REVIEW

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HISTORICAL LAND SYSTEMS OF RUSSIA: TRENDS, BIASES, AND GAPS IN THE LITERATURE

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ABSTRACT. This paper presents a systematic literature review of 210 peer-reviewed studies to analyze the state and trends of Land System Science (LSS) research on historical land use and land cover change in Russia from 2000 to 2024. The review reveals a significant and persistent geographical bias, with the vast majority of case studies concentrated in the European part of Russia (e.g., Belgorod, Tula, Moscow regions), while vast areas of Siberia, the Far East, and the Arctic remain critically understudied. Thematically, research is dominated by studies on agricultural land abandonment and forest landscape dynamics, with urban landscapes receiving scant attention. Long-term studies covering periods of more than a century are prevalent. However, their analytical depth is often limited by reliance on historical surveys or aggregated statistics. Satellite remote sensing, especially Landsat images, is the most common source of data. These images are often combined with other types of data. The use of historical cartographic sources (e.g., General Land Survey plans) is hindered by issues of accessibility, digitization, and often insufficient thematic detail for comprehensive landscape analysis. Consequently, studies often use just two time points and a single spatial scale, typically based on administrative rather than biogeographical units. The review identifies a clear linguistic and international visibility gap: 82% of publications are in Russian only, and a substantial portion appear in journals not indexed in international databases, limiting their global integration. Furthermore, a concerning number of studies (74%) do not systematically analyze the driving forces behind the observed landscape changes. This synthesis underscores the urgent need to address regional research disparities, enhance the methodological depth by integrating multi-source historical data and robust causal analysis, and improve the international accessibility of Russian LSS research. By doing so, the Russian LSS community can not only fill critical knowledge gaps within the country but also make a more substantial contribution to global land change science, offering unique insights from its vast and diverse socio-ecological systems.

KEYWORDS: land use land cover change, historical land change, landscape dynamics, old maps, land system science, long-term socio-ecological research

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INTRODUCTION

Land-use change is one of the most significant drivers of environmental transformation, with profound and often nonlinear impacts on ecosystems, biodiversity, and socio-economic stability (Foley et al. 2005; Lambin et al. 2001). From deforestation to urbanization, these changes threaten the resilience of both natural systems and human societies, necessitating integrated scientific approaches to understand and mitigate their effects. LSS has emerged as a critical interdisciplinary field to address these challenges, combining insights from geography, ecology, economics, and political science (de Bremond et al. 2019; Grove and Pickett 2019; Turner et al. 2007). By analyzing the interactions between human activities and landscapes, LSS provides a framework for sustainable land management and policy development. However, while global syntheses exist, regional disparities in research coverage persist (Boillat et al. 2017; Liu and Tian 2010; Newbold et al. 2015) – particularly in vast and ecologically diverse regions like Russia, where land-use dynamics remain understudied in international literature.

Russian researchers have made notable contributions to understanding global environmental change, particularly in paleogeographic and paleoecologic reconstructions (Borisova 2021; Filimonova 2021; Novenko et al. 2019; Velichko et al. 2016), boreal forest carbon dynamics (Arkhipova 2020; Chernova et al. 2018; Dolman et al. 2012), and permafrost-climate feedbacks (Broushkov et al. 2024; Romanovsky et al. 2010). Their work has been instrumental in IPCC assessments and global carbon cycle modeling (Kurganova et al. 2024; Kuricheva et al. 2023). Notably, the TEEB Russia initiative (Bukvareva et al. 2019, 2021) advanced ecosystem services (ES) valuation at national and regional scales, highlighting Russia's vast natural capital. Recent systematic reviews on urban ecosystem services in Russia (Dushkova et al. 2025), demonstrate progress in synthesizing fragmented research, though challenges persist in translating findings into policy. However, research on historical land-use patterns remains underdeveloped compared to Western Europe and North America, creating challenges for integrating Russian data into global models (Ellis et al. 2010; Hurtt et al. 2011; Klein Goldewijk and Verburg 2013). This gap limits comprehensive assessments of anthropogenic impacts on Russia's landscapes and their role in global environmental change.

Russia, the world's largest country by land area, plays a pivotal yet underappreciated role in global environmental processes, from carbon sequestration in boreal forests to the conservation of Arctic ecosystems (Danilov-Danilyan et al. 2023; Tishkov 2012). Its unique drivers of land-use change – such as post-Soviet agricultural abandonment, industrial expansion in Siberia, and climate-driven shifts in permafrost – differ markedly from those in Europe or North America (Gunya 2017; Lyuri et al. 2010; Prishchepov et al. 2020). Despite this, global syntheses do not adequately represent Russia's land-system research. This gap limits the integration of Russian data into international models. It also obscures the country's contributions to key debates on biodiversity loss, climate adaptation, and sustainable development. Bridging this divide requires not only greater access to Russian research but also targeted collaborations to highlight its distinct socio-ecological trajectories.

Russia's environmental heterogeneity – from the steppes of the European Plains to the taiga of Siberia – has fostered diverse land-use practices shaped by climatic constraints, institutional policies, and historical contingencies (Josephson et al. 2013; Moon 2013; Smirnova et al. 2017; Trapeznikova 2017). For example, the Soviet Virgin Lands Campaign of the 1950s transformed vast grasslands into croplands, while post-1991 market reforms led to widespread farmland abandonment and forest regrowth (Kraemer et al. 2015; Prishchepov et al. 2013; Schierhorn et al. 2013). These shifts were further modulated by regional factors, such as soil fertility in the European south or permafrost instability in the Far East. Nevertheless, research remains fragmented, with strong biases toward European Russia (Alix-Garcia et al. 2016; Matasov et al. 2019, Vampilova and Sikan 2023) and limited attention to the Urals, Far East, and Arctic (Aleinikov 2021; Bocharnikov, Steblyanskaya 2022; Belousova 2024; Bergen et al. 2020). Compounding this, Russia's scientific traditions emphasize localized, qualitative case studies over quantitative meta-analyses, reflecting both methodological preferences and data limitations.

A critical barrier to understanding Russia's land-use history is the scarcity of accessible, high-resolution historical data. Despite the existence of extensive cartographic resources, their development was highly uneven, shaping strong geographical and temporal biases in research possibilities (Alyabina et al. 2015; Goldenberg and Postnikov 1985). Pre-revolution materials include the General Land Survey (Generalnoye mezhevaniye) plans (1765–1888), covering 36 provinces and providing key insights into pre-industrial land use; the detailed Mende maps (1847–1867) of central regions; and military topographic maps such as the Three-Verst Map (1:126,000), the Ten-Verst Map (1:420,000), and maps of the Caucasus, which offer valuable though often generalized landscape information (Golubinsky et al. 2011; Kusov 1993; Postnikov and Melnikova 1980). The Soviet period introduced detailed State Topographic Maps (Genshtab maps) and various thematic maps. These included forest inventories, agricultural land use maps, and land management (Zemleustroitelnaya) plans. While they systematically covered vast territories, their primary purpose was often administrative (Dolgov et al. 2018).

However, the application of these materials in systematic land system science faces major challenges. Significant portions of the cartographic legacy, especially large-scale Soviet-era maps, remain difficult to access due to archival restrictions and fragmented preservation. Moreover, only a small part of them has been digitized and georeferenced to modern standards, limiting their use in GIS-based analyses (Golubinsky et al. 2013; Matasov 2016). Thematic inconsistency across time and regions, a focus on economic or military features rather than ecological detail, and a pronounced decline in map coverage east of the Urals further constrain research. While remote sensing (e.g., Landsat) has partially compensated for these gaps by capturing changes since the 1980s (Ershov et al. 2022; Gutman and Radeloff 2017), it cannot illuminate earlier critical transitions, such as those during the Soviet era. Thus, integrating multi-temporal cartographic sources with satellite data, developing unified national datasets, leveraging GIS technologies, and fostering collaborations between historians, ecologists, and remote-sensing experts could unlock new insights into Russia's land-system resilience and vulnerabilities.

Thematic priorities in Russian land-use research often diverge from western LSS, with a stronger focus on soil degradation (Chendev et al. 2023; Chernova et al. 2018), local landscape typologies (Khoroshev and Dyakonov 2020), palaeoecological and historical reconstructions (Kosenkov and Kolbovsky 2012; Novenko et al. 2017; Shilov and Kozlov 2019) rather than globalized drivers like commodity markets or telecoupling. This divergence reflects both contextual differences and the isolation of Russian academia, where the majority of studies are published in domestic journals (e.g., Izvestiya RAN. Seriya Geograficheskaya) with limited international indexing. Linguistic barriers further exacerbate this disconnect, as few Russian researchers engage in English-language publications or global networks like the Global Land Programme. To address this, systemic support for translation, open-access publishing, and comparative studies is essential – not only to elevate Russia's scientific visibility but also to enrich global LSS with its unique empirical and theoretical perspectives (Meyfroidt et al. 2018; Verburg et al. 2013).

