificates do not specify land plots, most of the shareowners have not withdrawn their land property from joint use by former collective farms. Over 70% of land in Russia is still used by large enterprises for rent, 25% is contributed to the capital of large enterprises, and only 4% is retained by private owners [109]. In the breadbasket southern and central European territories of Russia, large agricultural holding companies have aggregated even more agricultural land property when compared to the Soviet period [110].

To a large extent, the existing demand-based distribution matches the land activity map (Figure 3), as the highest demand for land is identified in the central parts of the country close to Moscow. This demand primarily exists due to non-agricultural businesses. For type I and II territories, this correlates well with the finding of strong links between the proportions of agricultural land categories, on one side, and those of residential, industrial, and infrastructure lands on the other. In type III southern locus (Krasnodar), Lerman and Shagaida [20] reported high demand for land among corporate farms. In that classification, type I and II territories are considered as less developed areas in terms of agricultural production (sometimes even as "agriculturally depressed regions" ([20] p. 20)), where corporate farms tend to reduce their holdings and abandon land plots. Our results, on the contrary, demonstrated that in the south of European Russia, where the concentration of croplands is the highest, agricultural land activity is lower compared to many other territories of the country.

In the territories where a high proportion of croplands coexist with low agricultural land activity, many of the variations in the composition of a land fund could be explained by socio-economic factors. Van de Steeg et al. [111] and Gärtner et al. [112] confirmed that the distribution of agricultural land strongly correlates with the level of rural development, proximity to economic and market centers, urbanization, and the demand for agricultural land from non-agricultural industries. Our study revealed correlations between the proportions of agricultural and urban lands across type I–III territories, which could represent losing agricultural land due to urban development. In type II territories, the compositions of agricultural land funds are more affected by urban development than the compositions of type I and III. These results supported the findings of Daniels [113], Su et al. [114], Yeh and Huang [115], and Dredge [116], i.e., the proximity to urban development can be a powerful predictor of changes in agricultural land use. Many scholars, including Parsipour et al. [117], Li et al. [118], and Al-Kofahi et al. [119], among others, agree that the accelerating urbanization has been causing increasingly harmful effects on agricultural lands. In the case of Russia, we did not reveal the acceleration of agriculture land loss in urbanized type I–III territories. What was revealed, however, was the strengthening of the correlation between the variations in the compositions of agricultural land funds and residential, industrial, and infrastructure lands. As Zubair et al. [120] and Lucero and Tarlock [121] forecasted, such stronger associations would continue to put increasing pressure on agricultural lands and result in more fragmented agricultural land use in the future.

Along with urbanization, an orientation of a land fund composition towards agricultural production is determined by the population density [111,122]. In urbanized type I and II territories, agricultural land use is affected by the variations in the acreage of residential lands. In agriculture-oriented Krasnodar, Rostov, and Stavropol, the changes in agricultural land fund compositions are mainly linked with those of lands for transportation and communication. This result was consistent with what Ramadani and Bytyqi [123], Li et al. [118], and Al-Kofahi et al. [119] reported when assessing the effects of more significant concentrations of the population on the lower proportions of agricultural lands in a land fund.

Reversely, Meyfroidt et al. [124] and Nguyen et al. [125] revealed that in the industrialized areas in Russia, where the density of population is lower, the concentration of abandoned lands is higher. There is an array of studies that have reported a link between industrial growth, changes in agricultural land distribution, and the degradation of farming opportunities internationally. Explicitly, Oyebanji et al. [126] confirmed the existence of a positive long-term relationship between industrialization and land loss in Nigeria. Deng and Li [127] revealed that the soil sealing effect has resulted from industrial and infrastructure construction in China, while Müller and Sikor [128], Milanova et al. [33], and Müller et al. [129] linked changes in agricultural land distribution and agricultural abandonment in EU countries with unfavorable environmental conditions due to increasing industrialization. The expansion of urban and industrial infrastructure not only triggers agriculture-to-urban and agriculture-to-industry land transfers but also leads to the overexploitation and degradation of remaining agricultural lands [127]. Many areas in Russia may soon face a reduction in farming opportunities due to various kinds of environmental pollution. Many experts tend to explain the unprecedented increase of barren land in Russia (by four million ha during the past two decades) by the intensive exploitation of mineral resources and industrial construction [39,130]. Kashtanov [131] and Dobrovolski [132] associated the expansion of industrial infrastructure with long-term and irreversible losses of cropland in Russia. In support of the earlier findings of Sorokin et al. [130] and Solgerel et al. [133] concerning the close relationships between industrial development and arable acreage, strong correlations between the proportions of croplands, perennial plantings, and industrial lands are revealed in both urbanized type I and II territories and sparsely populated yellow belt areas.

Distinct from urbanization, industrialization may affect agricultural land use in remote areas. According to Sorokin et al. [130], most of the abandoned lands are located in the north of Russia. This agrees well with our finding of strong correlations between the variations in the acreage of croplands, disturbed lands, and barren lands in the north locus of the yellow belt. Prishchepov et al. [39] and MacDonald et al. [134] also reported abandoned agricultural land concentrated in remote and isolated industrialized areas in northern Russia. Nakvasina et al. [135] claimed that the proximity to urban areas might be used as a critical criterion to transfer disturbed and barren lands back into agricultural use. However, we did not identify strong correlations between the variations in agricultural land fund compositions and residential lands for type III territories.

In diverse land activity patterns across the Russian territories, changes in the compositions of agricultural and non-agricultural land funds depend on the degree of industrial development. As mentioned by Postek et al. [136] and Prishchepov et al. [39], agricultural land loss due to increasing industrialization causes the fragmentation of arable lands as smaller locations with lower productivity. However, according to Popov [137], fragmentation is not a problem in agriculture-oriented areas due to the excessive lease of agricultural land. The issue is particularly topical in territories where arable land is scarce, however [138,139]. Nefedova [140] reported that in northern and eastern parts of Russia, agricultural land distribution is extremely fragmented. Our results demonstrated that in the Russian North and Far East, low activity of cropland is coupled with the prevalence of hayfields in the composition of the agricultural land funds there. High intragroup correlations between the proportions of cropland, rangeland, hayfields, and perennial plantings in type IV territories confirm the observations of King and Burton [141], Tan et al. [142], and Dhakal and Khanal [143], i.e., the fragmentation results in the competition between the categories of agricultural lands.

We performed our analysis in the short-term, but it is commonly known that land transformations (particularly, for croplands and annual crops) can be rapid, whereas transformations are slower in grassland-livestock oriented areas and permanent crop areas. Nationally, the ongoing loss of croplands may not have an immediate effect on the agricultural output of Russia. Still, this represents enormous environmental, economic, and social costs that will be hard to absorb in terms of a long-term perspective [144]. Griewald et al. [34] and Hunt et al. [145] outlined five principal drivers of long-term change in agricultural land use in Russia, environmental drivers being one of them. Our findings would allow one to expect that the evolution of land-use change will be affected by the pressure exerted on ecosystems by various land management types [34]. While some authors, including Diputra and Baek [146] and Mahcene et al. [147], reported little evidence that industrialization causes a significant increase in disturbed land acreage, our results suggested that lower activity of agricultural land categories is correlated with a higher activity of barren land, disturbed land, and industrial land. Weaker, but still significant, correlations between the proportions of agricultural and industrial land categories are revealed in type I and II territories here. In type IV territories, the contributions of croplands and perennial plantings to regional land funds are also linked with variations in the acreage of barren lands.

Among the drivers of land-use change, in the long run, there are also economic, social, technological, and policy-related factors. Bukvareva et al. [148] stated that current land-use policies in Russia pay little attention to the environmental costs associated with the re-use of abandoned lands. In light of the economic recession that Russia has been experiencing since the mid-2010s, farmers tend to reinforce the exploitation of all available lands to ensure sufficient income inflow. Often, this is done regardless of whether some lands are of high environmental value or are socioeconomically marginal [29]. In the short-term perspective, we did not reveal an increase in the acreage of croplands due to the use of other categories of agricultural land. To some extent, however, the correlations between the proportions of agricultural land categories are identified in type III territories. In these yellow belt areas, land reclamation programs will require substantial investments for clearing forested land, liming, and other works. In the short-term, high reclamation costs along with poor soil quality may reduce expected economic returns [149]; however, in the long run, the incentives for reclamation may grow as both the availability and quality of croplands in type I and II territories degrade. Such a perspective highlights the need for a deeper investigation of the variations in land fund compositions within a sustainable agricultural land management approach as a component of the broader economic and environmental system [150,151].

5. Conclusions

In recent decades, there has been increasing concern for ensuring the effective utilization of agricultural land due to the limited area of highly productive arable land and the growing demand for food and farming products internationally. In Russia, an orientation of state policy towards the growth of agricultural production, along with a low level of environmental awareness among farmers, has impeded the prospects of sustainable land management as an integral aspect of land use planning. The degradation of agricultural lands due to irrational use has posed environmental, economic, and social threats to the national development objectives of land management in many territories of the country. As most studies in Russia have focused on land changes between the categories of agricultural land, the influence of agriculture-to-urban and agriculture-to-industry transfers has been downplayed.

