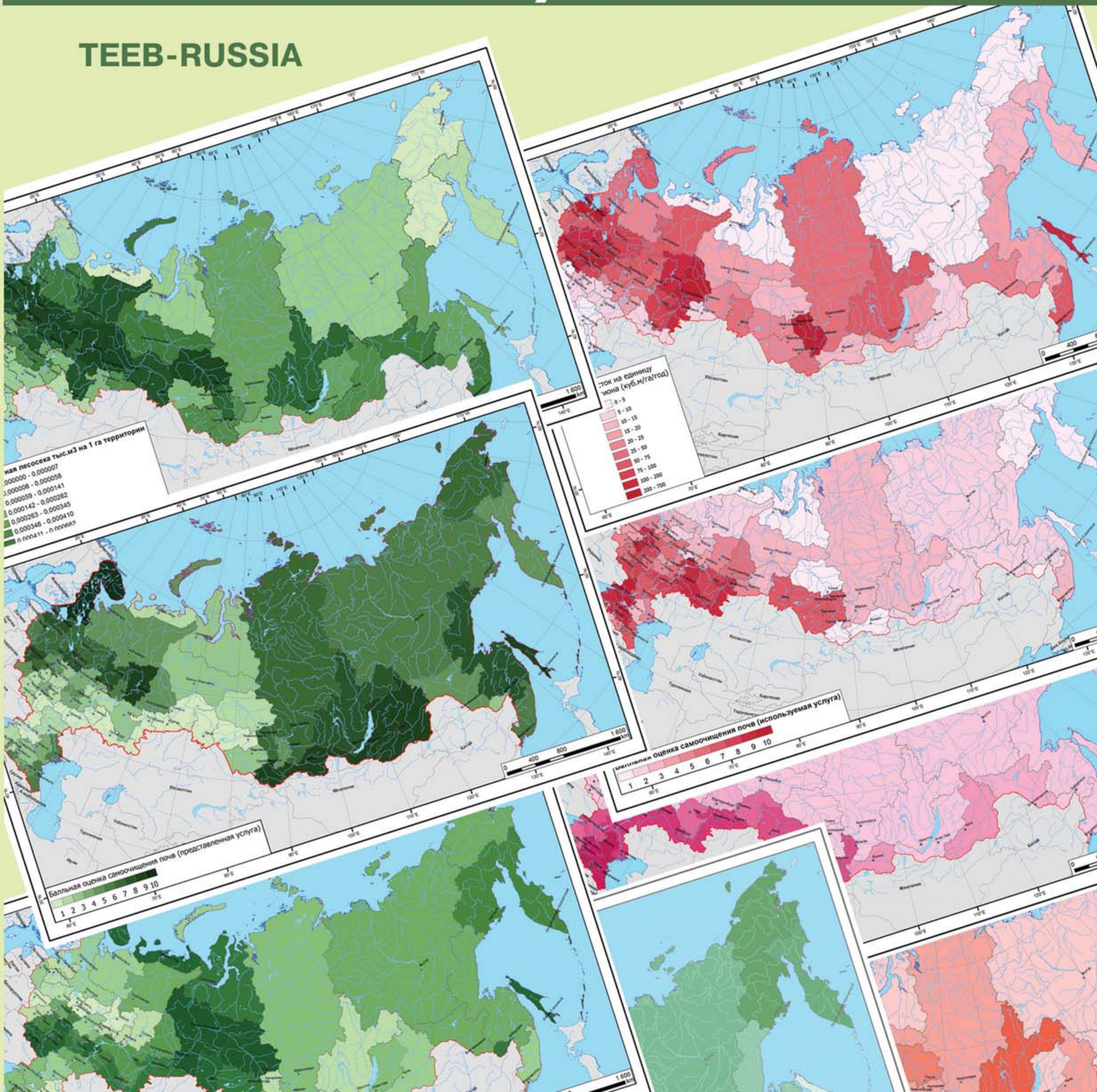
Ecosystem Services of Russia

Prototype National Report

Terrestrial Ecosystems Services

TEEB-RUSSIA



TEEB-Russia

Biodiversity Conservation Center

Leibniz Institute of Ecological Urban and Regional Development

ECOSYSTEM SERVICES OF RUSSIA

PROTOTYPE NATIONAL REPORT

Volume 1
Terrestrial Ecosystems Services

Adapted English version of the report, originally published in Russian in 2016

Edited and compiled by
E. N. Bukvareva
D. G. Zamolodchikov

Moscow – 2018

ISBN 978-5-93699-090-8

The report is the first national assessment of ecosystem services (ES) of Russia that considers terrestrial natural ecosystems in Russia. A methodology for ES assessment was developed with allowance for the current status of the national public statistics. The units of ES assessment are the constituent entities of the Russian Federation. ES volumes supplied by ecosystems and consumed by humans were assessed. A number of productive (provisioning) and environment-forming (regulating) ES were evaluated in terms of quantitative scientific indicators; others were scored in terms of natural and socioeconomic factors that determine the supply and use of ES. The degree to which ES are consumed by humans was assessed by the ratio of supplied ES volumes to consumed ES volumes. The constituents of the Russian Federation were compared with respect to supplied and consumed ES volumes. Regions that are ES donors and ES recipients were identified.
The present publication is an adapted English version of the report, which was originally published in Russian in 2016.