In our systematic literature review, we aimed to analyze various publications on LSS in Russia to address the main research question: what is the current state of research on historical land use in Russia? To achieve this goal, we formulated the following subquestions. First, we sought to identify the methodological approaches used to assess historical changes in land systems across different regions of Russia. This involved grouping various research approaches by identifying key research areas, methods, and objects of the studies. Second, we aimed to determine the main pathways of historical LSS development in Russia. This included classifying and describing typical research studies and identifying the principal directions for further development in this field.

The paper consists of several sections: the methodology presents a location-based context, describes the general approach used in the study, and provides an overview of the materials (data sources) and methods employed, explaining the literature review steps. The results section offers a detailed examination of LSS terms used in Russian scientific literature and specifies general patterns observed in the reviewed studies. The analysis of case study research encompasses two domains: spatial distributions and thematic analyses of these studies. Finally, a qualitative analysis of the most frequently cited studies is provided to summarize and systematize the findings, which are also critically reflected in the discussion section.

MATERIALS AND METHODS

Data Sources and article search

Our method followed established guidelines for systematic review and systematic mapping and was inspired by previous systematic review exercises in comparable fields (Dushkova et al. 2025; Herrero-Jáuregui et al. 2018; Plieninger et al. 2016). We focused on Russian- and English-language peer-reviewed articles published in international and Russian scientific journals between 2000 and 2024. Research results published in dissertations, monographs, textbooks, and regional planning documents were excluded from this review. The search for English-language articles was conducted using the Scopus, ISI Web of Science, and ResearchGate databases. For Russian-language studies, we used the Russian Scientific Electronic Library eLIBRARY[1] and CyberLeninka[2]. The search was performed using the following terms and their analogues in Russian and English: "land use", "land use change", "cultural landscape", "agrolandscape", "forest / agricultural landscape transformation", "land use system", "forest dynamics", "geosystems", "development stages", "settlement system", "anthropogenic transformation", "cropland abandonment", "land use system" , "reforestation", "long term change", "forest degradation", "forest fragmentation", "transformation of landscapes", "historical reconstruction", "landscape dynamics", "historical geography". Search terms were entered into the publication title, abstract, and keywords. The same filter was used for both international and Russian databases. After verifying the correct display of search terms and removing language duplicates, the search yielded 412 works selected for the next stage of the screening process.

Based on the works of Geist and Lambin (2002), Magliocca et al. (2015), Plieninger et al. (2016), we defined four inclusion criteria for articles: the study had to (1) describe a landscape that has undergone changes over a period of at least 30 years; (2) provide analysis of research results based on methodology for quantitative or qualitative measurement of landscape change processes; (3) focus on the territory of Russia at regional and local scales (within its borders as of the year 2000), conducted by Russian researchers or with their participation; and (4) offer explanations for the causes of landscape change. Thus, research based on social and economic analysis, theoretical works, geographically unattached, conceptual, and summarizing publications was excluded. A sample of 210 scientific articles was finally included in the review for subsequent spatial and thematic analysis.

Data analysis

To analyze keyword trends and map research themes, we used VOSviewer software[3]. We applied the co-occurrence analysis method, which clusters keywords based on how frequently they appear together in publications. This shows the strength of relationships between terms. In the resulting visualizations, the size of a node represents how often a keyword is used, and the thickness of the connecting lines indicates how strong the link between two terms is. The color of a node indicates its cluster. Shorter distances between nodes represent stronger relationships between keywords.

We used a standardized data extraction sheet to systematically categorize each study. This sheet recorded general parameters and key attributes such as the spatial focus of the research, the scale of analysis, the types of data sources used, the methodological approach, etc. (Table 1).

The analysis considered the number of spatial scales in each study. We defined two types: single-scale studies (e.g., focused on one specific region or site) and multi-scale studies (using two different spatial scales for analysis or modeling). Multi-scale studies are crucial for understanding complex systems where interactions at different levels influence overall dynamics. We also recorded the number of study sites and classified their boundaries into three types: administrative (e.g., regional borders), biophysical (e.g., watersheds), and author-defined (e.g., borders of satellite imagery scenes or cadastral map sheets).

For methodological analysis, we examined the types of source data and indicators used. Based on a preliminary review, we grouped the source data into six categories: 1) statistical data (official reports, statistical yearbooks); 2) literary sources (previously published articles); 3) historical maps (pre-1917 maps of various scales); 4) cadastral and thematic maps (topographic, land use, and planning maps); 5) solely Landsat; 6) satellite imagery (e.g., MODIS, CORONA, Sentinel). Data processing methods were classified into four groups: 1) descriptive (comparative analysis of published data); 2) statistical (mathematical processing of data); 3) geostatistical (spatial analysis and modeling); 4) custom methodology (author-developed approach). Each study was categorized based on these parameters. Studies employing a custom methodology were specifically noted.

Finally, we used descriptive statistics to identify the main driving forces of landscape change and their interactions. The categories for this analysis were pretested to ensure consistency. The statistical analysis was performed using R, and maps showing the spatial distribution of the studies were created in QGIS v4.20.

RESULTS

Overview of the keywords in articles

The co-occurrence of keywords indicates the prevailing research trends within the field. After consolidating synonymous terms and correcting errors, a final list of 231 unique keywords was compiled. From this list, 67 keywords occurring more than three times were selected for further analysis (Table 2). A co-occurrence network map was constructed from these keywords, which were subsequently grouped into nine distinct clusters, each denoted by a different color (Fig. 1). Within this network, the size of a node (representing a keyword) corresponds to its "total link strength"—a metric quantifying the strength of its connections to all other keywords. The lines between nodes represent the individual co-occurrence links between pairs of keywords. The central network area is dominated by larger nodes, indicating keywords with high frequency. The most prevalent keywords are "land use" (56 occurrences), "forest cover" (25 occurrences), "GIS" (24 occurrences), and "remote sensing" (21 occurrences). Finally, Table 2 lists the ten keywords with the highest total link strength.

[1]URL: https://www.elibrary.ru, accessed on 20 January 2025.
[2]URL: https://www.cyberleninka.ru, accessed on 20 January 2025.
[3]URL: https://www.vosviewer.com, accessed on 6 August 2025.

Table 1. Variables used in the data extraction sheet

Variables name	Classes/Units
Authors Affiliation	institute, country
Article Language	Russian, English, Russian and English
Year of publication	number
Indexation base	RINC, core RINC, WoS or Scopus
Citations	number
Study region	country, administrative regions
Type of relief	plains, mountains
Land system	agro, forest, urban, mixed
Natural zone	boreal, hemiboreal, nemoral, steppe
Period, years	0–30, 30–100, >100
Number of study periods	2, 3-4, >5
Number of study areas	1, 2-3, >4
Number of scales	1, 2
Type of study area border	administrative, natural, user-defined
Data Source	statistical data, literature, historical data, maps, Landsat, other satellite
Methods of analysis	statistic, geostatistics, description, custom
Type of analysis	quantitative, qualitative, no analyze (statement)
Factors or drivers in study	social, natural, no factors

Table 2. Ten keywords with the maximum total link strength from VOSviewer

Keyword	Total link strength	Occurrences
land use	158	56
GIS	84	24
forest cover	74	25
remote sensing	74	21
reforestation	63	21
agriculture	56	21
satellite images	49	13
land use change	41	12
Landsat	41	14
arable lands	40	12