We conducted this work, intending to study such variations by revealing the interdependencies between the proportions of agricultural land categories, on the one hand, and urban, industrial, and other types of land on the other. First, land distribution was mapped based on a share of agricultural lands in a composition of a land fund and, second, by a "land activity rating" of Russia's territories. Such a two-step approach to mapping allowed us to find that the proportions of agricultural lands in the composition of a land fund do not appropriately reveal the variations in the activities of agricultural land categories. In the territories, where agricultural lands dominated in the structure of a land fund, the agricultural land activity could be depressed by high proportions of non-agricultural lands. In urbanized and densely populated territories, the composition of the agricultural land fund was predominantly affected by the changes in the acreage of residential and industrial lands, as well as the lands for transportation and communication. In industrialized but underpopulated territories, the acreages of croplands and perennial plantings were strongly correlated with those of disturbed and barren lands. We also found that lower land activity tended to increase the variations within the agricultural land fund, which might indicate intercategory competition for more fertile, more productive, and better-located agricultural lands.

By establishing and testing the five-stage algorithm, we attempted to solve the scientific problem of low awareness in the causality between land-use processes and the composition of the land funds at regional scales. As distinguished from previous studies in the area, we investigated variations in the compositions of a land fund as interactions between the proportions of agricultural and non-agricultural lands. Practically, in territory-scale studies, such an approach might complement regionally adapted monitoring networks by targeting the mismatches between the cadaster-based mappings of agricultural land distributions and ranking-based activities of agricultural lands. Theoretically, such an algorithm allows one to capture the complex relationships of a variety of land categories and the resulting correlations between their proportions, therefore, being applicable for studying territorial land-use patterns, the simulation of agricultural land distribution systems, and the extrapolation of current trends into the future. Potentially, the algorithm is suitable for numerous locations. However, one of the limitations of the current study was that it used the Russian system of land statistics, which is built on thirteen land categories. Due to the different sources of land use data in different countries, an adjustment of the array of land categories to a national land reporting system is needed when implementing the method in a broader international context. Another limitation that could potentially challenge cross-country comparisons is the different sizes of territorial units. Russia's case demonstrates that this problem may arise even within one country, where territories substantially differ in size. In an attempt to overcome a data discrepancy obstacle, we conversed cadastral classification data into land-rating values. To address the diversity of territories, we used an agricultural land activity parameter. This allowed us to adjust agricultural and non-agricultural-oriented ranking systems to make them comparable. Nevertheless, further research is needed to assess to what extent the approach would be able to appropriately picture variations in agricultural land activity patterns in the conditions of information asymmetries among countries.

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Appendix A

Table A1. Land acreage data of the Central Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_1	2713.4	1645.2	0	34.0	55.8	399.3	241.9	90.5	25.1	73.1	57.9	22.5	6.5	61.6
T_2	3485.7	1174.9	121.4	26.0	205.5	346.5	1183.6	121.4	31.6	56.8	72.0	75.1	5.1	65.8
T_3	2908.4	605.7	46.6	20.0	163.9	159.1	1582.7	74.9	32.7	38.0	75.0	38.3	16.3	55.2
T_4	5221.6	3046.2	41.9	52.8	159.0	776.8	482.4	149.5	64.0	113.4	121.1	40.6	1.9	172.0
T_5	2143.7	565.9	9.8	9.0	124.1	112.5	1047.8	28.5	65.0	42.0	51.2	50.3	7.4	30.2
T_6	2977.7	956.1	36.1	21.0	131.2	232.2	1376.9	35.5	21.0	56.9	50.2	28.6	2.1	29.9
T_7	6021.1	655.0	31.2	5.6	154.5	148.3	4574.1	98.9	97.0	35.6	101.7	86.8	5.7	26.7
T_8	2999.7	1943.4	0.7	27.9	101.6	364.3	249.3	68.1	38.3	56.4	72.5	32.1	11.0	34.1
T_9	2404.7	1553.9	0.1	35.2	83.6	281.0	190.7	61.4	27.0	47.9	61.7	16.4	2.5	43.3
T_{10}	4579.9	1130.3	6.7	113.9	183.0	229.4	1998.3	35.2	90.1	303.1	158.8	50.6	34.7	98.8
T_{11}	2465.2	1570.0	55.7	25.3	58.6	341.5	203.1	74.2	14.4	21.9	72.8	3.8	0.7	23.2
T_{12}	3960.5	1535.2	26.1	24.6	202.6	722.4	1067.8	66.3	67.2	37.1	105.1	55.4	6.6	44.1
T_{13}	4977.9	1461.7	17.7	19.5	215.1	380.0	2167.6	357.6	53.7	55.7	86.5	115.3	18.0	29.5
T_{14}	3446.2	2127.5	9.6	32.4	166.0	388.8	371.7	97.9	42.8	55.1	60.8	43.9	1.7	48.0
T_{15}	8420.1	1504.3	19.4	14.7	379.1	501.0	4742.2	233.3	248.1	96.9	116.4	465.2	20.3	79.2
T_{16}	2567.9	1554.4	7.6	45.0	67.9	298.0	372.3	43.0	22.8	32.3	90.4	1.9	10.0	22.3
T_{17}	3617.7	793.3	0.3	14.6	123.7	196.1	1725.7	93.0	386.8	59.4	65.8	109.7	15.2	34.1

Note: T_1 = Belgorod; T_2 = Bryansk; T_3 = Vladimir; T_4 = Voronezh; T_5 = Ivanovo; T_6 = Kaluga; T_7 = Kostroma; T_8 = Kursk; T_9 = Lipetsk; T_{10} = Moscow Oblast; T_{11} = Orel; T_{12} = Ryazan; T_{13} = Smolensk; T_{14} = Tambov; T_{15} = Tver; T_{16} = Tula; T_{17} = Yaroslavl; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Table A2. Land acreage data of Northwestern Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_{18}	18,052.0	82.3	0.1	5.9	85.4	39.2	9850.2	22.1	4188.2	38.3	87.6	3543.6	13.4	95.7
T_{19}	41,677.4	102.4	0	6.5	239.6	69.6	31,093.5	135.6	641.5	48.2	144.8	4073.1	15.8	5106.8
T_{20}	41,310.3	302.5	1.8	9.1	304.1	109.8	22,948.6	126.3	811.5	93.3	131.3	5823.3	5.5	10,643.2
T_{21}	14,452.7	822.0	48.0	9.4	343.9	225.2	10,456.4	330.9	658.6	38.3	178.3	1271.8	22.2	47.7
T_{22}	1512.5	392.6	0	14.3	153.6	248.9	295.1	18.8	200.3	40.6	40.9	31.0	4.4	72.0
T_{23}	8390.8	434.1	0	44.4	194.6	125.4	5015.7	125.3	1266.8	58.7	112.7	830.0	23.0	160.1
T_{24}	14,490.2	19.4	0	3.1	2.8	0.3	5383.6	580.8	1191.5	37.1	31.3	5701.2	19.7	1519.4
T_{25}	5450.1	510.6	4.2	6.1	173.1	135.9	3580.9	138.6	174.8	25.5	69.8	548.5	10.4	71.7
T_{26}	5539.9	744.3	186.4	20.5	279.0	280.9	2249.0	785.3	375.3	34.8	71.9	476.2	8.9	27.4
T_{27}	17,681.0	0.2	0	0	19.8	5.7	1740.8	1439.2	1000.5	12.8	10.8	3381.8	2.5	10,066.9

Note: T_{18} = Karelia; T_{19} = Komi; T_{20} = Arkhangelsk; T_{21} = Vologda; T_{22} = Kaliningrad; T_{23} = Leningrad; T_{24} = Murmansk; T_{25} = Novgorod; T_{26} = Pskov; T_{27} = Nenets; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Table A3. Land acreage data of the Southern Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_{28}	779.2	259.6	0.3	9.3	4.9	85.7	288.8	7.7	53.5	22.1	18.8	4.0	0.3	24.2
T_{29}	7473.1	836.9	10.6	2.5	103.2	5363.6	32.6	42.3	175.6	32.2	65.1	123.5	4.0	681.0
T_{30}	2608.1	1271.6	10.6	75.8	1.9	433.6	266.2	35.0	211.7	118.8	43.4	5.2	1.5	132.8
T_{31}	7548.5	3985.4	0.2	125.2	63.1	531.1	1541.3	158.7	385.6	202.9	196.0	179.6	5.4	174.0
T_{32}	4902.4	352.0	6.7	9.8	404.8	2482.7	104.2	19.5	684.6	28.2	57.4	114.7	0.5	637.3
T_{33}	11,287.7	5854.0	4.7	42.8	206.9	2652.8	591.0	131.3	489.8	165.9	117.6	35.2	3.0	992.7
T_{34}	10,096.7	5907.3	0	58.2	88.4	2459.2	293.0	281.9	346.1	150.8	220.5	55.0	7.1	229.2

Note: T_{28} = Adygeya; T_{29} = Kalmykia; T_{30} = Crimea; T_{31} = Krasnodar; T_{32} = Astrakhan; T_{33} = Volgograd; T_{34} = Rostov; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Table A4. Land acreage data of the North Caucasian Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_{35}	5027.0	520.1	4.8	72.4	162.3	2588.6	585.0	57.2	176.9	34.5	63.0	20.6	2.5	739.1
T_{36}	362.8	111.0	0	4.7	9.7	96.6	101.0	2.3	1.7	4.5	5.5	0.1	0.1	25.6
T_{37}	1247.0	300.7	0	30.1	56.3	309.3	196.8	13.3	15.5	17.6	26.8	1.2	1.0	278.4
T_{38}	1427.7	161.1	3.8	4.9	140.9	353.2	431.2	9.7	22.5	13.9	14.1	1.3	0.8	270.3
T_{39}	798.7	202.4	0.4	5.1	23.2	169.7	205.9	9.7	11.5	19.1	12.0	0.5	0.3	138.9
T_{40}	1564.7	332.2	0.2	11.0	56.8	575.2	336.0	27.6	28.6	43.4	21.5	2.7	1.4	128.1
T_{41}	6616.0	3998.6	14.0	44.2	104.9	1625.8	110.2	144.1	127.0	107.5	147.9	28.8	3.4	159.6