Edited and compiled by E. N. Bukvareva and D. G. Zamolodchikov

Authors: S. N. Bobylev, E. N. Bukvareva, A. A. Danilkin, Y. Y. Dgebuadze, A. V. Drozdov, O. F. Filenko, V. I. Grabovsky, A. V. Khoroshev, G. N. Kraev, R. A. Perelet, I. E. Smelyansky, B. R. Striganova, A. A. Tishkov, D. G. Zamolodchikov

Maps prepared by A. N. Narykov

Outside experts: K. Grunewald, O. Bastian, L. Kümper-Schlake

The translation of the Russian text into English was done by C. Hofmann, KERN AG, Sprachendienste in Dresden, and we thank F. Pahl, Berlin, for the final language polishing.

Recommended citation: *Bukvareva, E. N., Zamolodchikov, D. G.* (Eds.). (2018). Ecosystem services of Russia: Prototype National Report. Vol. 1. Terrestrial ecosystems services. Adapted English version of the report, originally published in Russian in 2016. Moscow: BCC Press.

The book was prepared and published as part of the project "Ecosystem services evaluation in Russia and other NIS countries of Northern Eurasia: first steps". It was commissioned by the German Federal Agency for Nature Conservation (BfN) with funds from the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) and supported by the Ministry of Natural Resources and Environment of the Russian Federation with active participation of experts from the Russian Academy of Sciences (A. N. Severtsov Institute of Ecology and Evolution, Institute of Geography, Center for Forest Ecology and Productivity, and Institute for Systems Analysis) and Moscow State University (faculties of Biology, Geography and Economics) as well as the German Leibniz Institute of Ecological Urban and Regional Development in Dresden.

Project Director: A. V. Zimenko
Project Coordinator: A. R. Grigoryan

The prototype national report (vol. 1) includes this publication and an electronic appendix with spreadsheets of quantitative assessments of ecosystem services and high-resolution maps (www.biodiversity.ru/teeb-russia.html).

Please send comments and suggestions to further develop the prototype or contribute to related activities to the Biodiversity Conservation Center.
Postal Address: Russia, 117312, Moscow, Vavilova Street, 41, Office 2.
E-Mail: bcc@biodiversity.ru. Website: www.biodiversity.ru.

CONTENTS

INTRODUCTION
Project goal and objectives

The field of ecosystem services (ES) is one of the most rapidly developing areas of current ecological research. It aims at maintaining life-supporting functions of biodiversity and sustainable development of the biosphere. The importance and necessity of developing the ES concept in Russia was proclaimed by the scientific community, and a substantial body of pioneering work on ES assessments was carried out in Russia and other post-Soviet newly independent states (Bastian et al., 2015; Bukvareva et al., 2015; Grunewald et al., 2014a, b). However, these work samples had a local or regional scale.

The Russian-German project “TEEB-Russia – Ecosystem Services Evaluation in Russia: First Steps” was initiated in 2013 by the Biodiversity Conservation Center (Moscow) in cooperation with the Leibniz Institute of Ecological Urban and Regional Development (Dresden) in accordance with the decision (of May 23, 2012) of the permanent Russian-German working group “Conservation of Nature and Biological Diversity”. This study was commissioned by the German Federal Agency for Nature Conservation (BfN) with funds from the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) as part of a broader project also involving other NIS countries of Northern Eurasia (“Ecosystem services evaluation in Russia and other NIS countries of Northern Eurasia: first steps”). The project is also supported by the Ministry of Natural Resources and Environment of the Russian Federation. The Project TEEB-Russia is the first attempt at ES assessment in Russia at the national level.

The goal of the project is to create a Prototype of the National Report on Ecosystem Services of Russia, which demonstrates approaches to country-scale ecosystem services (ES) assessment as well as the urgency to start forming a national system of ES monitoring and assessment and integrating their value into the economic and political decision-making processes.

In the first phase of the project (2013-2015), Volume 1 of the Prototype Report considering terrestrial ES was created. The following main results were obtained:

- an ES classification adapted to Russian conditions was developed;
- possible approaches to qualitative and quantitative evaluation of ES at the national level were demonstrated;
- the most important ES of the Russian regions were assessed quantitatively in scientific indicators or were scored in terms of natural and socioeconomic factors that determine the supply and use of ES;
- the regions were compared with respect to the balance of natural factors determining ES supply and socioeconomic factors determining ES use.

The Prototype of the National Report is an innovative initial piece of work that cannot claim a final comprehensive ES assessment. The document pursues methodological goals and shows possible approaches to ES estimation on the national level and their importance for the socioeconomic development and population welfare of Russia.

All the ES estimates presented in the Prototype of the National Report are only illustrations of the possible assessment approaches and should be significantly refined for use in decision-making.