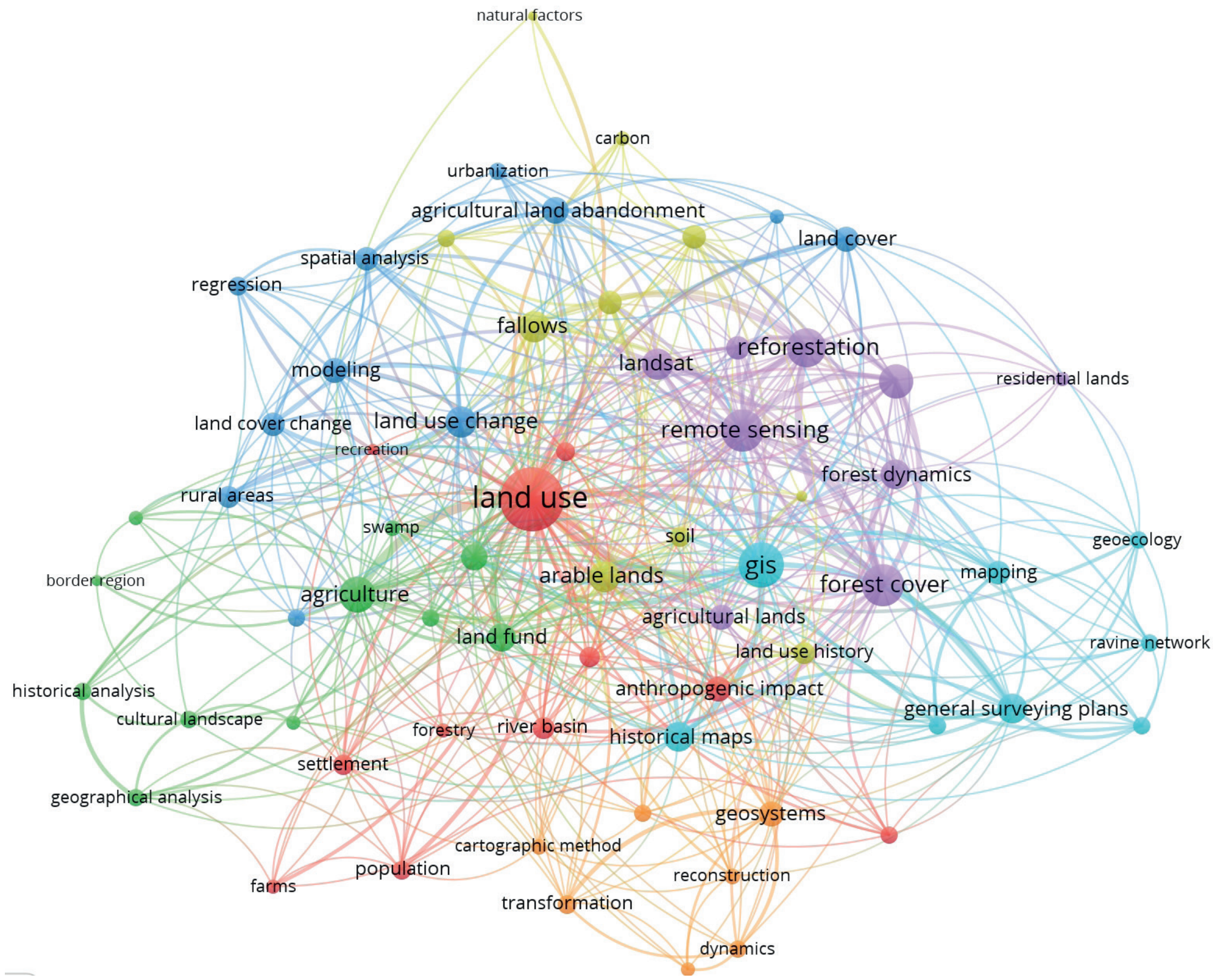

Fig. 1. Authors' keywords concerning LSS in Russia

The co-occurrence network analysis reveals a coherent intellectual structure within the domain of land change science, characterized by a central thematic core and distinct, interconnected methodological and thematic clusters. The pronounced centrality of "land use" and its dynamic counterpart, "land use change," establishes them as the principal research foci, functioning as the nexus to which all other concepts connect. This core is methodologically underpinned by a robust cluster comprising "GIS," "remote sensing," and "spatial analysis," signifying their indispensable role as the primary analytical framework for the discipline. The network further delineates specialized, yet interrelated, research streams: one cluster emphasizes ecological dynamics and forest transitions, investigating processes such as "reforestation" and "forest cover" change, often linked to drivers like "agricultural land abandonment." A parallel strand is dedicated to historical and reconstruction-based approaches, leveraging "historical maps" and "cartographic methods" to analyze long-term "cultural landscape" transformation and "anthropogenic impact." The clustering of keywords into distinct yet connected groups illustrates the field's multidisciplinary nature, integrating spatial analysis, landscape transformation studies, and historical reconstruction to understand the dynamics of land cover change driven by both anthropogenic and natural factors.

General and thematic overview

Our review identified a total of 210 case studies on land systems conducted by Russian researchers, focusing primarily on regions within Russia but also including some studies in neighboring countries. Analysis of publication years shows a gradual increase in the number of studies, peaking in 2017–2018, followed by a decline to around 9–10 publications per year recently.

The vast majority of articles (82%) were published only in Russian, while 9% were published only in English, and another 9% were bilingual (published simultaneously in both languages). As shown in Fig. 2, the share of English-language and bilingual publications has varied over time. Since 2013, such publications have appeared annually, and in some years, they accounted for 50–60% of the annual total.

Another important indicator is the international visibility of Russian research, which we assessed based on indexing in international databases (IDB), particularly Scopus and Web of Science. During the first decade of the study period (2000–2011), only a few Russian journals were indexed in these databases. However, since 2012, annual publications of IDB-indexed articles have ranged from 10% to 55% (Fig. 3).

The studies were published in 124 different journals, most of which are multidisciplinary, covering fields such as geography, environmental science, ecology, agriculture, forestry, and remote sensing.

Most studies (96%) focused on territories within Russia, with a small number including areas in neighboring countries such as Ukraine, Belarus, Kazakhstan, Estonia, Lithuania, Latvia, Poland, and even the United States. The overwhelming majority of studies (182 out of 210) were conducted within a single Russian region. Only a few studies covered two, three, or five regions. The highest number of studies (24) were conducted in Belgorod Oblast, followed by Tula and Tambov Oblasts (19 each), Moscow Oblast