Note: T_{35} = Dagestan; T_{36} = Ingushetia; T_{37} = Kabardino-Balkaria; T_{38} = Karachaevo-Cherkessia; T_{39} = North Osetia-Alania; T_{40} = Chechnya; T_{41} = Stavropol; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Table A5. Land acreage data of the Volga Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_{42}	14,294.7	3670.5	0	43.6	1266.7	2346.1	5765.6	227.9	149.9	132.1	260.1	50.8	17.2	364.2
T_{43}	2337.5	472.1	128.0	7.9	56.6	108.2	1340.6	18.9	85.0	26.2	39.5	33.1	1.4	20.0
T_{44}	2612.8	1084.8	56.8	14.5	62.3	437.2	726.1	64.8	20.8	33.5	53.0	15.9	1.5	41.6
T_{45}	6784.7	3420.6	0.7	41.1	144.2	932.8	1199.1	129.4	451.6	141.7	157.8	50.6	4.8	110.3
T_{46}	4206.1	1382.3	9.3	15.2	112.5	321.5	2019.1	102.0	53.8	36.2	99.5	16.7	5.3	32.7
T_{47}	1834.3	806.3	6.2	19.9	48.3	153.8	603.6	17.5	48.1	35.3	60.1	5.1	0.5	29.6
T_{48}	16,023.6	1980.7	67.8	25.4	388.8	376.5	11,749.2	145.5	399.6	124.1	209.1	369.8	8.5	178.6
T_{49}	12,037.4	2480.3	51.8	15.0	374.2	399.1	7949.0	150.6	118.0	48.7	148.4	133.3	12.9	156.1
T_{50}	7662.4	2035.8	180.0	33.8	218.6	642.5	3817.1	90.2	162.7	112.8	143.4	123.0	6.0	96.5
T_{51}	12,370.2	6115.3	0	23.0	698.0	3979.5	618.6	199.3	111.3	158.7	184.7	15.3	13.0	253.5
T_{52}	4335.2	2263.6	153.4	22.5	71.4	528.1	975.7	77.2	42.2	59.7	89.7	13.5	0.9	37.3
T_{53}	5356.5	2937.5	103.5	42.3	67.0	847.5	685.6	104.5	226.0	103.0	123.7	42.0	3.9	70.0
T_{54}	10,124.0	5981.1	0	39.9	122.2	2400.5	614.2	121.2	357.9	113.3	149.4	19.2	2.4	202.7
T_{55}	3718.1	1655.7	105.8	17.7	37.8	390.3	1035.2	55.0	228.5	34.8	85.6	10.7	1.4	59.6

Note: T_{42} = Bashkortostan; T_{43} = Mari El; T_{44} = Mordovia; T_{45} = Tatarstan; T_{46} = Udmurtia; T_{47} = Chuvashia; T_{48} = Perm; T_{49} = Kirov; T_{50} = Nizhny Novgorod; T_{51} = Orenburg; T_{52} = Penza; T_{53} = Samara; T_{54} = Saratov; T_{55} = Ulyanovsk; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Table A6. Land acreage data of the Ural Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_{56}	7148.8	2402.6	459.3	12.4	559.0	1024.8	1759.5	37.2	318.7	49.1	86.3	383.9	1.1	54.9
T_{57}	19,430.7	1470.4	99.5	32.4	624.3	351.1	13,631.8	230.7	262.3	162.4	228.5	2046.2	61.8	229.3
T_{58}	16,012.2	1353.0	364.7	11.7	895.8	756.7	7112.8	144.9	508.5	80.0	96.1	4609.1	4.6	74.3
T_{59}	8852.9	3058.8	55.0	38.3	591.1	1352.0	2707.3	75.2	275.9	137.8	145.5	192.7	31.8	191.5
T_{60}	53,480.1	13.1	3.0	10.5	343.8	259.7	28,693.6	156.5	3185.4	141.6	170.7	19,913.4	55.7	533.1
T_{61}	76,925.0	0.9	0	0.2	165.3	57.3	18,763.5	4380.3	13,319.9	120.5	170.7	14,798.8	103.7	25,043.9

Note: T_{56} = Kurgan; T_{57} = Sverdlovsk; T_{58} = Tyumen; T_{59} = Chelyabinsk; T_{60} = Khanty-Mansi; T_{61} = Yamal-Nenets; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Table A7. Land acreage data of the Siberian Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_{62}	9290.3	143.5	2.2	1.7	120.9	1522.8	4357.7	190.0	86.3	10.9	23.1	73.3	0.4	2757.5
T_{63}	35,133.4	829.6	61.6	8.2	389.6	1856.8	23,660.6	220.7	2409.0	73.2	86.3	487.3	7.8	5042.7
T_{64}	16,860.4	191.3	147.9	0.9	76.5	3416.6	8667.2	450.1	228.1	21.7	29.3	1026.4	5.5	2598.9
T_{65}	6156.9	685.0	40.0	7.3	160.4	1022.5	3288.9	23.1	112.2	30.0	39.3	32.1	12.7	703.4
T_{66}	16,799.6	6654.4	298.9	27.8	1235.6	2789.7	4029.3	205.8	442.6	131.9	195.5	374.7	3.6	409.8
T_{67}	43,189.2	484.1	951.5	5.7	1722.6	4481.7	30,782.9	497.5	318.7	152.1	114.3	1076.9	24.2	2577.0
T_{68}	236,679.7	3120.1	136.4	37.4	781.8	1334.1	120,936.8	3185.0	9221.5	175.3	182.5	22,690.2	17.3	74,861.3
T_{69}	77,484.6	1734.5	3.3	30.0	390.1	640.8	66,080.5	235.1	2639.0	165.1	260.9	1709.4	26.3	3569.6
T_{70}	9572.5	1539.4	0.1	27.1	471.3	582.5	6074.7	163.2	91.7	107.5	174.5	90.5	83.4	166.6
T_{71}	17,775.6	3772.1	81.0	33.6	2197.9	2315.0	4799.2	280.3	766.5	102.4	166.8	3059.6	1.7	199.5
T_{72}	14,114.0	4156.6	175.9	26.5	1096.2	1265.5	4667.7	89.4	289.8	93.9	150.7	2026.8	5.0	70.0
T_{73}	31,439.1	675.9	1.3	9.4	479.9	204.5	19,939.9	88.1	608.3	42.5	87.9	9173.9	7.1	120.4

Note: T_{62} = Altay Republic; T_{63} = Buryatia; T_{64} = Tyva; T_{65} = Khakasia; T_{66} = Altay; T_{67} = Zabaikalsk; T_{68} = Krasnoyarsk; T_{69} = Irkutsk; T_{70} = Kemerovo; T_{71} = Novosibirsk; T_{72} = Omsk; T_{73} = Tomsk; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Table A8. Land acreage data of the Far Eastern Federal District in thousand hectares. Mean values for 2010–2018.

Territory	Total	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}
T_{74}	308,352.3	105.3	19.0	1.0	719.5	795.4	164,862.0	1837.7	13,087.5	82.6	129.1	19,783.6	30.9	106,898.7
T_{75}	46,427.5	64.3	1.0	5.3	97.3	307.7	26,810.0	305.8	844.5	16.3	17.0	2523.3	2.9	15,432.1
T_{76}	16,467.3	755.0	60.8	25.9	361.8	445.9	13,023.3	407.6	424.6	111.1	101.3	466.9	16.8	266.3
T_{77}	78,763.3	98.4	25.1	16.8	401.9	123.4	59,571.6	231.8	1476.3	79.3	95.7	5605.9	6.1	11,031.0
T_{78}	36,190.8	1577.2	244.0	11.9	418.0	482.5	26,136.8	268.4	1151.0	54.1	136.3	4794.1	12.7	903.8
T_{79}	46,246.4	23.8	3.5	0.1	51.5	42.6	28,467.1	340.8	477.3	9.5	14.5	4815.4	77.4	11,922.9
T_{80}	8710.1	51.2	0	7.6	63.6	60.0	6607.9	347.5	233.2	34.0	33.1	642.0	10.5	619.5
T_{81}	3627.1	94.6	70.3	3.1	119.2	250.0	1783.2	139.1	35.3	12.1	20.7	914.5	1.5	183.5
T_{82}	72,148.1	0.1	0	0	8.2	0.3	13,015.1	3878.3	2442.7	4.5	22.2	2833.0	47.5	49,896.2

Note: T_{74} = Sakha Yakutia; T_{75} = Kamchatka; T_{76} = Primorye; T_{77} = Khabarovsk; T_{78} = Amur; T_{79} = Magadan; T_{80} = Sakhalin; T_{81} = Jewish AO; T_{82} = Chukotka; $L_{(1–13)}$ = acreage of L_i category, thousand hectares: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren. Source: Authors' development.

Appendix B

Table A9. Activity per land category in Russia, Central Federal District. Mean values for 2010–2018.