Since the present report represents only the first step in the creation of a national system of ES assessment in Russia, the following issues were not considered at the first stage of the project and were scheduled for the next stages: the analysis of the importance of biodiversity for ES maintenance, economic ES valuation, specific recommendations on monitoring and management of ES of Russia. The present report considers only a part of the Russian ecosystems, namely natural terrestrial ecosystems. Terrestrial agroecosystems, the processes in which are basically controlled by humans, cultural landscapes significantly transformed by humans as well as marine ecosystems will also be analyzed in the next stages of the project.

The Biodiversity Conservation Center and the authors and compilers of this publication are sincerely grateful to the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety of Germany and the German Federal Agency for Nature Conservation for financial support for the project, to the Ministry of Natural Resources and Environment of the Russian Federation for its organizational support, and personally to Heinrich Schmauder, Lennart Kümper-Schlake (Germany), Amirkhan Amirkhanov, and Irina Fominykh (Russia) for political and technical assistance in the project.

METHODOLOGY FOR THE ASSESSMENT OF ECOSYSTEM SERVICES

CLASSIFICATION OF TERRESTRIAL ECOSYSTEM SERVICES OF RUSSIA

The Prototype Report employs a classification of ES combining the approaches of the Millennium Ecosystem Assessment (2005), CICES (Haines-Young & Potschin, 2013) and the National Strategy of Biodiversity Conservation in Russia (2001). It includes four ES categories (Table 1):

1) productive (provisioning) – production of biomass which is removed from ecosystems by people (in contrast to CICES, "production" of water is not included);

2) environment-forming (regulating) – establishment and maintenance of the environmental conditions conducive to human life and economic development;

3) informational (cultural) – all kinds of information which is contained in natural ecosystems and can be used by people;

4) recreational – establishment and maintenance of natural conditions for different types of recreation; recreational ES are integrative, as they are coupled to all of the groups above to various extents.

This ES classification is proposed for use in the national system of ES monitoring and assessment.

Table 1. Classification of terrestrial ES of Russia

Category	*ES*
Productive (provisioning)	1. Wood production 2. Non-wood production of the forest and other terrestrial ecosystems (mushrooms, berries, nuts, bark, medicinal, cosmetic, and decorative plants, etc.) 3. Production of fodder on natural pastures and hayfields 4. Production of freshwater ecosystems, including fish 5. Game production 6. Production of honey in natural areas
Environment-forming (regulating)	**1. Climate and atmosphere regulation** 1.1. Biogeochemical climate regulation: – carbon storage – regulation of greenhouse gas flows 1.2. Biogeophysical climate regulation: regulation of energy flows between the Earth's surface and atmosphere, reduction in wind strength and damage to vegetation from hurricanes and storms, regulation of moisture flows between the surface and atmosphere 1.3. Air purification by vegetation (pollutant absorption and dust precipitation) **2. Hydrosphere regulation** 2.1. Water protection and water regulation: – regulation of runoff volume – regulation of runoff variability (runoff stabilization), reduction in the intensity of and damage from floods 2.2. Assurance of water quality by terrestrial ecosystems 2.3. Assurance of water quality by freshwater ecosystems (self-cleaning and dilution) **3. Soil formation and protection** 3.1. Soil protection from erosion: – Soil protection from water erosion

Category	*ES*
	– Soil protection from wind erosion, prevention of dust storms – Prevention of damage from soil washing into water bodies – Prevention of damage from landslides and mudflows 3.2. Establishment of soil bioproductivity 3.3. Soil self-purification 3.4. Regulation of cryogenic processes **4. Regulation of biological processes important for the economy and for security** 4.1. Ecosystem regulation of species with economic importance: agricultural pests, forest pests, pollinators, invasive and synanthropic species 4.2. Ecosystem regulation of species with medical, biomedical and veterinary importance *The ES of reducing the intensity of and damage from extreme natural events are distributed among groups 1.2, 2.1, and 3.1.* *The ES of biological purification of components of the environment (assimilation services) are distributed among groups 1.3, 2.2, 2.3, and 3.3.*
Informational (cultural)	1. Genetic resources of wild species and populations 2. Information on the structure and functioning of natural systems that can be used by humans 3. Aesthetic and educational importance of natural systems 4. Ethical, spiritual, and religious importance of natural systems
Recreational	Establishment of natural conditions for recreation: – daily recreation near home – weekend recreation and picnics, recreation at summer cottages, recreational fishing, collecting mushrooms and berries (not including professional procurement of non-wood products) – educational tourism in nature – active tourism in nature, sport fishing and hunting – resort recreation (except seacoasts)

Ecological processes and ecosystem functions which do not directly affect human well-being (e.g. primary productivity, organic decomposition, habitat creation etc.) are considered necessary conditions for ES performance, and not separate ES.

The approaches to ES classification associated with the scale of the impact of ES are discussed in the section “Scale of ecosystem services”.

Primary data sources

The primary sources for assessing ES were open-source databases and published statistical digests and studies.

1. Databases of the Federal State Statistics Service (FSSS):

– Regions of Russia. Socioeconomic indicators (Rosstat, 2013b);

– Agriculture, Hunting and Game Management, Forest Management in Russia (Rosstat, 2013a).