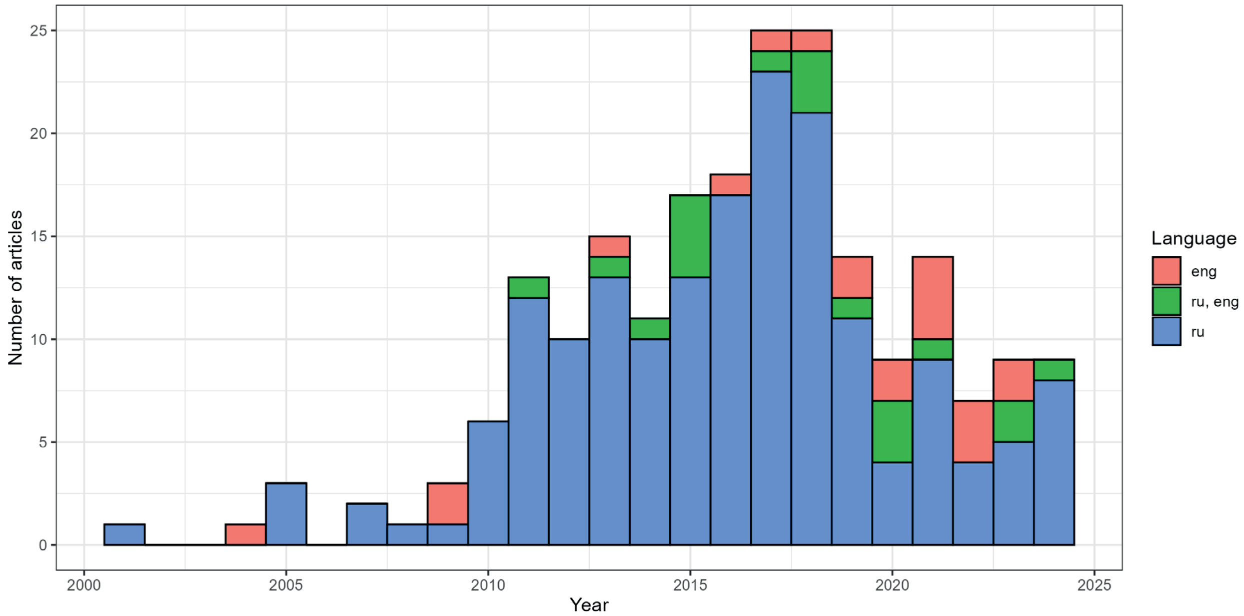

Fig. 2. Temporal distribution of the analyzed articles, separated by language

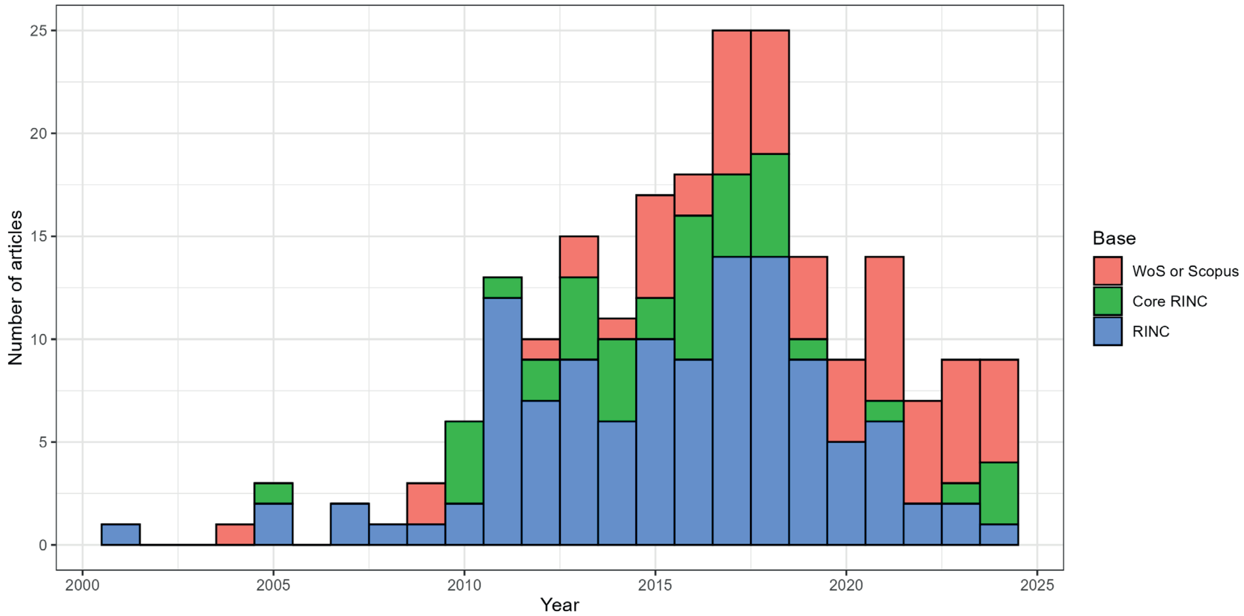

Fig. 3. Temporal distribution of the analyzed articles, separated by IDB indexing

(18), and Perm Krai, Ryazan Oblast, and Smolensk Oblast (16 each) (Fig. 4). The fewest studies were conducted in Siberian regions (with the exception of Irkutsk Oblast and Zabaykalsky Krai) and the Russian Far East. Studies covering the entire territory of Russia were rare.

The vast majority of studies (85%) were conducted in plain landscapes, while significantly fewer (13%) focused on mountainous areas, and only 2% included both landforms. Studies on agricultural land dynamics dominated the research period, followed by forest landscapes, which were studied half as frequently. Very few studies focused on urban landscapes or integrated analyses of all three landscape types (Fig. 5).

Analysis of the biogeographical distribution of study sites showed that more than half were located within a single natural zone. Most sites were in the nemoral and boreal zones; fewer were in the hemiboreal zone, and even fewer in steppe zones. About 20% of studies covered two, often adjacent, zones. Studies spanning three or more natural zones were rare (Fig. 6).

The overwhelming majority of studies (74.2%) were conducted within a single site or polygon, while only a small number used multiple sites (Fig. 7). Most studies also used only one spatial scale of analysis (Fig. 7). Administrative boundaries were the most commonly used type of study area delineation (62% of studies), often reflecting modern municipal or regional borders, and less frequently historical districts or provinces, largely due to the reliance on statistical data tied to administrative units. User-defined boundaries, such as satellite image scenes or thematic map extents, were used in about 25.4% of studies. Natural geographical boundaries, such as river basins, were used least frequently (12.7%).

The size of the study areas varied from a few square kilometers to millions of square kilometers. More than half of all studies were conducted at a regional scale, covering areas larger than 1,000 km^2 (Fig. 7). This preference was closely linked to the data sources used: statistical data, literary reviews, and medium-resolution satellite imagery (Fig. 8).

Analysis of data sources revealed that statistical data were the most commonly used, due to their ease of processing and availability. Medium-resolution satellite images (e.g., Landsat) were the second most frequent source, widely used for assessing agricultural and forest landscape dynamics over the past 30–40 years. Literary reviews ranked third. Beyond these primary sources, 28 different combinations of data

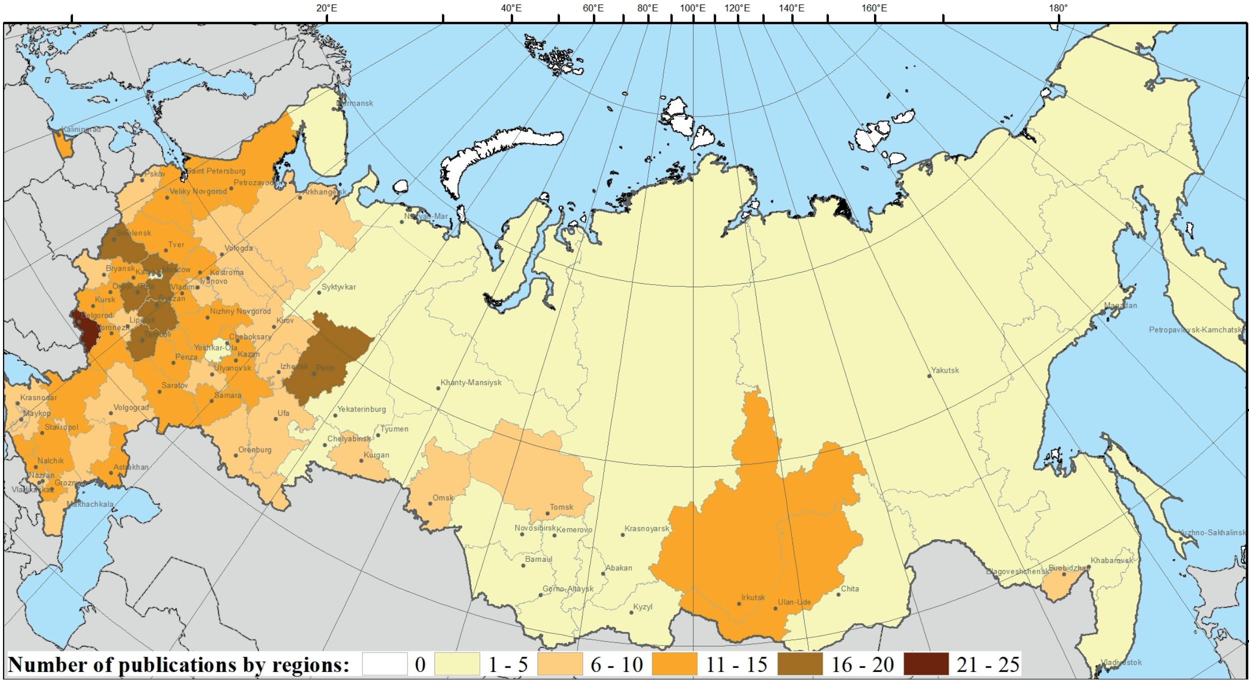

Fig. 4. Number of publications by Russian regions from 2000 to 2024. The borders of Russia as of 2000