Parameter	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}	$\overline{A_{T(1-17)Li}}$
L_1	0.606	0.337	0.208	0.583	0.264	0.321	0.109	0.648	0.646	0.255	0.637	0.388	0.294	0.617	0.179	0.605	0.219	0.367
V_{L1}	−0.002	+0.006	-	−0.003	−0.003	-	−0.002	−0.001	-	−0.008	-	-	-	−0.001	-	−0.001	-	
L_2	0	0.035	0.016	0.008	0.005	0.012	0.005	0	0	0.002	0.023	0.007	0.004	0.003	0.002	0.003	0	0.007
V_{L2}	-	−0.007	-	-	+0.001	-	-	-	-	+0.002	-	-	-	−0.002	-	-	-	
L_3	0.013	0.007	0.007	0.010	0.004	0.007	0.001	0.009	0.015	0.026	0.010	0.006	0.004	0.009	0.002	0.018	0.004	0.008
V_{L3}	-	-	-	-	-	-	-	-	-	+0.001	-	-	-	-	-	-	-	
L_4	0.021	0.059	0.056	0.030	0.058	0.044	0.026	0.034	0.035	0.041	0.024	0.051	0.043	0.048	0.045	0.026	0.034	0.040
V_{L4}	-	+0.001	-	-	-	-	-	-	-	−0.001	-	-	-	+0.006	-	−0.001	−0	
L_5	0.147	0.099	0.055	0.149	0.052	0.078	0.025	0.121	0.117	0.052	0.139	0.182	0.076	0.113	0.060	0.116	0.054	0.090
V_{L5}	-	-	-	+0.002	-	-	-	-	-	−0.003	-	-	-	+0.010	-	−0.001	-	
L_6	0.089	0.340	0.544	0.092	0.489	0.462	0.760	0.083	0.079	0.451	0.082	0.270	0.435	0.108	0.563	0.145	0.477	0.363
V_{L6}	-	-	-	+0.006	-	-	-	-	-	+0.001	-	+0.001	-	-	+0.002	-	+0.001	
L_7	0.033	0.035	0.026	0.029	0.013	0.012	0.016	0.023	0.026	0.008	0.030	0.017	0.072	0.028	0.028	0.017	0.026	0.027
V_{L7}	-	-	-	−0.006	-	-	+0.002	-	-	−0.001	-	-	−0.001	+0.006	−0.002	-	-	
L_8	0.009	0.009	0.011	0.012	0.030	0.007	0.016	0.013	0.011	0.020	0.006	0.017	0.011	0.012	0.029	0.009	0.107	0.020
V_{L8}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
L_9	0.027	0.016	0.013	0.022	0.020	0.019	0.006	0.019	0.020	0.068	0.009	0.009	0.011	0.016	0.012	0.013	0.016	0.019
V_{L9}	+0.001	-	-	+0.001	+0.001	-	-	+0.001	-	+0.005	-	-	-	-	-	+0.003	+0.001	
L_{10}	0.021	0.021	0.026	0.023	0.024	0.017	0.017	0.024	0.026	0.036	0.030	0.027	0.017	0.018	0.014	0.035	0.018	0.022
V_{L10}	+0.001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
L_{11}	0.008	0.022	0.013	0.008	0.023	0.010	0.014	0.011	0.007	0.011	0.002	0.014	0.023	0.013	0.065	0.001	0.030	0.019
V_{L11}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
L_{12}	0.002	0.001	0.006	0	0.003	0.001	0.001	0.004	0.001	0.008	0	0.002	0.004	0	0.002	0.004	0.004	0.003
V_{L12}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
L_{13}	0.023	0.019	0.018	0.033	0.014	0.010	0.004	0.011	0.018	0.022	0.010	0.011	0.006	0.013	0.009	0.009	0.009	0.015
V_{L13}	-	−0.005	−0.006	−0.007	−0.003	−0.001	−0.002	−0.004	−0.004	−0.003	−0.005	−0.005	−0.002	−0.004	−0.001	−0.003	−0.004	

Note: T_1 = Belgorod; T_2 = Bryansk; T_3 = Vladimir; T_4 = Voronezh; T_5 = Ivanovo; T_6 = Kaluga; T_7 = Kostroma; T_8 = Kursk; T_9 = Lipetsk; T_{10} = Moscow Oblast; T_{11} = Orel; T_{12} = Ryazan; T_{13} = Smolensk; T_{14} = Tambov; T_{15} = Tver; T_{16} = Tula; T_{17} = Yaroslavl; $L_{(1-13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1-13)}$ = variability of $L_{(1-13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Table A10. Activity per land category in Russia, Northwestern Federal District. Mean values for 2010–2018.

Parameter	T_{18}	T_{19}	T_{20}	T_{21}	T_{22}	T_{23}	T_{24}	T_{25}	T_{26}	T_{27}	$\overline{A_{T(18–27)Li}}$
L_1	0.005	0.002	0.007	0.057	0.260	0.052	0.001	0.094	0.134	0	0.020
V_{L1}	-	-	-	+0.004	−0.005	+0.002	-	−0.002	+0.003	-	
L_2	0	0	0	0.003	0	0	0	0.001	0.034	0	0.001
V_{L2}	-	-	-	-	-	-	-	-	−0.003	-	
L_3	0	0	0	0.001	0.009	0.005	0	0.001	0.004	0	0.001
V_{L3}	-	-	-	-	+0.001	−0.001	-	-	-	-	
L_4	0.005	0.006	0.007	0.024	0.102	0.023	0	0.032	0.050	0.001	0.011
V_{L4}	+0.001	−0.001	+0.001	−0.003	+0.004	−0.002	-	+0.001	+0.003	-	
L_5	0.002	0.002	0.003	0.016	0.165	0.015	0	0.025	0.051	0	0.007
V_{L5}	-	-	-	+0.002	−0.005	+0.001	-	+0.001	−0.003	-	
L_6	0.546	0.746	0.556	0.723	0.195	0.598	0.372	0.657	0.406	0.098	0.549
V_{L6}	+0.012	−0.009	+0.004	−0.033	+0.017	−0.005	+0.023	−0.008	+0.014	+0.002	
L_7	0.001	0.003	0.003	0.023	0.012	0.015	0.040	0.025	0.142	0.081	0.022
V_{L7}	-	-	-	+0.002	-	-	−0.001	−0.001	−0.011	+0.002	
L_8	0.232	0.015	0.020	0.046	0.132	0.151	0.082	0.032	0.068	0.057	0.062
V_{L8}	+0.006	−0.001	-	+0.002	+0.004	−0.003	-	-	+0.001	+0.002	
L_9	0.002	0.001	0.002	0.003	0.027	0.007	0.003	0.005	0.006	0.001	0.003
V_{L9}	-	-	-	-	−0.003	-	-	-	+0.001	-	
L_{10}	0.005	0.003	0.003	0.012	0.027	0.013	0.002	0.013	0.013	0.001	0.005
V_{L10}	−0.001	-	-	+0.001	−0.002	-	-	-	−0.001	-	
L_{11}	0.196	0.098	0.141	0.088	0.020	0.099	0.393	0.101	0.086	0.191	0.152
V_{L11}	+0.004	−0.003	+0.010	+0.003	-	−0.002	+0.007	−0.013	−0.002	+0.004	
L_{12}	0.001	0	0	0.002	0.003	0.003	0.001	0.002	0.002	0	0.001
V_{L12}	-	-	-	-	-	-	-	-	-	-	
L_{13}	0.005	0.123	0.258	0.003	0.048	0.019	0.105	0.013	0.005	0.569	0.165
V_{L13}	−0.004	−0.023	+0.011	-	+0.014	+0.008	+0.025	+0.005	−0.004	+0.054	

Note: T_{18} = Karelia; T_{19} = Komi; T_{20} = Arkhangelsk; T_{21} = Vologda; T_{22} = Kaliningrad; T_{23} = Leningrad; T_{24} = Murmansk; T_{25} = Novgorod; T_{26} = Pskov; T_{27} = Nenets; $L_{(1–13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1–13)}$ = variability of $L_{(1–13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Table A11. Activity per land category in Russia, Southern Federal District. Mean values for 2010–2018.