2. Digital Cartographic Materials “Land Resources of Russia” (Stolbovoi & McCallum, 2002).

3. Map of the Terrestrial Ecosystems of Northern Eurasia (Bartalev et al., 2004).

4. National Atlas of Russia (2004–2008).

5. National Atlas of Soils of the Russian Federation (Shoba, 2011).

6. Statistical and analytical digests on a number of bioresources (Egoshina, 2005; Lomanova, 2011).

The FSSS statistical data used refer to 2012; other statistical and cartographic data refer to the period from 2002 to 2012.

Inasmuch as the Prototype National Report on Ecosystem Services of Russia has primarily a methodological focus and is intended to demonstrate possible approaches to ES assessment, the objectives for it did not include an analysis of the accuracy of the data that were used or their correction. The accuracy of the ES assessments we produced is consistent with the accuracy of the initial data. Further ES assessments will have to be updated on the basis of more detailed and corrected initial data.

Assessment units – the constituents of the Russian Federation

The constituents of the Russian Federation – oblasts, krais, republics etc. (the top-level administrative units), hereinafter the regions – were used as assessment units. All socioeconomic data and some environmental indicators were obtained from the public FSSS databases and the databases of other federal agencies, which produce data for the regions of the Russian Federation. There were multiple sources of physical, geographical and biological data used for ES assessment, which were available at various scales from the level of medium-resolution satellite imagery to the level of natural domains. To make our assessment uniform, we used values scaled down or up to the level of regions using GIS methods.

A significant challenge in assessing ES for Federation constituents is the large size of some of them in the North, Siberia and the Far East. Single assessments for the huge areas of Krasnoyarsk Krai and Yakutia obviously do not fully reflect the diversity of natural and socioeconomic conditions within these extensive regions. Novaya Zemlya is part of Arkhangelsk Oblast and therefore has the same indicators as the continental part of that region. The authors acknowledge the simplification of this approach to describing the spatial distribution of ES but had to rely on the form in which information was presented in government statistical databases. A more detailed consideration of the spatial distribution of ES may be performed on the level of administrative districts, which seems appropriate for regional studies.

Methods of ES assessment

Depending on data availability and methodological clarity the following methods were used.

1. **Direct quantitative evaluation** when statistical data are available on supplied, demanded and consumed ES.

2. **Indirect quantitative evaluation** based on a combination of other quantitative data on regional ecosystems and economy.

3. **Estimation of scores** if there is no data to evaluate an ES and it is only possible to estimate factors affecting it. Scores of supplied ES show the relative intensity of natural factors that determine the performance of ES (e.g., the share of natural ecosystems of the area of the region). Scores of demanded and consumed ES show the relative intensity of social and economic factors that determine the need for ES and their use (e.g., population density and transport accessibility of the territory). The range of values of the selected factor was divided into 10 classes, with a score from 1 to 10 points assigned to each class (smaller scores correspond to lower values of the factor). If it is necessary to combine several factors, their scores in the regions were summed up, and the resulting total values were translated into a 10-point scale.

4. **Statement of the task** of ES assessment, if methodological approaches are not ready for the above methods or data were not available.

Table 2 shows the methods used for the Prototype National Report to assess various ES. The list of assessed ES differs from the full list in Table 1, since not all components of ES were estimated. For example, for the ES of air purification by vegetation, only the capture of stationary source pollutants by suburban forests was assessed, whereas other kinds of pollution and the functions of non-wood vegetation were not considered.

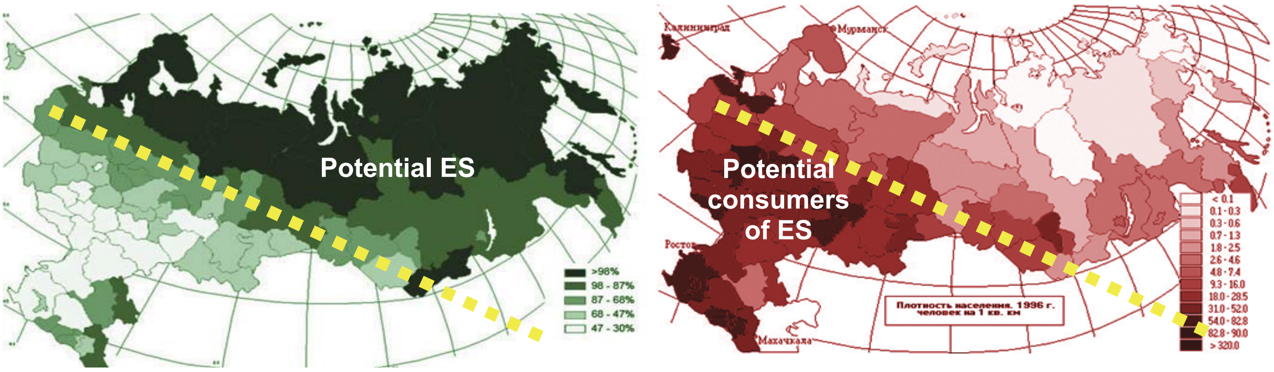
Table 2. Methods for assessing ES
(numbers correspond to the assessment methods noted in the text)