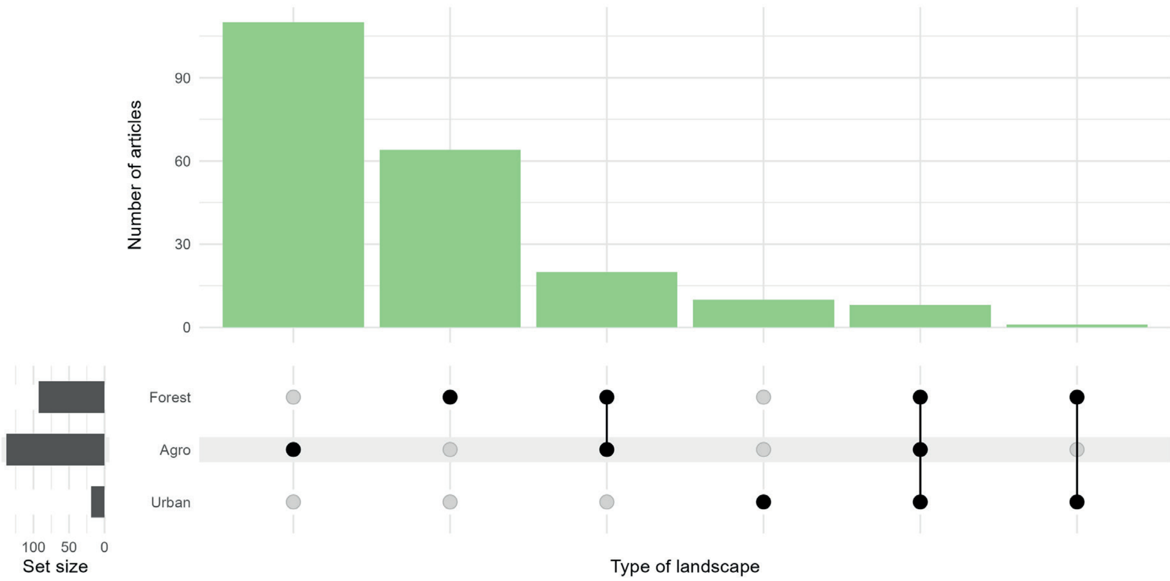

Fig. 5. The distribution of articles by type of studied landscape

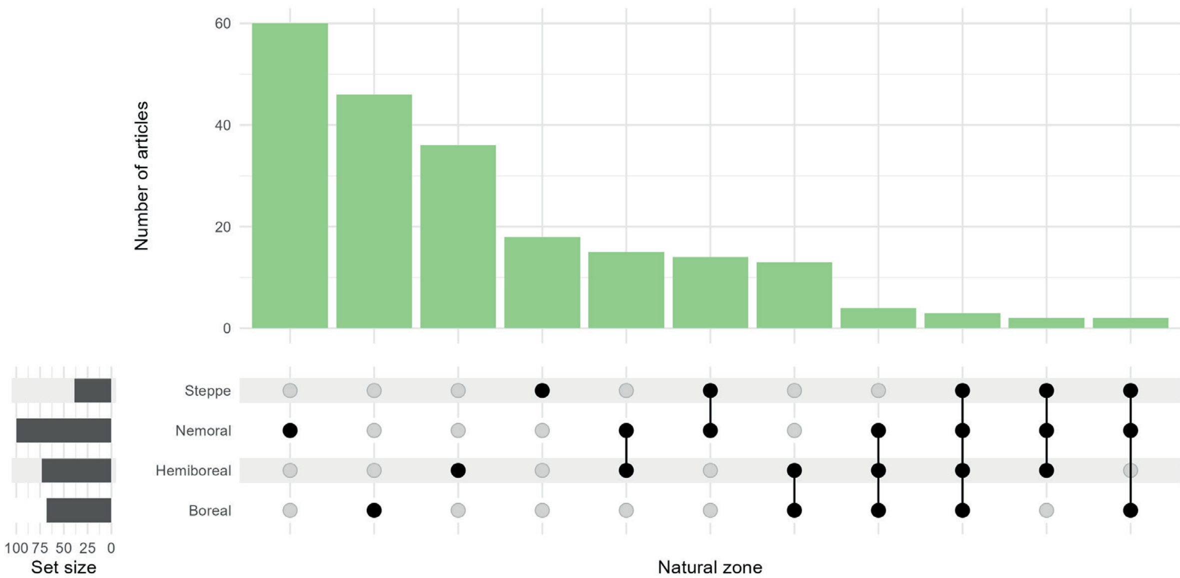

Fig. 6. The distribution of articles by location in natural zones

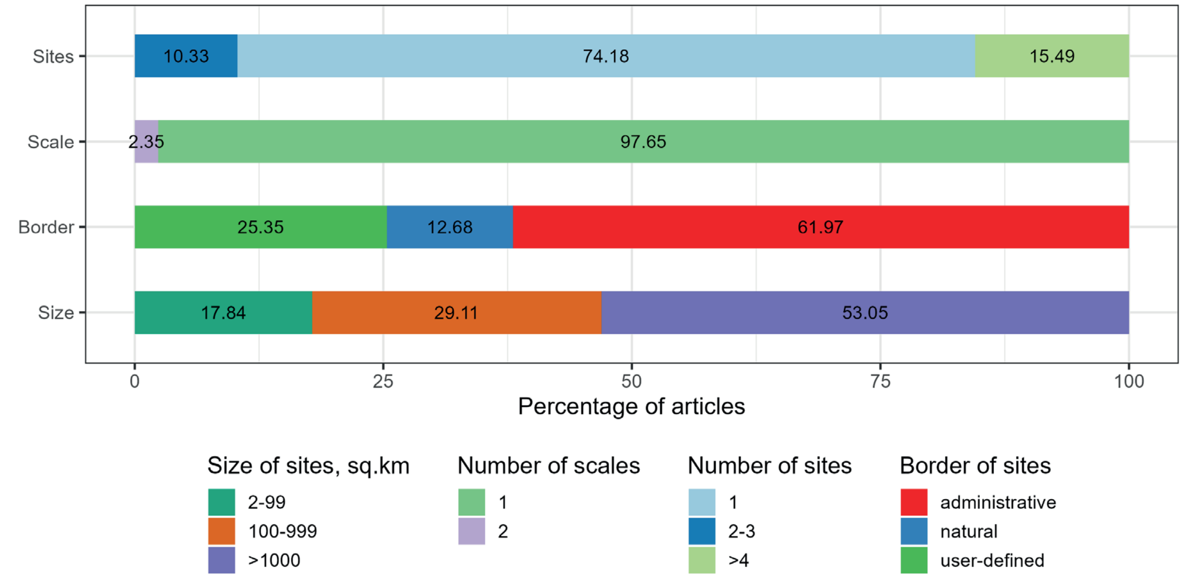

Fig. 7. The distribution of studies by spatial scale, number and size of sites, as well as the nature of their boundaries

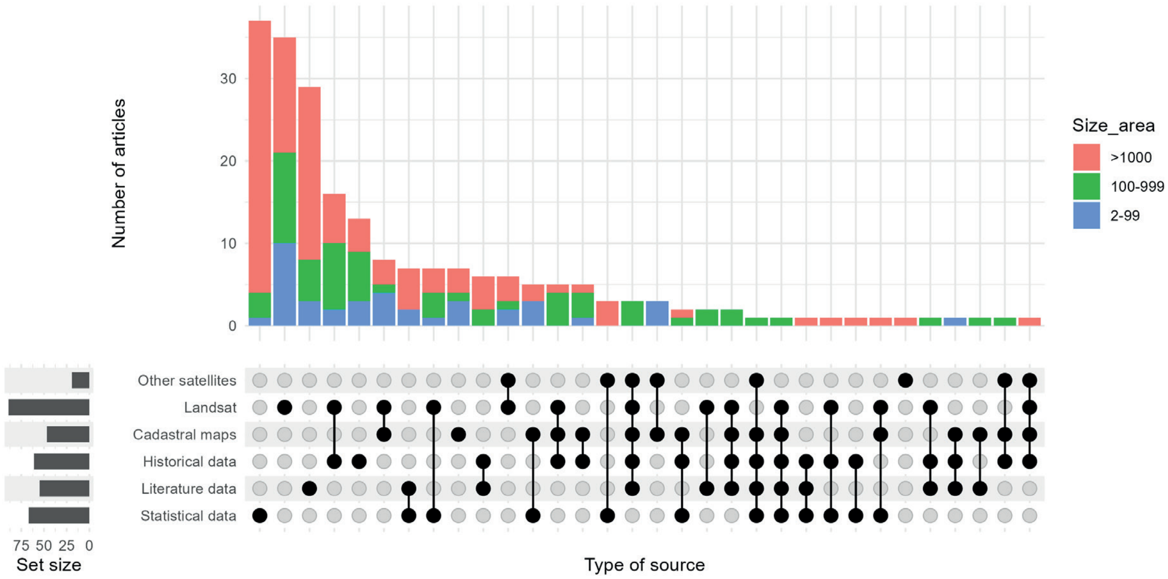

Fig. 8. Distribution of articles by data sources and object sizes

sources were identified. The most frequent combination was Landsat imagery paired with historical maps, used to represent two time points (Fig. 8).

The reliance on remote sensing and cartographic data led to a predominance of geostatistical processing methods. Descriptive (including personal interpretation) and statistical methods were the second and third most common, respectively. Many studies used combinations of these three main methods, reflecting the use of multiple data sources (Fig. 9).

Analysis of the time depth of the studies showed a focus on long-term changes (over 100 years; 43.2% of studies). Short-term (up to 30 years) and medium-term (30–100 years) changes were studied less frequently (31.9% and 24.9%, respectively) (Fig. 10). Most studies using satellite imagery or General Land Survey data were limited to two time points: historical and contemporary. Studies based on statistical or literary reviews were able to incorporate a greater number of time slices.

Analysis of study parameters revealed a clear trend toward an increasing number of studies providing quantitative analysis of land dynamics (Fig. 11).