Parameter	T_{28}	T_{29}	T_{30}	T_{31}	T_{32}	T_{33}	T_{34}	$\overline{A_{T(28–34)Li}}$
L_1	0.333	0.112	0.488	0.528	0.072	0.519	0.585	0.413
V_{L1}	−0.002	−0.007	-	−0.001	+0.003	−0.007	+0.004	
L_2	0	0.001	0.004	0	0.001	0	0	0.001
V_{L2}	-	-	+0.001	-	-	-	-	
L_3	0.012	0	0.029	0.017	0.002	0.004	0.006	0.007
V_{L3}	+0.002	-	−0.003	+0.002	-	-	+0.001	
L_4	0.006	0.014	0.001	0.008	0.083	0.018	0.009	0.020
V_{L4}	-	−0.001	-	-	+0.004	+0.002	−0.005	
L_5	0.110	0.718	0.166	0.070	0.506	0.235	0.244	0.313
V_{L5}	−0.006	+0.005	−0.003	−0.004	−0.010	+0.009	+0.003	
L_6	0.371	0.004	0.102	0.204	0.021	0.052	0.029	0.070
V_{L6}	+0.004	-	−0.002	+0.005	−0.001	−0.002	−0.003	
L_7	0.010	0.006	0.013	0.021	0.004	0.012	0.028	0.015
V_{L7}	-	-	+0.001	−0.002	-	-	+0.002	
L_8	0.069	0.023	0.081	0.051	0.140	0.043	0.034	0.052
V_{L8}	−0.006	+0.001	−0.003	+0.002	−0.005	-	-	
L_9	0.028	0.004	0.046	0.027	0.006	0.015	0.015	0.016
V_{L9}	+0.002	-	−0.001	+0.001	-	-	+0.001	
L_{10}	0.024	0.009	0.017	0.026	0.012	0.010	0.022	0.016

Table A11. *Cont.*

Parameter	T_{28}	T_{29}	T_{30}	T_{31}	T_{32}	T_{33}	T_{34}	$\overline{A_{T(28–34)Li}}$
V_{L10}	−0.001	-	+0..002	-	-	-	−0.001	
L_{11}	0.005	0.017	0.002	0.024	0.023	0.003	0.005	0.012
V_{L11}	-	+0.001	-	-	+0.001	-	-	
L_{12}	0	0.001	0.001	0.001	0	0	0.001	0
V_{L12}	-	-	-	-	-	-	-	
L_{13}	0.031	0.091	0.051	0.023	0.130	0.088	0.023	0.064
V_{L13}	+0.013	+0.014	-	+0.004	+0.033	+0.021	+0.004	

Note: T_{28} = Adygeya; T_{29} = Kalmykia; T_{30} = Crimea; T_{31} = Krasnodar; T_{32} = Astrakhan; T_{33} = Volgograd; T_{34} = Rostov; $L_{(1–13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1–13)}$ = variability of $L_{(1–13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Table A12. Activity per land category in Russia, North Caucasian Federal District. Mean values for 2010–2018.

Parameter	T_{35}	T_{36}	T_{37}	T_{38}	T_{39}	T_{40}	T_{41}	$\overline{A_{T(35–41)Li}}$
L_1	0.103	0.306	0.241	0.113	0.253	0.212	0.604	0.330
V_{L1}	+0.002	−0.003	+0.006	+0.002	−0.003	+0.004	+0.011	
L_2	0.001	0	0	0.003	0.001	0	0.002	0.001
V_{L2}	-	-	-	-	-	-	-	
L_3	0.014	0.013	0.024	0.003	0.006	0.007	0.007	0.010
V_{L3}	−0.001	+0.002	−0.005	-	-	+0.001	−0.001	
L_4	0.032	0.027	0.045	0.099	0.029	0.036	0.016	0.033
V_{L4}	+0.003	+0.004	-	+0.002	+0.002	−0.001	+0.002	
L_5	0.515	0.266	0.248	0.247	0.212	0.368	0.246	0.336
V_{L5}	−0.006	−0.004	−0.007	+0.002	+0.011	+0.006	−0.004	
L_6	0.116	0.278	0.158	0.302	0.258	0.215	0.017	0.115
V_{L6}	−0.003	+0.006	+0.012	−0.008	−0.003	−0.005	+0.002	
L_7	0.011	0.006	0.011	0.007	0.012	0.018	0.022	0.015
V_{L7}	-	-	−0.001	-	+0.003	−0.002	+0.004	
L_8	0.035	0.005	0.012	0.016	0.014	0.018	0.019	0.023
V_{L8}	+0.004	-	−0.001	−0.002	+0.003	+0.001	−0.003	
L_9	0.007	0.012	0.014	0.010	0.024	0.028	0.016	0.014
V_{L9}	-	+0.001	+0.002	-	−0.001	+0.003	+0.001	
L_{10}	0.013	0.015	0.021	0.010	0.015	0.014	0.022	0.017
V_{L10}	−0.002	-	-	-	+0.001	−0.002	−0.003	
L_{11}	0.004	0	0.001	0.001	0.001	0.002	0.004	0.003
V_{L11}	-	-	-	-	-	-	−0.001	
L_{12}	0	0	0.001	0.001	0	0.001	0.001	0.001
V_{L12}	-	-	-	-	-	-	-	
L_{13}	0.147	0.071	0.223	0.189	0.174	0.082	0.024	0.102
V_{L13}	+0.010	+0.009	+0.021	+0.021	+0.044	+0.005	+0.005	

Note: T_{35} = Dagestan; T_{36} = Ingushetia; T_{37} = Kabardino-Balkaria; T_{38} = Karachaevo-Cherkessia; T_{39} = North Osetia-Alania; T_{40} = Chechnya; T_{41} = Stavropol; $L_{(1–13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1–13)}$ = variability of $L_{(1–13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Table A13. Activity per land category in Russia, Volga Federal District. Mean values for 2010–2018.

Parameter	T_{42}	T_{43}	T_{44}	T_{45}	T_{46}	T_{47}	T_{48}	T_{49}	T_{50}	T_{51}	T_{52}	T_{53}	T_{54}	T_{55}	$\overline{A_{T(42–55)Li}}$
L_1	0.257	0.202	0.415	0.504	0.329	0.440	0.124	0.206	0.266	0.494	0.522	0.548	0.591	0.445	0.350
V_{L1}	+0.003	+0.011	+0.010	+0.009	+0.003	+0.003	+0.007	+0.009	+0.002	+0.018	+0.012	+0.004	+0.008	+0.007	
L_2	0	0.055	0.022	0	0.002	0.003	0.004	0.004	0.023	0	0.035	0.019	0	0.028	0.008
V_{L2}	-	−0.003	−0.001	-	-	-	+0.001	-	−0.002	-	−0.004	−0.002	-	−0.003	
L_3	0.003	0.003	0.006	0.006	0.004	0.011	0.002	0.001	0.004	0.002	0.005	0.008	0.004	0.005	0.003
V_{L3}	-	-	+0.001	+0.001	-	−0.002	-	-	+0.001	-	-	+0.001	-	-	
L_4	0.089	0.024	0.024	0.021	0.027	0.026	0.024	0.031	0.029	0.056	0.016	0.013	0.012	0.010	0.035
V_{L4}	−0.004	−0.003	−0.005	−0.002	−0.003	−0.002	−0.004	−0.003	−0.005	−0.004	−0.001	−0.002	−0.001	−0.002	
L_5	0.164	0.046	0.167	0.137	0.076	0.084	0.023	0.033	0.084	0.322	0.122	0.158	0.237	0.105	0.134
V_{L5}	+0.001	+0.002	+0.004	+0.001	+0.002	+0.004	−0.001	−0.001	+0.003	+0.003	+0.005	+0.006	+0.007	−0.003	
L_6	0.403	0.574	0.278	0.177	0.480	0.329	0.733	0.660	0.498	0.050	0.225	0.128	0.061	0.278	0.377
V_{L6}	+0.003	+0.005	+0.003	−0.002	−0.012	−0.007	+0.013	+0.017	+0.012	−0.001	+0.004	−0.003	-	+0.003	
L_7	0.016	0.008	0.025	0.019	0.024	0.010	0.009	0.013	0.012	0.016	0.018	0.020	0.012	0.015	0.015
V_{L7}	−0.002	-	−0.002	+0.003	+0.001	−0.001	-	-	+0.001	+0.002	−0.002	−0.001	+0.002	+0.002	
L_8	0.010	0.036	0.008	0.067	0.013	0.026	0.025	0.010	0.021	0.009	0.010	0.042	0.035	0.061	0.024
V_{L8}	+0.003	+0.006	+0.001	+0.008	−0.001	−0.001	+0.003	+0.001	−0.002	-	-	+0.003	−0.001	+0.003	
L_9	0.009	0.011	0.013	0.021	0.009	0.019	0.008	0.004	0.015	0.013	0.014	0.019	0.011	0.009	0.011
V_{L9}	-	-	+0.001	−0.002	-	+0.002	-	-	−0.002	+0.004	-	−0.004	-	-	
L_{10}	0.018	0.017	0.020	0.023	0.024	0.033	0.013	0.012	0.019	0.015	0.021	0.023	0.015	0.023	0.017
V_{L10}	+0.003	+0.002	+0.001	+0.002	+0.001	−0.001	−0.001	−0.001	−0.003	+0.001	+0.002	+0.002	+0.001	+0.001	
L_{11}	0.004	0.014	0.006	0.007	0.004	0.003	0.023	0.011	0.016	0.001	0.003	0.008	0.002	0.003	0.009
V_{L11}	−0.001	−0.001	−0.002	+0.001	-	-	−0.004	−0.002	−0.005	-	-	+0.001	-	-	
L_{12}	0.001	0.001	0.001	0.001	0.001	0	0.001	0.001	0.001	0.001	0	0.001	0	0	0.001
V_{L12}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
L_{13}	0.025	0.009	0.016	0.016	0.008	0.016	0.011	0.013	0.013	0.020	0.009	0.013	0.020	0.016	0.016
V_{L13}	+0.002	-	-	-	-	−0.003	−0.003	−0.002	-	−0.002	-	-	-	-	

Note: T_{42} = Bashkortostan; T_{43} = Mari El; T_{44} = Mordovia; T_{45} = Tatarstan; T_{46} = Udmurtia; T_{47} = Chuvashia; T_{48} = Perm; T_{49} = Kirov; T_{50} = Nizhny Novgorod; T_{51} = Orenburg; T_{52} = Penza; T_{53} = Samara; T_{54} = Saratov; T_{55} = Ulyanovsk; $L_{(1–13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1–13)}$ = variability of $L_{(1–13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Table A14. Activity per land category in Russia, Ural Federal District. Mean values for 2010–2018.