ES	*Methods*			
	1	**2**	**3**	**4**
Productive (provisioning)				
Wood production	X			
Non-wood production of forest and other terrestrial ecosystems	X			
Production of fodder on natural pastures (hayfields were not taken into consideration)		X		
Production of freshwater ecosystems, primarily fish				X
Game production	X			
Production of honey in natural areas				X
Environment-forming (regulating)				
Climate and atmosphere regulation				
Biogeochemical climate regulation				
Carbon storage	X			
Regulation of greenhouse gas flows (only CO_2 was considered)	X			
Biogeophysical climate regulation				X
Air purification by vegetation (absorption of pollutants by suburban forests)		X		
Hydrosphere regulation				
Water protection and water regulation				
Regulation of runoff volume		X		
Regulation of runoff variability (runoff stabilization)		X		
Assurance of water quality by terrestrial ecosystems		X		
Assurance of water quality by freshwater ecosystems (water self-purification and dilution)		X		
Soil formation and protection				
Soil protection from erosion				
Soil protection from water erosion			X	
Soil protection from wind erosion			X	
Prevention of damage from soil washing into water bodies				X
Prevention of damage from landslides and mudflows				X
Establishment of soil bioproductivity				X
Self-purification of soils			X	
Regulation of cryogenic processes		X		
Regulation of biological processes important for the economy and for security				
Ecosystem regulation of species with economic importance (agricultural and forest pests, invasive and synanthropic species)				X
Pollination of farm crops			X	
Ecosystem regulation of species with medical, biomedical and veterinary importance				X
Informational (cultural)				
Genetic resources of wild species and populations			X	
Information on structure and functioning of natural systems that can be used by hymans			X	
Aesthetic and educational importance of natural systems			X	
Ethical, spiritual and religious importance of natural systems				X
Recreational				
Formation of natural conditions for daily recreation near home, weekend recreation, recreation at summer cottages			X	
Formation of natural conditions for educational and active tourism in the nature			X	
Formation of natural conditions for resort recreation (except seacoasts)				X

Depending on the ES assessing method, either physical units of measure or scores were used (Table 3).

SUPPLIED, DEMANDED AND CONSUMED ES

The extreme diversity of natural and socioeconomic conditions in Russia required specific approaches to the assessment of the ES that could potentially be supplied by ecosystems, the ES necessary for people and the ES actually used by people. Supplied ES are generally correlated with the area of ecosystems. Demanded and consumed ES and the value of the ES for human well-being are linked to the population density, economic development and transport accessibility of the regions. The most common pattern is an inverse relationship between the area of natural ecosystems and the density of ES consumers (Fig. 1), because human economic activity in most cases is associated with the destruction or disruption of natural ecosystems.



The share of natural ecosystems of the region's area (%) *Population density*

Figure 1. Comparison of the distribution of potential ES provided by ecosystems and potential consumers of ES in different regions of Russia

The possibility of converting an ecosystem function (potential ES) into an actual ES depends on its spatial scale (see section "Scale of ecosystem services"). A spatial comparison of the volumes of potential ES and consumed ES may be accomplished through an assessment of each service on the basis of the three indicators: supplied, demanded and consumed volumes (Table 3).

Supplied ES were defined as ES produced by ecosystems regardless of the presence or absence of people. Supplied ES correspond to the capacity of ecosystems to perform functions that are useful to people and meet their needs. Supplied ES are determined by natural factors: the state of ecosystems and biodiversity, the intensity and stability of ecosystem functioning, the degree of ecosystem disturbance. This indicator should be assessed taking into account the sustainable use of ecosystems and their components, i.e., it is equal to the volume of ES that can be used by people without disturbance of ecosystem structure and functioning (e.g., the amount of bioresource extraction that does not disturb the structure, reproduction and ecosystem functions of exploited populations).

Demanded ES were defined as ES which correspond to the ES yield necessary to fulfill the needs of the population and economy of a region.

Consumed ES were defined as the ES yield which is materially or immaterially being used by the population, or which people derive benefits from at the present time.

The examples of supplied, demanded and consumed ES volumes for the different ES categories are shown in Table 3.