Analysis of the drivers of change showed that the vast majority of studies did not investigate causal factors. Among those that did, social factors were most frequently identified as the main drivers, while natural factors played a significantly smaller role (Fig. 12).

Overview of several typical groups

Based on a methodological analysis of the studies, we identified several distinct types of research, categorized according to their primary data sources and the depth of historical generalization.

Review of Land Use History

This category comprises publications that describe the history of settlement, land development, and the typology, characteristics, and periodization of land use over different historical periods. A significant number of works are dedicated to reconstructing past landscape development. These studies are typically based on the analysis of available historical literature and archaeological findings. They are often large-scale, long-term reviews without precise geographical referencing. A classic example is an article by Levchenkov (2016), which provides a comprehensive historical overview of the Kaliningrad region's development from the 13th century, illustrating the formation of its cultural landscape for each historical period. Fetisov (2014)

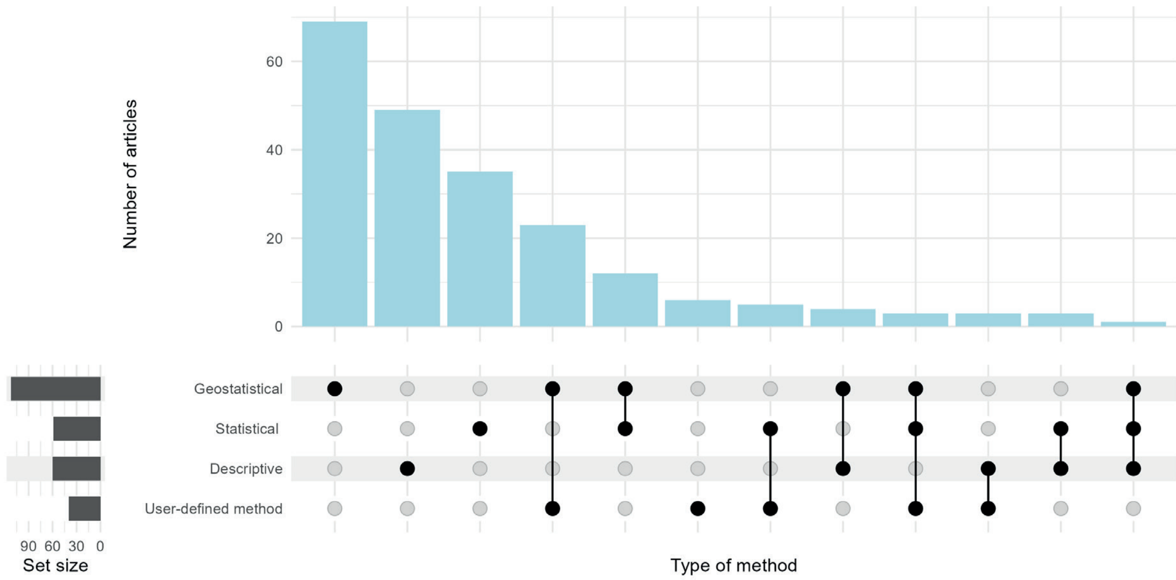

Fig. 9. Distribution of articles by used methods

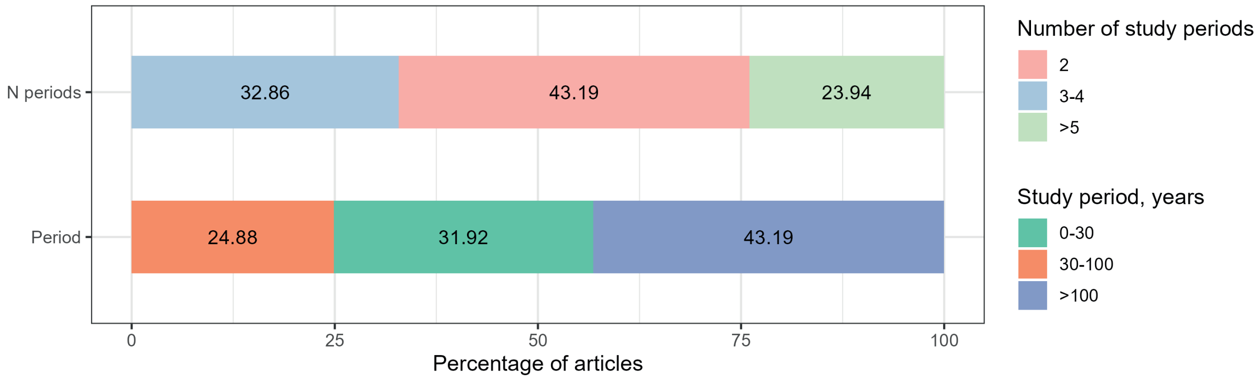

Fig. 10. The distribution of articles by the number of analyzed periods and the time-depth of research

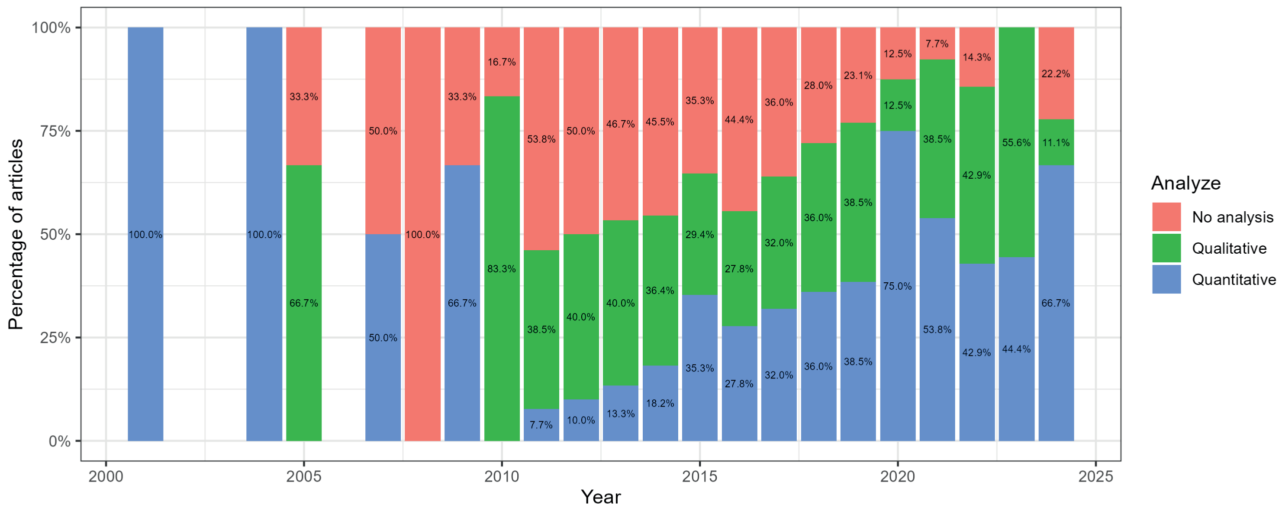

Fig. 11. Temporal distribution of the articles, separated by the type of analysis

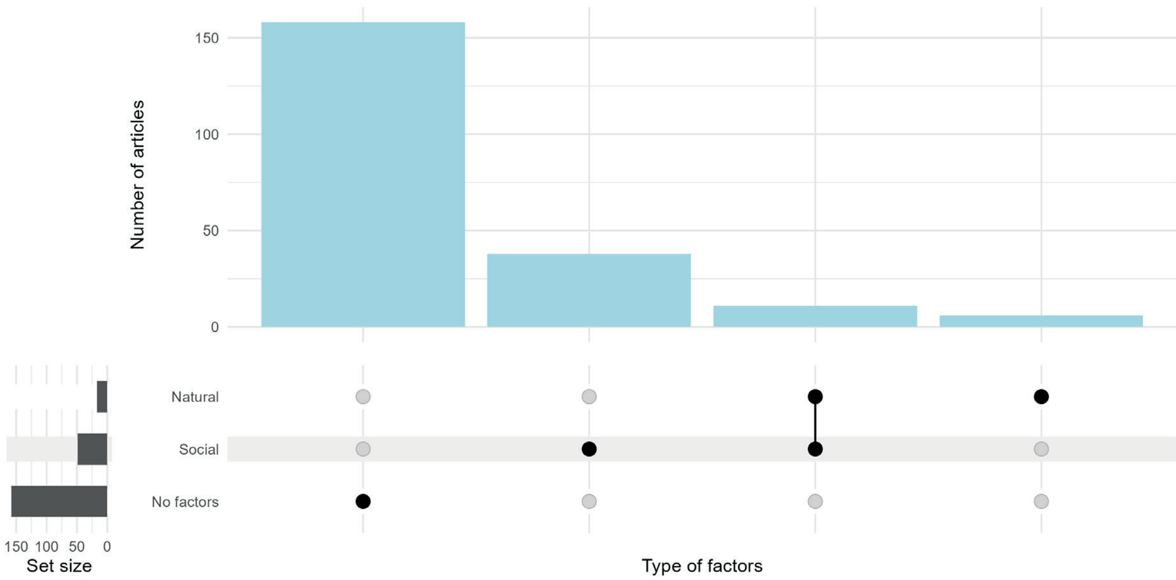

Fig. 12. The distribution of articles by the factors considered in the analysis

examined land use history in the Jewish Autonomous Region from the late 19th to early 20th centuries. They identified five development stages, created land use maps for each, and analyzed land area dynamics. Other studies have frequently utilized statistical reviews. For example, Vinogradova (2020b) calculated landscape composition ratios and changes in land use systems over 80 years in the Kaliningrad region. The study constructed maps showing the proportion of anthropogenic, natural, and recovering landscapes for ten historical time slices and calculated the Shannon diversity index and number of land use types.