Parameter	T_{56}	T_{57}	T_{58}	T_{59}	T_{60}	T_{61}	$\overline{A_{T(56–61)Li}}$
L_1	0.336	0.076	0.084	0.346	0	0	0.046
V_{L1}	+0.012	−0.002	−0.001	+0.003	-	-	
L_2	0.064	0.005	0.023	0.006	0	0	0.005
V_{L2}	+0.002	-	−0.002	−0.001	-	-	
L_3	0.002	0.002	0.001	0.004	0	0	0.001
V_{L3}	+0.001	-	-	+0.001	-	-	
L_4	0.078	0.032	0.056	0.067	0.006	0.002	0.017
V_{L4}	+0.004	−0.002	+0.003	+0.004	+0.001	-	
L_5	0.143	0.018	0.047	0.153	0.005	0.001	0.021
V_{L5}	−0.005	−0.003	−0.001	−0.005	+0.002	-	
L_6	0.246	0.702	0.444	0.306	0.537	0.244	0.400
V_{L6}	−0.003	−0.004	+0.002	−0.003	−0.015	−0.004	
L_7	0.005	0.012	0.009	0.008	0.003	0.057	0.028
V_{L7}	-	+0.002	+0.003	+0.001	-	+0.005	
L_8	0.045	0.013	0.032	0.031	0.060	0.173	0.098
V_{L8}	−0.013	−0.011	−0.002	−0.003	−0.004	−0.003	
L_9	0.007	0.008	0.005	0.016	0.003	0.002	0.004
V_{L9}	+0.001	+0.002	-	+0.003	-	-	
L_{10}	0.012	0.012	0.006	0.016	0.003	0.002	0.005
V_{L10}	+0.002	+0.003	+0.002	+0.004	+0.001	-	
L_{11}	0.054	0.105	0.288	0.022	0.372	0.192	0.231
V_{L11}	+0.001	−0.002	−0.004	−0.002	−0.003	−0.004	
L_{12}	0	0.003	0	0.004	0.001	0.001	0.001
V_{L12}	-	+0.001	-	+0.002	-	-	
L_{13}	0.008	0.012	0.005	0.022	0.010	0.326	0.144
V_{L13}	+0.004	+0.002	-	+0.004	+0.002	+0.004	

Note: T_{56} = Kurgan; T_{57} = Sverdlovsk; T_{58} = Tyumen; T_{59} = Chelyabinsk; T_{60} = Khanty-Mansi; T_{61} = Yamal-Nenets; $L_{(1–13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1–13)}$ = variability of $L_{(1–13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Table A15. Activity per land category in Russia, Siberian Federal District. Mean values for 2010–2018.

Parameter	T_{62}	T_{63}	T_{64}	T_{65}	T_{66}	T_{67}	T_{68}	T_{69}	T_{70}	T_{71}	T_{72}	T_{73}	$\overline{A_{T(62–73)Li}}$
L_1	0.015	0.024	0.011	0.111	0.396	0.011	0.013	0.022	0.161	0.212	0.295	0.021	0.047
V_{L1}	+0.002	+0.001	−0.001	+0.003	+0.004	−0.003	−0.004	+0.003	−0.005	−0.004	+0.006	+0.001	
L_2	0	0.002	0.009	0.006	0.018	0.022	0.001	0	0	0.005	0.012	0	0.004
V_{L2}	-	-	+0.001	−0.002	−0.002	+0.001	-	-	-	+0.001	−0.003	-	
L_3	0	0	0	0.001	0.002	0	0	0	0.003	0.002	0.002	0	0
V_{L3}	-	-	-	-	-	-	-	-	+0.001	-	-	-	
L_4	0.013	0.011	0.005	0.026	0.074	0.040	0.003	0.005	0.049	0.124	0.078	0.015	0.018
V_{L4}	−0.002	−0.001	−0.001	−0.003	−0.004	−0.002	-	-	−0.004	−0.006	−0.001	-	
L_5	0.164	0.053	0.203	0.166	0.166	0.104	0.006	0.008	0.061	0.130	0.090	0.007	0.042
V_{L5}	+0.002	+0.001	+0.004	+0.003	+0.001	+0.003	+0.001	+0.001	−0.001	+0.003	+0.005	+0.001	
L_6	0.469	0.673	0.514	0.534	0.240	0.713	0.511	0.853	0.635	0.270	0.331	0.634	0.578
V_{L6}	−0.002	−0.005	−0.003	−0.006	−0.003	−0.012	−0.014	−0.018	−0.013	−0.003	−0.005	−0.008	
L_7	0.020	0.006	0.027	0.004	0.012	0.012	0.013	0.003	0.017	0.016	0.006	0.003	0.011
V_{L7}	−0.003	−0.001	−0.003	-	−0.002	−0.001	−0.002	-	−0.004	−0.003	-	-	
L_8	0.009	0.069	0.014	0.018	0.026	0.007	0.039	0.034	0.010	0.043	0.021	0.019	0.033
V_{L8}	-	−0.001	-	-	−0.001	-	+0.002	+0.001	-	−0.002	+0.001	+0.003	
L_9	0.001	0.002	0.001	0.005	0.008	0.004	0.001	0.002	0.011	0.006	0.007	0.001	0.002
V_{L9}	-	-	-	+0.001	+0.002	+0.001	-	-	+0.002	+0.001	+0.001	-	

Table A15. *Cont.*

Parameter	T_{62}	T_{63}	T_{64}	T_{65}	T_{66}	T_{67}	T_{68}	T_{69}	T_{70}	T_{71}	T_{72}	T_{73}	$\overline{A_{T(62–73)Li}}$
L_{10}	0.002	0.002	0.002	0.006	0.012	0.003	0.001	0.003	0.018	0.009	0.011	0.003	0.003
V_{L10}	-	-	-	+0.002	+0.003	-	-	+0.001	+0.001	+0.001	+0.002	-	
L_{11}	0.008	0.014	0.061	0.005	0.022	0.025	0.096	0.022	0.009	0.172	0.144	0.292	0.081
V_{L11}	+0.001	−0.001	−0.002	-	−0.001	−0.001	−0.002	−0.002	−0.001	+0.005	+0.003	−0.003	
L_{12}	0	0	0	0.002	0	0.001	0	0	0.009	0	0	0	0
V_{L12}	-	-	-	+0.001	-	-	-	-	+0.001	-	-	-	
L_{13}	0.297	0.144	0.154	0.114	0.024	0.060	0.316	0.046	0.017	0.011	0.005	0.004	0.181
V_{L13}	+0.004	+0.003	+0.005	+0.004	-	+0.004	+0.005	+0.002	-	-	-	-	

Note: T_{62} = Altay Republic; T_{63} = Buryatia; T_{64} = Tyva; T_{65} = Khakasia; T_{66} = Altay; T_{67} = Zabaikalsk; T_{68} = Krasnoyarsk; T_{69} = Irkutsk; T_{70} = Kemerovo; T_{71} = Novosibirsk; T_{72} = Omsk; T_{73} = Tomsk;$L_{(1–13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1–13)}$ = variability of $L_{(1–13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Table A16. Activity per land category in Russia, Far Eastern Federal District. Mean values for 2010–2018.

Parameter	T_{74}	T_{75}	T_{76}	T_{77}	T_{78}	T_{79}	T_{80}	T_{81}	T_{82}	$\overline{A_{T(74–82)Li}}$
L_1	0	0.001	0.046	0.001	0.044	0.001	0.006	0.026	0	0.004
V_{L1}	-	-	+0.001	-	+0.001	-	-	−0.001	-	
L_2	0	0	0.004	0	0.007	0	0	0.019	0	0.001
V_{L2}	-	-	−0.001	-	−0.002	-	-	+0.002	-	
L_3	0	0	0.002	0	0	0	0.001	0.001	0	0
V_{L3}	-	-	-	-	-	-	-	-	-	
L_4	0.002	0.002	0.022	0.005	0.012	0.001	0.007	0.033	0	0.004
V_{L4}	-	-	+0.003	+0.001	+0.001	-	−0.001	+0.002	-	
L_5	0.003	0.007	0.027	0.002	0.013	0.001	0.007	0.069	0	0.004
V_{L5}	+0.001	+0.001	+0.002	-	+0.003	-	+0.001	+0.004	-	
L_6	0.535	0.577	0.791	0.756	0.722	0.616	0.759	0.492	0.180	0.552
V_{L6}	−0.002	−0.004	−0.012	−0.011	−0.015	−0.012	−0.021	−0.020	−0.017	
L_7	0.006	0.007	0.025	0.003	0.007	0.007	0.040	0.038	0.054	0.013
V_{L7}	−0.001	−0.001	−0.002	-	-	−0.001	−0.003	−0.004	−0.011	
L_8	0.042	0.018	0.026	0.019	0.032	0.010	0.027	0.010	0.034	0.033
V_{L8}	−0.002	−0.001	+0.001	+0.001	−0.003	-	-	+0.001	−0.002	
L_9	0	0	0.007	0.001	0.001	0	0.004	0.003	0	0.001
V_{L9}	-	-	+0.001	-	-	-	+0.001	+0.001	-	
L_{10}	0	0	0.006	0.001	0.004	0	0.004	0.006	0	0.001
V_{L10}	-	-	+0.001	-	+0.001	-	+0.001	+0.001	-	
L_{11}	0.064	0.054	0.028	0.071	0.132	0.104	0.074	0.252	0.039	0.069
V_{L11}	−0.002	−0.002	−0.001	−0.005	−0.004	−0.006	−0.001	−0.009	−0.003	
L_{12}	0	0	0.001	0	0	0.002	0.001	0	0.001	0
V_{L12}	-	-	-	-	-	-	-	-	-	
L_{13}	0.347	0.332	0.016	0.140	0.025	0.258	0.071	0.051	0.692	0.320
V_{L13}	+0.019	+0.024	+0.003	+0.005	-	+0.031	+0.004	+0.005	+0.040	

Note: T_{74} = Sakha Yakutia; T_{75} = Kamchatka; T_{76} = Primorye; T_{77} = Khabarovsk; T_{78} = Amur; T_{79} = Magadan; T_{80} = Sakhalin; T_{81} = Jewish AO; T_{82} = Chukotka; $L_{(1–13)}$ = portion of L_i category in a composition of the land fund in T_j territory, percentage: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $V_{L(1–13)}$ = variability of $L_{(1–13)}$, i.e., change in 2018 compared to 2010; "-" = no change or insignificant change. Source: Authors' development.