Table 3. Indicators and measures for estimation of supplied, demanded and consumed ES volumes

Category	*Supplied ES volume*	*Demanded ES volume*	*Consumed ES volume*	*Measures*
Productive	The part of a bioresource yield that could be extracted from nature without undermining species populations and their ecosystem functions. *Examples:* – annual allowable cut; – allowable shooting of commercial species (the total numbers of game animals were used as a proxy).	Yield of a bioresource necessary for sustainable socioeconomic development of a region (including needs of the population and enterprises in the region).	Current bioresource extraction. *Examples:* – logging volume; – game harvest; – mushroom and berry harvest.	mass; number; kg/ha; numb./ha; kg/ha/yr; numb./ha/yr
Environment-forming	Potential ability of ecosystems to regulate the parameters of the environment. *Examples:* – potential intensity of water self-purification in natural reservoirs; – the maximum amount of pollutants that can be captured by vegetation from the air without significant damage to it.	The volume of ecosystem regulation of the environment necessary for a good quality of life of people and economic development, taking into account existing standards of the quality of the environment. *Example:* – amount of pollutants which must be neutralized by ecosystems (annual pollutant emissions were used as a proxy).	The volumes of actual regulation of the environment directly affecting the quality of life of people and the economy. *Examples:* – the amount of pollution neutralized in water bodies due to natural processes; – the amount of pollution actually captured by vegetation from the air; – the amount of runoff provided by the functioning of terrestrial ecosystems.	volume; area; mass; kg/ha/yr; m^2/ha/yr; m^3/ha/yr
	The sum of natural factors affecting the potential volumes of environment regulation. *Examples:* – area of natural ecosystems; – the capacity for ecosystems' self-cleaning.	*Not assessed*	The sum of socioeconomic factors affecting potential profit (prevention of damage) from environment regulation. *Examples:* – population; – agricultural area.	Score
Informational	The sum of natural factors affecting the amount of information in natural systems. *Examples:* – species richness; – diversity of ecosystems and landscapes.	*Not assessed*	The sum of socioeconomic factors affecting the amount of information that people can obtain from nature. *Examples:* – population; – density of road network; – research costs.	Score
Recreational	The sum of natural factors affecting the recreational potential. *Examples:* – comfort of natural conditions for people; – degree of nature degradation; – beauty and diversity of scenery.	*Not assessed*	The sum of socioeconomic factors affecting the number of people engaged in recreation and the actual recreational load. *Examples:* – transport accessibility; – tourist infrastructure.	Score

The supplied, demanded and consumed ES indicators we used partially follow the “cascade model” of Haines-Young and Potschin (2013): the supplied amount can be compared with “final services”, the consumed amount with “benefits” (Fig. 2).

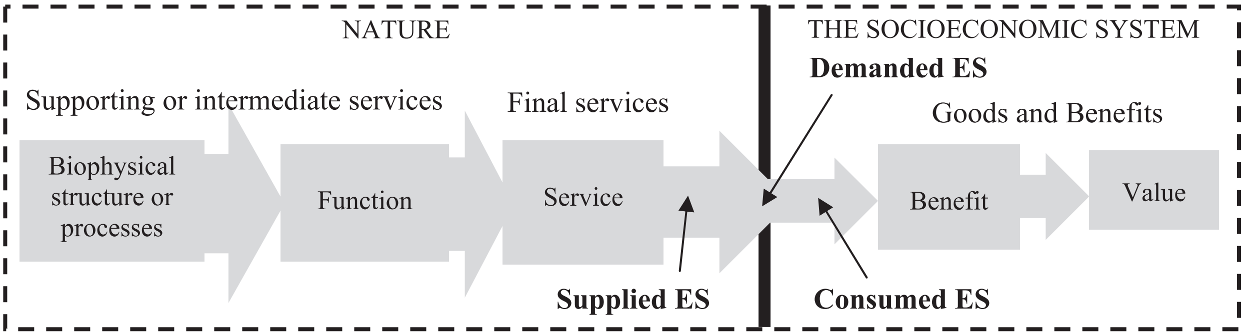


Figure 2. Supplied, demanded and consumed ES in the “ES Cascade” (after Haines-Young & Potschin, 2013, with changes)

The ratio of supplied, demanded and consumed ES volumes is determined, on the one hand, by the intensity and stability of the functioning of the ecosystems and, on the other hand, by the socio-economic characteristics of the regions (population density, economic development, transport accessibility, available mechanisms and means of using ecosystem services).

The demanded volume could exceed the supplied volume (Fig. 3, left) for all ES categories. This occurs in densely populated regions located in the central and southern parts of European Russia and in patches in the south of Siberia. By contrast, in remote regions where the population density is lower, the demanded ES is usually smaller than the supplied ES (Fig. 3, right). Such regions are found in the major part of Siberia and in the north of Russia. Relationships between consumed and supplied ES volumes are specific to ES categories. The consumed ES volume can exceed the supplied volume of provisioning and recreational ES (number 1 in Fig. 3), which leads to overexploitation (overfishing, overhunting, etc.) or disturbance by excessive recreational load. The consumed ES volume cannot exceed the supplied volume of regulating and cultural ES because they cannot be overused. People can exist only in the given environment and draw benefit or harm from it. If the demanded ES volume exceeds the supplied ES volume, ecosystems cannot maintain acceptable parameters of the environment and people have to live in an unfavorable environment. For example, if emissions of toxic gases exceed the ability of forests to absorb them, then the consumed ES volume is equal to the supplied ES volume, since forests absorb only the amount that they can. In this case, the quality of the environment deteriorates. Similarly, it is impossible to overexploit informational ES, since it is impossible to use more information than there is in nature. This information can be lost due to the degradation of ecosystems or the extinction of species, but it is obviously impossible to over-use it.