Statistical Data Analysis

These are comparative historical studies based on statistical data (without cartographic materials) concerning the area of various land categories or forest cover over time. The temporal scope of these studies is limited by the availability of official statistics, and their geographical scope is often confined to administrative boundaries (municipalities or regions). For instance, Vinogradova (2020a) analyzed the dynamics of agricultural land use in Northwestern Russia and the Baltic countries from 1848 to 2018, mapping the ratio of cultivated agricultural land areas, assessing rates of change, tracing grain yield dynamics, and forecasting future agricultural development. Some studies tracked 5-7 land categories (e.g., agricultural, settlements, industry, protected areas, forest fund, water fund), as for the Akhtubinsky district of the Astrakhan region over 30 years (Barmin, Iolin, Sharova, and Golub, 2011), or for arable land, fallow, perennial plantings, hayfields, and pastures in the northern zone of the Omsk region from 1954 to 2011 (Makenova and Stepanov 2017). However, publications analyzing the dynamics of a single category, most often agricultural land and its subtypes, predominate. Some studies focused on forest cover dynamics, e.g., Musievskiy (2013) for the Voronezh region since the 16th century. Analyzing data across multiple regions allows for identifying regional differences, such as grouping regions in European Russia based on the ratio of sown area in 2013 to 2004 levels (Kitov and Tsapkov 2015); a similar typology was later applied to all of Russia (Lyuri et al. 2018).

Historical Map Analysis

This type involves reconstructing land and forest use through the analysis of historical maps. Frequently used sources include the Materials of the General Land Survey (Plans General'nogo mezhevaniya), which record the state of territories in the late 18th century. Methodological approaches for analyzing and reconstructing the spatial structure of land use using this source are detailed in Matasov (2016). The method involves preparing outlines of individual landholdings, combining them into a unified coverage, transforming and georeferencing them to a modern base, reconstructing land use structure, and restoring the socio-economic infrastructure of the historical period. Numerous examples exist, such as Kukushkina (2018), reconstructing land use in Balakhna district, Nizhny Novgorod province, based on the General Land Survey and soil maps. Alyabina et al. (2015) compared socio-economic and soil-geographical information for central European Russia in the late 18th century to calculate average plowing per household, soil fertility, and use efficiency; Kanischev et al. (2020) analyzed settlement trends in Tambov province in the second half of the 18th century; and Beshentsev et al. (2024) reconstructed 20th century environmental change in the central Lake Baikal basin using topographic maps from the Corps of Military Topographers.

Historic and Thematic Maps Integration

This method analyzes land use dynamics by comparing boundaries and areas from General Land Survey plans with modern maps and/or remote sensing data. Classic examples include Ivanova et al. (2023), who assessed land distribution over seven time slices based on General Land Survey plans, Strelbitsky's maps, RKKA topographic maps, and modern General Staff maps, analyzing the spatial location of arable land at different development stages; Shilov and Kozlov (2019), who reconstructed settlement and land use systems during the General Land Survey period and assessed land suitability for plowing on the Valdai Heights; Matasov et al. (2019), who used historical maps, statistics, and satellite imagery to reconstruct landscape change and classify it into six land use regimes in the Ryazan region; and Belyaeva and Popov (2016), who used General Land Survey plans, Schubert's map, Strelbitsky's map, General Staff maps, and Landsat imagery to compare forest cover in Vereysky Uyezd, Moscow region. Comparing multi-temporal historical and thematic maps provides insights into land use dynamics, forest cover change, and landscape transformation (Belevantsev et al.

2019; Kozykin and Nakvasina, 2024). Studying traditional land use history helps understand modern ecosystem structure and function and identify rare ecosystems; for example, Loiko et al. (2024) used historical maps to identify reference soil sites in Northern Priotomye never subjected to plowing.

Thematic Map Analysis

These are comparative studies of land and forest use dynamics based on specialized departmental maps, such as farm soil maps for agricultural land and forest management materials for forests. Examples include Avvakumova (2018), who assessed spatiotemporal soil erosion dynamics in the Republic of Tatarstan based on 1970s soil maps, and Aleinikov et al. (2024), who analyzed 85 years of dynamics of forests with Siberian pine in the Northern Urals by comparing forest management materials.

Satellite Imagery Analysis

These studies analyze land use dynamics using remote sensing data, primarily Landsat satellite imagery processed by expert or automatic interpretation methods. Examples include analyses of agricultural land use changes in Perm Krai from 1986 to 2018 (Belousova and Bryzhko 2021); studies on the waterlogging of arable land in the Tambov region using Landsat and 1960s CORONA archival imagery (Shapovalov et al. 2018); assessments of vegetation fragmentation in the Valdai Lake District since 2009 (Belonovskaya et al. 2015); investigations into afforestation in the Belgorod region based on 1970 CORONA high-resolution data (Chendev et al. 2023); and the use of decision tree algorithms on Landsat imagery to map permanent steppes and their recovery from 1990 to 2018 (Pazur et al. 2021).

Analysis of the study types revealed a predominance of works using satellite imagery and literature reviews as the simplest methods. Studies using thematic maps and reconstructions based on General Land Survey plans were the least common (Fig. 13).

DISCUSSION

General Overview and Limitations of Results

Our review reveals a noticeable decline in publication output after 2018, which may be attributed to factors such as the COVID-19 pandemic, political situation, shifts in research funding, or the retirement of key researchers. We intentionally focused on domestic Russian journals to capture the breadth of Russian-language scholarship, though this may have excluded some already well-known English-language studies conducted by international teams (Andreeva et al. 2021; Ioffe et al. 2004; Prishchepov et al. 2017). Terminology differences between Russian and Western LSS traditions affect comparability. In landscape ecology, the process of integrating terms has been presented (Bastian et al. 2015; Frolova 2019); while in land system science, this is yet to be done (Meyfroidt et al. 2016). Nonetheless, the corpus of literature analyzed provides a comprehensive overview of historical LSS in Russia. It is also worth noting that significant contributions have been made in monographs and international collaborations (Josephson et al. 2013; Lyuri et al. 2010), though these were beyond the scope of this review.

Regional and Thematic Patterns, Methodological Challenges and Gaps

The spatial distribution of studies is highly uneven, with a strong concentration in European Russia (e.g., Belgorod, Tula, Moscow regions) and minimal coverage of Siberia and the Far East. This bias reflects not only the higher population density in the European part of Russia compared to Siberia and the Far East. This disparity is a result of the historical development of research schools in historical geography and landscape science, often rooted in Soviet-era institutions. Regions with strong academic traditions (e.g., Perm, Irkutsk, Kaliningrad) produced clusters of studies, while vast territories remain under-researched. The correlation between research density and the availability of historical maps (e.g., General Land Survey, Mende maps) is evident: European regions benefit from detailed pre-20th-century materials, whereas Asian Russia relies heavily on satellite imagery and statistical data, limiting temporal depth. Plain landscapes are the subject of 6.5 times more studies than mountain landscapes, despite these two categories representing a relatively balanced share of Russia's territory at approximately 60% and 40%, respectively (Ogureeva et al. 2018). This disparity reflects a strong research bias towards lowland regions, which can probably be attributed to factors such as superior accessibility, more readily available data, and the historical focus on agricultural development. The thematic focus is