Appendix C

Table A17. Ranking of T_j territories on land activity, Central Federal District.

Parameter	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}	$\overline{R_{(1–17)i}}$
R_1	77	58	40	72	49	54	30	81	80	46	79	60	51	78	37	76	43	59
R_2	0	64	53	49	42	51	44	15	6	26	59	47	36	32	30	33	12	35
R_3	72	63	60	68	48	62	24	65	75	79	69	57	45	66	33	77	47	59
R_4	31	72	69	48	71	61	40	54	56	59	35	67	60	64	62	43	55	56
R_5	56	43	32	57	29	39	21	50	49	28	54	67	37	47	33	48	31	42
R_6	71	43	23	70	31	35	2	72	74	36	73	52	38	67	20	64	33	47
R_7	9	8	16	11	43	49	35	24	18	62	10	34	2	12	14	33	17	23
R_8	73	74	63	62	33	79	52	59	64	43	80	51	65	61	34	76	5	57
R_9	4	17	26	8	11	14	51	15	10	0	40	37	35	19	31	29	16	21
R_{10}	20	22	7	14	11	32	31	9	8	0	3	5	29	28	39	1	27	17
R_{11}	54	39	47	57	32	52	43	51	59	49	75	45	34	48	24	79	28	48
R_{12}	13	20	2	57	8	39	31	5	29	1	63	17	6	51	12	4	3	21
R_{13}	27	40	39	29	43	59	79	62	45	46	65	61	74	51	69	66	67	54
$\sum R_{j(1-13)}$	507	563	477	602	451	626	483	562	573	475	705	600	512	624	438	629	384	542

Note: T_1 = Belgorod; T_2 = Bryansk; T_3 = Vladimir; T_4 = Voronezh; T_5 = Ivanovo; T_6 = Kaluga; T_7 = Kostroma; T_8 = Kursk; T_9 = Lipetsk; T_{10} = Moscow Oblast; T_{11} = Orel; T_{12} = Ryazan; T_{13} = Smolensk; T_{14} = Tambov; T_{15} = Tver; T_{16} = Tula; T_{17} = Yaroslavl; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Table A18. Ranking of T_j territories on land activity, Northwestern Federal District.

Parameter	T_{18}	T_{19}	T_{20}	T_{21}	T_{22}	T_{23}	T_{24}	T_{25}	T_{26}	T_{27}	$\overline{R_{(18–27)i}}$
R_1	10	9	12	24	48	23	7	28	35	1	20
R_2	1	0	8	34	0	0	0	22	63	0	13
R_3	16	7	13	22	67	53	12	25	43	0	26
R_4	10	13	17	36	80	34	1	50	66	4	31
R_5	7	6	9	18	62	17	1	22	27	2	17
R_6	22	5	21	7	60	17	41	13	39	69	29
R_7	81	75	76	23	45	39	5	19	0	1	36
R_8	0	54	44	17	4	2	6	29	10	14	18
R_9	67	74	65	62	6	45	64	56	50	77	57
R_{10}	61	64	67	46	4	41	73	44	43	77	52
R_{11}	5	16	10	18	40	15	0	14	19	7	14
R_{12}	35	54	74	19	10	11	21	15	18	73	33
R_{13}	71	16	8	80	28	60	18	55	76	1	41
$\sum R_{j(1-13)}$	386	393	424	406	454	357	249	392	489	326	388

Note: T_{18} = Karelia; T_{19} = Komi; T_{20} = Arkhangelsk; T_{21} = Vologda; T_{22} = Kaliningrad; T_{23} = Leningrad; T_{24} = Murmansk; T_{25} = Novgorod; T_{26} = Pskov; T_{27} = Nenets; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Table A19. Ranking of T_j territories on land activity, Southern Federal District.

Parameter	T_{28}	T_{29}	T_{30}	T_{31}	T_{32}	T_{33}	T_{34}	$\overline{R_{(28\text{–}34)i}}$
R_1	56	32	65	70	25	68	73	56
R_2	18	25	38	4	24	19	0	18
R_3	71	18	80	76	37	44	55	54
R_4	14	26	2	18	77	30	19	27
R_5	46	81	65	36	79	70	72	64
R_6	42	81	68	59	79	76	78	69
R_7	56	71	42	26	73	52	13	48
R_8	8	40	7	15	3	18	26	17
R_9	2	57	1	5	53	23	21	23
R_{10}	10	56	33	6	50	53	18	32
R_{11}	63	41	72	31	33	68	61	53
R_{12}	53	47	43	37	75	66	40	52
R_{13}	53	21	72	75	25	31	33	44
$\sum R_{j(1–13)}$	492	596	588	458	633	618	509	556

Note: T_{28} = Adygeya; T_{29} = Kalmykia; T_{30} = Crimea; T_{31} = Krasnodar; T_{32} = Astrakhan; T_{33} = Volgograd; T_{34} = Rostov; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Table A20. Ranking of T_j territories on land activity, North Caucasian Federal District.

Parameter	T_{35}	T_{36}	T_{37}	T_{38}	T_{39}	T_{40}	T_{41}	$\overline{R_{(35\text{–}41)i}}$
R_1	29	53	44	33	45	42	75	46
R_2	23	0	0	31	20	14	28	17
R_3	74	73	78	41	58	61	59	63
R_4	52	44	63	79	47	57	28	53
R_5	80	76	75	74	69	78	73	75
R_6	66	49	63	47	53	58	80	59
R_7	54	67	55	65	47	31	25	49
R_8	25	81	60	53	55	48	46	53
R_9	47	30	24	36	7	3	18	24
R_{10}	45	35	19	54	36	40	17	35
R_{11}	65	81	77	78	80	74	64	74
R_{12}	50	64	33	45	56	32	49	47
R_{13}	14	24	10	12	7	20	50	20
$\sum R_{j(1–13)}$	624	677	601	648	580	558	612	614

Note: T_{35} = Dagestan; T_{36} = Ingushetia; T_{37} = Kabardino-Balkaria; T_{38} = Karachaevo-Cherkessia; T_{39} = North Osetia-Alania; T_{40} = Chechnya; T_{41} = Stavropol; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Table A21. Ranking of T_j territories on land activity, Volga Federal District.

Parameter	T_{42}	T_{43}	T_{44}	T_{45}	T_{46}	T_{47}	T_{48}	T_{49}	T_{50}	T_{51}	T_{52}	T_{53}	T_{54}	T_{55}	$\overline{R_{(42\text{–}55)i}}$
R_1	47	38	62	67	55	63	34	39	50	66	69	71	74	64	57
R_2	0	66	57	13	29	35	39	40	61	0	65	55	0	62	37
R_3	39	40	54	56	42	70	29	27	50	34	52	64	46	51	47
R_4	78	38	37	32	45	42	39	49	46	70	29	24	23	20	41
R_5	61	25	66	53	38	40	20	24	41	77	51	59	71	45	48
R_6	40	19	50	62	32	45	6	12	29	77	57	65	75	48	44
R_7	37	61	20	29	22	57	58	44	51	36	30	28	48	40	40
R_8	66	23	77	11	58	37	39	68	41	75	69	21	24	12	44
R_9	39	33	28	9	41	12	44	58	22	27	25	13	34	38	30
R_{10}	26	30	23	13	12	2	42	47	24	37	21	15	38	16	25
R_{11}	67	44	60	58	66	71	35	50	42	76	69	56	73	70	60
R_{12}	25	42	44	38	23	65	48	26	34	27	71	36	67	55	43
R_{13}	36	81	56	58	64	44	49	37	57	35	70	54	48	47	53
$\sum R_{j(1–13)}$	561	540	634	499	527	583	482	521	548	637	678	561	621	568	569

Note: T_{42} = Bashkortostan; T_{43} = Mari El; T_{44} = Mordovia; T_{45} = Tatarstan; T_{46} = Udmurtia; T_{47} = Chuvashia; T_{48} = Perm; T_{49} = Kirov; T_{50} = Nizhny Novgorod; T_{51} = Orenburg; T_{52} = Penza; T_{53} = Samara; T_{54} = Saratov; T_{55} = Ulyanovsk; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Table A22. Ranking of T_j territories on land activity, Ural Federal District.