The consumed ES volume could be less than the supplied volume of all ES categories. The primary reason for this would be low demand for a service, when the demanded volume is less than the supplied ES volume (number 4 in Fig. 3). The consumed ES volume could be less than the demanded volume due to lack of supplied ES (number 2 in Fig. 3), for example, because of depletion of fish stocks or when the emission of pollutants exceeds the capacity of forests to absorb them. A lack of technological, legal or economic means for ES use was another widespread cause of insufficient consumption of supplied ES volume (numbers 3 in Fig. 3). For example, a lack of logging equipment or roads prevents cutting down the amount of timber required for normal operation of wood-processing enterprises in a region. Potentially useful natural genetic resources might not be used due to lack of theoretical knowledge and technologies.

Relationships between consumed and demanded ES volumes are also specific to ES categories. The consumed volume of provisioning and recreational ES can exceed the required volume in case of an extremely inefficient planning and management system. For example, if biological resources are harvested in excessive amounts that cannot be processed or transported to another region or if the number of people who relax in nature is excessively high, this reduces the quality of their rest and the economic profit from recreation.

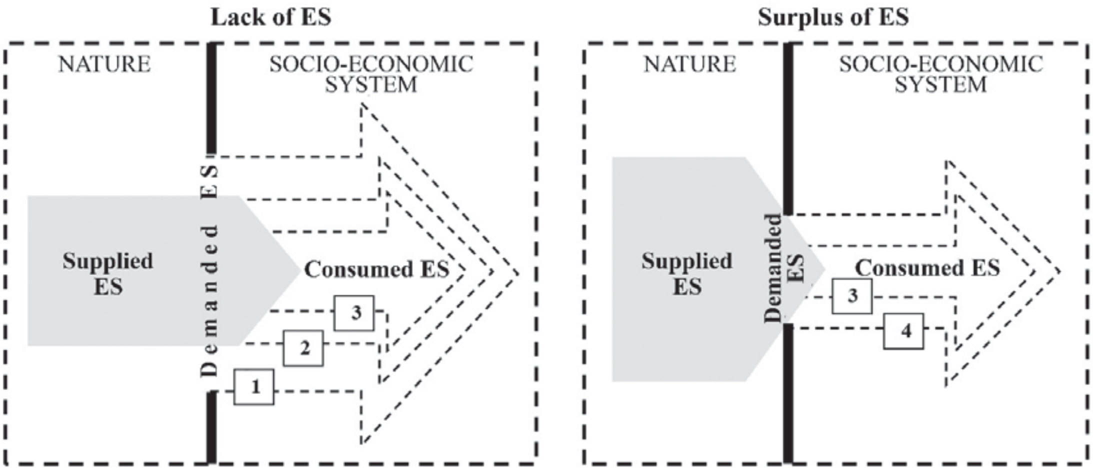


Figure 3. Relationships between supplied, demanded and consumed ES:
1 – consumed ES are equal to demanded ES and exceed supplied ES (possible for provisioning and recreational ES);
2 – consumed ES are less than demanded ES because of lack of supplied volume (all ES);
3 – consumed ES are less than demanded ES because of lack of technological, legal or economic means of ES use (all ES);
4 – consumed ES are less than supplied ES because of low demand for a service when demanded ES is less than supplied ES (all ES)

Ratios and differences of supplied, demanded and consumed ES volumes show the degree of use of ES and the satisfaction of needs for ES (Table 4), which is important information for the assessment of the environmental situation in the regions and interregional comparisons. These indicators are relative indices in the case of ratios and are measured in the same units as ES volumes in the case of differences.

Table 4. Ratios and differences of ES volumes and their application in ES assessment

Ratios and differences of ES volumes	*Application in ES assessment*	*Examples from the Prototype Report*
$V_{supplied} / V_{consumed}$ $V_{supplied} / V_{consumed} \times 100\%$	**The degree of ES use**	The share of fodder eaten by livestock The share of actually purified water volume in the cleaning capacity of terrestrial ecosystems The share of regional carbon stock in managed forests
$V_{supplied} - V_{consumed}$	Unused (if positive) or overdrawn (if negative) ES volume	The unused residual of the annual allowable cut The supplied ecosystem runoff unused by people
$V_{supplied} / V_{demanded}$ $V_{supplied} / V_{demanded} \times 100\%$	**The potential satisfaction of the demand for ES**	The share of toxic gases which can be absorbed by suburban forests
$V_{demanded} - V_{supplied}$	Deficit (if positive) or excess (if negative) of ES	The excess volume of toxic gases over the ecosystem's capacity to trap pollutants The residual volume of polluted runoff which cannot be neutralized by water ecosystems or water ecosystems' untapped opportunities for wastewater treatment
$V_{consumed} / V_{demanded}$ $V_{consumed} / V_{demanded} \times 100\%$	**The actual satisfaction of the demand for ES**	The share of purified runoff in polluted runoff The share of toxic gases absorbed by suburban forests
$V_{demanded} - V_{consumed}$	Volume of unmet need for ES	The residual of polluted runoff unpurified by terrestrial ecosystems (the difference between polluted and purified runoff)