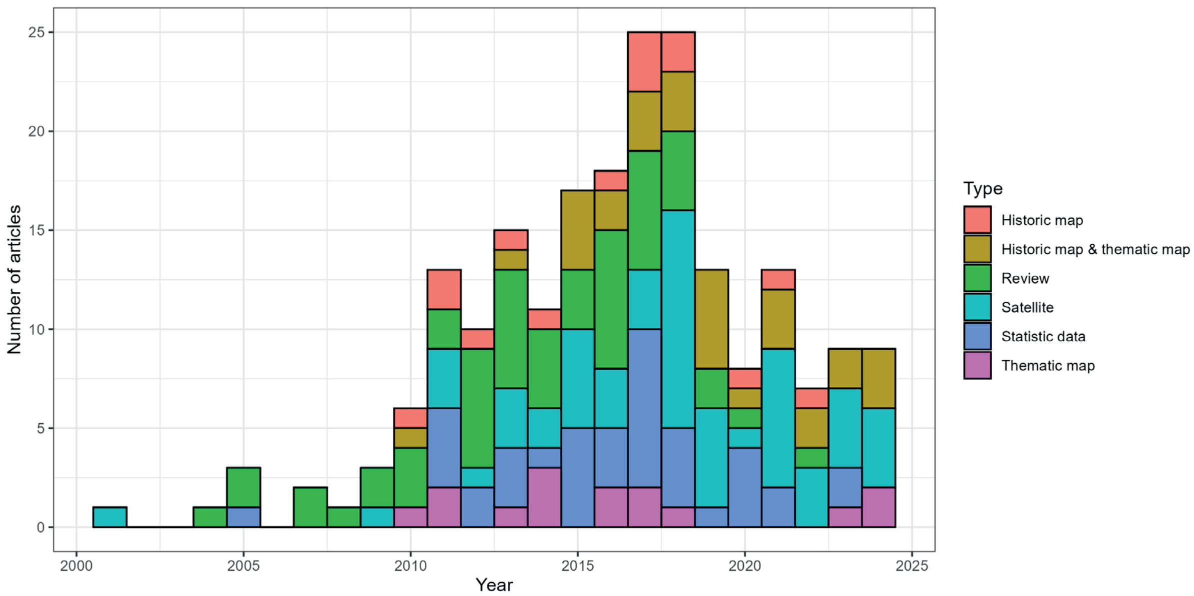

Fig. 13. Temporal distribution of article types

predominantly on the dynamics of agricultural and, to a lesser extent, forested landscapes, primarily in the southern boreal and northern nemoral zones. These regions are characterized by active historical development, which has resulted in pronounced landscape dynamics. In contrast, urban and mountain landscapes are largely overlooked.

We suggest that historical geoinformation science in Russia is currently in its early stages, where research focuses on the simplest objects of natural resource management. These objects—such as plowed or forested areas—possess direct cartographic or spectral signatures and do not require additional modeling. This methodological simplicity is reflected in several other observations. For example, the overwhelming majority of studies are confined to a single site, employ a single spatial resolution, and are limited to a single administrative unit for which a historical map or satellite image is used for comparison. While a significant proportion of long-term studies covering periods exceeding 100 years are promising, most are based on historical surveys or statistical data, which constrains analytical depth.

A clear correlation is evident between the methods used and the spatial and temporal scope of the research. Unfortunately, these methods are often rigidly constrained by historical sources, which can represent a lower limit for historical analysis. The geostatistical methods applied are generally limited to basic area comparisons. Similarly, statistical data analysis methods remain elementary. More advanced techniques—such as spatial modeling, multivariate analysis, machine learning, and interdisciplinary frameworks integrating environmental, historical, and economic data—are almost entirely absent.

It is worth noting a gradual increase in studies that provide quantitative assessments of change as a key conclusion. However, this trend is primarily tied to the growing number of studies using area comparisons based on satellite imagery. Few studies integrate socio-economic drivers or use multi-scale approaches, hindering mechanistic understanding of land change processes. A major constraint to the growth of deep research is the limited accessibility and digitization of historical cartographic materials. Many pre-Soviet and Soviet-era maps remain classified, poorly georeferenced, or fragmented, preventing large-scale integration of GIS analysis methods for them. This forces researchers to rely on remote sensing, which only covers post-1990 trends. Methodologically, geostatistical approaches dominate, but few studies employ advanced modeling, machine learning, or interdisciplinary frameworks that combine ecological, historical, and economic data. There is also a notable lack of open historical mapping platforms or harmonized land cover databases for Russia, which limits reproducibility and comparative analysis.

Positioning Russian LSS within the European and Global Context

Our review shows that the Russian research field contrasts with patterns found in Western and Central Europe. For instance, it differs markedly from the synthesis by Plieninger et al. (2016). While their study found a dense coverage of case studies in EU member states (e.g., Spain, Czech Republic, Italy), our results highlight a significant knowledge gap for Russia, which was notably absent from their analysis along with other Eastern European countries. This disparity underscores Russia's status as a critical blind spot in the pan-European understanding of land system change. The Russian context, characterized by unique post-Soviet socio-economic transitions, vast scales, and specific biogeographic zones (e.g., boreal forests, steppes, Arctic), offers a distinct and complementary set of drivers and trajectories that are poorly represented in European meta-analyses (Jepsen et al. 2015; Levers et al. 2018). For instance, while land abandonment is a dominant proximate driver across Europe, its causes and consequences in the Russian context – linked to the collapse of state farms and depopulation of remote villages – differ markedly from the market-driven dynamics in Western Europe or the Mediterranean.

Furthermore, the Russian scientific tradition, with its strength in detailed, local-scale historical reconstructions and qualitative case studies, provides a valuable counterbalance to the quantitative, satellite-driven approaches that dominate Western literature. Therefore, integrating Russia's fragmented but deep insights is crucial. It is not merely about filling a geographical gap. It is essential for building a comprehensive LSS theory that accounts for all socio-ecological contexts (Meyfroidt et al. 2013, 2018; Verburg et al. 2013). This integration aligns with the goals of Long-Term Socio-Ecological Research, which emphasizes the need for place-based, long-term data to understand complex system dynamics (Angelstam et al. 2019; Singh et al. 2010). Our synthesis of Russian studies provides a crucial foundational step towards creating such a platform for Russia, enabling future cross-site comparisons and enriching global models like HYDE (Klein Goldewijk et al. 2011) with much-needed data from the world's largest country. Ultimately, bridging this divide is paramount for addressing transboundary sustainability challenges, from carbon sequestration in boreal forests to biodiversity conservation across Eurasia.

CONCLUSION

Studying land-use dynamics in Russia is critically important due to the country's significant global influence. Its extensive boreal forests act as a major carbon sink, while the thawing of permafrost threatens to release vast quantities of greenhouse gases. Furthermore, Russian policies on agriculture and resource extraction have a direct impact on global food and energy security. Ultimately, these changes in land use both reflect and shape pivotal economic, environmental, and geopolitical trends that extend far beyond its borders. The systematic review uncovers pronounced geographical and thematic disparities in Russian LSS research. Empirical findings demonstrate a strong spatial bias, with the overwhelming majority of case studies concentrated in the European part of the country, such as the Belgorod and Moscow regions, while vast areas of Siberia, the Far East, and the Arctic remain critically understudied. Thematically, research is dominated by investigations into agricultural land abandonment and forest dynamics, whereas urban landscapes receive minimal scholarly attention. This uneven coverage limits a comprehensive understanding of land-change processes across Russia's diverse socio-ecological systems. Methodologically, the researches are characterized by significant constraints. A substantial majority of studies (74.2%) are confined to a single spatial scale and a single study site, predominantly using administrative boundaries rather than biogeographical units. Furthermore, 74% of the reviewed publications do not systematically analyze the causal drivers behind the observed landscape changes. Compounding these issues is a persistent linguistic and visibility gap, with 82% of studies published only in Russian and a significant portion not indexed in international databases, which severely limits the global integration of this research.

This paper is the first in a series of review articles that aim to foster knowledge exchange among researchers – including ecologists, geographers, historians, economists, and climatologists – as well as practitioners involved in the study and management of Russian lands. To advance LSS in Russia, we recommend:

• Expanding research into understudied regions, such as Siberia, the Far East, and the Arctic.

• Integrating multi-source historical and modern data through GIS and machine learning techniques.

• Fostering interdisciplinary collaborations across fields such as ecology, history, economics, and archaeology.

• Developing open-access geodatabases and producing regional historical land-cover reconstructions.

• Enhancing international engagement by disseminating findings in both English and Russian and promoting collaborative projects.

These efforts would not only increase the visibility of research from Russia but also contribute significantly to the global understanding of land-system dynamics within its unique socio-ecological contexts.

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