Parameter	T_{56}	T_{57}	T_{58}	T_{59}	T_{60}	T_{61}	$\overline{R_{(56–61)i}}$
R_1	57	26	27	59	3	2	29
R_2	67	43	60	45	9	0	37
R_3	32	31	21	49	10	2	24
R_4	76	51	68	73	15	6	48
R_5	55	19	26	58	10	3	29
R_6	54	10	37	46	24	55	38
R_7	72	50	59	60	79	3	54
R_8	16	57	31	32	13	1	25
R_9	46	42	54	20	63	69	49
R_{10}	48	49	59	34	66	72	55
R_{11}	26	12	3	38	1	6	14
R_{12}	72	9	62	7	28	22	33
R_{13}	73	52	68	32	41	6	45
$\sum R_{j(1–13)}$	694	451	575	553	362	247	480

Note: T_{56} = Kurgan; T_{57} = Sverdlovsk; T_{58} = Tyumen; T_{59} = Chelyabinsk; T_{60} = Khanty-Mansi; T_{61} = Yamal-Nenets; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Table A23. Ranking of T_j territories on land activity, Siberian Federal District.

Parameter	T_{62}	T_{63}	T_{64}	T_{65}	T_{66}	T_{67}	T_{68}	T_{69}	T_{70}	T_{71}	T_{72}	T_{73}	$\overline{R_{(62–73)i}}$
R_1	16	19	14	31	61	13	15	18	36	41	52	17	28
R_2	16	27	50	46	54	58	21	7	2	41	52	5	32
R_3	9	14	4	26	30	6	8	19	38	36	35	15	20
R_4	25	21	9	41	74	58	8	11	65	81	75	27	41
R_5	60	30	68	64	63	44	11	15	34	52	42	12	41
R_6	34	11	27	26	56	9	28	0	14	51	44	15	26
R_7	27	69	15	74	46	53	41	77	32	38	68	80	52
R_8	72	9	56	49	36	78	22	27	71	19	42	45	44
R_9	73	68	72	55	43	60	76	66	32	52	49	71	60
R_{10}	70	71	74	57	51	69	76	65	25	55	52	68	61
R_{11}	55	46	23	62	36	30	17	37	53	8	9	2	32
R_{12}	81	69	61	14	70	46	79	60	0	77	58	68	57
R_{13}	9	15	13	19	34	17	5	23	42	63	78	77	33
$\sum R_{j(1–13)}$	547	469	486	564	654	541	407	425	444	614	656	502	526

Note: T_{62} = Altay Republic; T_{63} = Buryatia; T_{64} = Tyva; T_{65} = Khakasia; T_{66} = Altay; T_{67} = Zabaikalsk; T_{68} = Krasnoyarsk; T_{69} = Irkutsk; T_{70} = Kemerovo; T_{71} = Novosibirsk; T_{72} = Omsk; T_{73} = Tomsk; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Table A24. Ranking of T_j territories on land activity, Far Eastern Federal District.

Parameter	T_{74}	T_{75}	T_{76}	T_{77}	T_{78}	T_{79}	T_{80}	T_{81}	T_{82}	$\overline{R_{(74–82)i}}$
R_1	4	8	22	6	21	5	11	20	0	11
R_2	10	3	37	17	48	11	0	56	0	20
R_3	3	5	28	11	17	1	23	22	0	12
R_4	7	5	33	12	22	3	16	53	0	17
R_5	8	13	23	5	16	4	14	35	0	13
R_6	25	18	1	4	8	16	3	30	61	18
R_7	70	66	21	78	63	64	6	7	4	42
R_8	20	50	38	47	30	67	35	70	28	43
R_9	79	78	48	75	70	80	59	61	81	70
R_{10}	78	79	58	75	63	80	62	60	81	71
R_{11}	22	25	29	21	11	13	20	4	27	19
R_{12}	76	80	30	78	59	16	24	52	41	51
R_{13}	2	4	38	11	30	3	22	26	0	15
$\sum R_{j(1–13)}$	404	434	406	440	458	363	295	496	323	402

Note: T_{74} = Sakha Yakutia; T_{75} = Kamchatka; T_{76} = Primorye; T_{77} = Khabarovsk; T_{78} = Amur; T_{79} = Magadan; T_{80} = Sakhalin; T_{81} = Jewish AO; T_{82}= Chukotka; $R_{(1–13)}$ = ranks of land activity per land categories: R_1 = cropland; R_2 = fallow; R_3 = perennial plantings; R_4 = hayfields; R_5 = rangeland; R_6 = woodlands; R_7 = forest range; R_8 = water reserve lands; R_9 = residential and industrial lands; R_{10} = lands under transportation and communication infrastructure; R_{11} = wetlands; R_{12} = disturbed lands; R_{13} = barren. Source: Authors' development.

Appendix D

Table A25. Ranking of T_j territories on a parameter of agricultural land activity, federal districts grouping.

Land Category	Parameter	Central	Northwestern	Southern	North Caucasian	Volga	Ural	Siberian	Far Eastern
L_1	$\overline{A_{jL1}}$	0.367	0.020	0.413	0.330	0.350	0.046	0.047	0.004
	$\overline{R_{j1}}$	59	20	56	46	57	29	28	11
	$\sum R_{j1}$	1011	197	389	321	799	174	333	97
L_2	$\overline{A_{jL2}}$	0.007	0.001	0.001	0.001	0.008	0.005	0.004	0.001
	$\overline{R_{j2}}$	35	13	18	17	37	37	32	20
	$\sum R_{j2}$	599	128	128	116	522	224	379	182
L_3	$\overline{A_{jL3}}$	0.008	0.001	0.007	0.010	0.003	0.001	0.000	0
	$\overline{R_{j3}}$	59	26	54	63	47	24	20	12
	$\sum R_{j3}$	1010	258	381	444	654	145	240	110
L_4	$\overline{A_{jL4}}$	0.040	0.011	0.020	0.033	0.035	0.017	0.018	0.004
	$\overline{R_{j4}}$	56	31	27	53	41	48	41	17
	$\sum R_{j4}$	947	311	186	370	572	289	495	151
L_5	$\overline{A_{jL5}}$	0.090	0.007	0.313	0.336	0.134	0.021	0.042	0.004
	$\overline{R_{j5}}$	42	17	64	75	48	29	41	13
	$\sum R_{j5}$	721	171	449	525	671	171	495	118
L_6	$\overline{A_{jL6}}$	0.363	0.549	0.070	0.115	0.377	0.400	0.578	0.552
	$\overline{R_{j6}}$	47	29	69	59	44	38	26	18
	$\sum R_{j6}$	804	294	483	416	617	226	315	166
L_7	$\overline{A_{jL7}}$	0.027	0.022	0.015	0.015	0.015	0.028	0.011	0.013
	$\overline{R_{j7}}$	23	36	48	49	40	54	52	42
	$\sum R_{j7}$	397	364	333	344	561	323	620	379
L_8	$\overline{A_{jL8}}$	0.020	0.062	0.052	0.023	0.024	0.098	0.033	0.033
	$\overline{R_{j8}}$	57	18	17	53	44	25	44	43
	$\sum R_{j8}$	974	180	117	368	621	150	526	385
L_9	$\overline{A_{jL9}}$	0.019	0.003	0.016	0.014	0.011	0.004	0.002	0.001
	$\overline{R_{j9}}$	21	57	23	24	30	49	60	70
	$\sum R_{j9}$	363	566	162	165	423	294	717	631

Table A25. *Cont.*

Land Category	Parameter	Central	Northwestern	Southern	North Caucasian	Volga	Ural	Siberian	Far Eastern
L_{10}	$\overline{A_{jL10}}$	0.022	0.005	0.016	0.017	0.017	0.005	0.003	0.001
	$\overline{R_{j10}}$	17	52	32	35	25	55	61	71
	$\sum R_{j10}$	286	520	226	246	346	328	733	636
L_{11}	$\overline{A_{jL11}}$	0.019	0.152	0.012	0.003	0.009	0.231	0.081	0.069
	$\overline{R_{j11}}$	48	14	53	74	60	14	32	19
	$\sum R_{j11}$	816	144	369	519	837	86	378	172
L_{12}	$\overline{A_{jL12}}$	0.003	0.001	0	0.001	0.001	0.001	0	0
	$\overline{R_{j12}}$	21	33	52	47	43	33	57	51
	$\sum R_{j12}$	361	330	361	329	601	200	683	456
L_{13}	$\overline{A_{jL13}}$	0.004	0.085	0.011	0.042	0.005	0.071	0.092	0.235
	$\overline{R_{j13}}$	54	41	44	20	53	45	33	15
	$\sum R_{j13}$	922	413	310	137	736	272	395	136
	$\sum \overline{R_{ji}}$ per district	542	388	556	614	569	480	526	402
	$\sum R_{ji}$ per district	9211	3876	3894	4300	7960	2882	6309	3619

Note: L_1 = cropland; L_2 = fallow; L_3 = perennial plantings; L_4 = hayfields; L_5 = rangeland; L_6 = woodlands; L_7 = forest range; L_8 = water reserve lands; L_9 = residential and industrial lands; L_{10} = lands under transportation and communication infrastructure; L_{11} = wetlands; L_{12} = disturbed lands; L_{13} = barren; $\overline{A_{jLi}}$ is averaged in respect to individual values of A_{jLi} in T_j territories per districts; $\overline{R_{ji}}$ is averaged in respect to individual rankings R_{ji} in T_j territories per districts; $\sum R_{ji}$ = sum of land activity rankings per districts. Source: Authors' development.

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