The degree of use of services that were rated in points was calculated as the difference in the scores of supplied and consumed volumes. As mentioned above (section "Methods of ES assessment"), scores show the relative strength of natural factors that determine the ES volume supplied by ecosystems and socioeconomic factors that determine ES use and the demand for them. Score assessments of the degree of ES use and the degree to which the demand for them is met show the ratio of natural factors of service provision and socioeconomic factors of their use in the regions. Negative values indicate that socioeconomic factors that determine the high demand for ES and their intense consumption outweigh natural factors that determine the provision of ES by ecosystems. Positive values indicate that natural factors for ES provision outweigh socioeconomic factors. Zero values indicate regions where socioeconomic and natural factors are more or less equal.

Proportion of the area of natural ecosystems in Russian Federation constituents

The proportion of the area of each region that is occupied by natural ecosystems is determined by the terrestrial ecosystems map (Bartalev et al., 2004). Settlements, agricultural lands, complexes of forests, meadows and steppes with agricultural lands were regarded as areas completely or substantially transformed by man. Other land cover types were recognised as natural ecosystems. Thus, the percentage of the area of each region occupied by natural ecosystems was calculated (Fig. 4). As subsequent analysis showed, however, the methods for identifying ecosystem types used to create the map of Bartalev et al. (2004) somewhat overstate the percentage of natural ecosystems in the regions. For example, this map showed that in the Moscow region natural ecosystems occupy more than 80% of the area, which most likely exceeds the actual figures. In spite of these inaccuracies, we had to use the data of this map, since at the time of the project other data were not available. For future assessments these estimations have to be corrected on the basis of more accurate data on the vegetative cover of Russia.

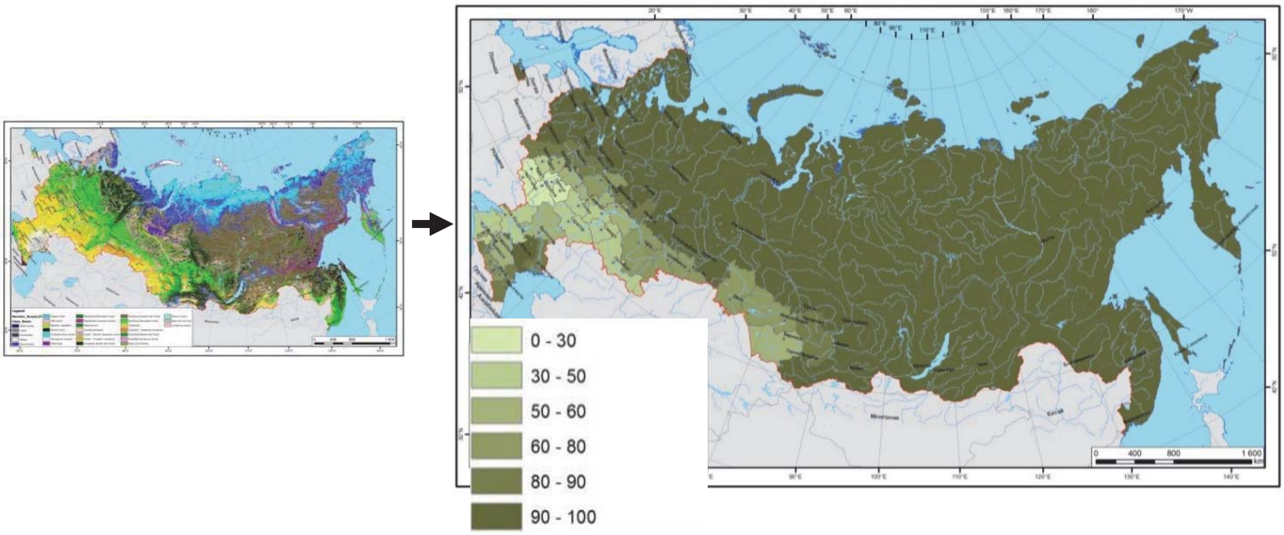


Figure 4. Percentages of the area of RF regions occupied by natural ecosystems (%) obtained from the terrestrial ecosystems map (Bartalev et al., 2004)

ASSESSMENT OF THE MAIN ECOSYSTEM SERVICES IN RUSSIA

PRODUCTIVE SERVICES

Productive (provisioning) ES are defined as benefits to man from harvesting any kinds of biomass from natural ecosystems: timber and non-wood products of terrestrial ecosystems, livestock fodder, products of freshwater ecosystems (primarily fish), game production, and products from harvesting honey from domesticated bees from natural meadows.

Wood production

Wood production is the productive ES that is most economically important for Russia. It is important on all management levels: local (providing the rural population with building materials and firewood), regional (the forest industry plays a key role in the economy of a number of regions) and national.

Data on wood stocks in forests and timber harvesting in Federation constituents are now available. It is therefore possible to directly assess the supplied and consumed volumes of the ES.

The ES volume supplied by ecosystems was assessed by two methods to demonstrate two types of indicators:

– on the basis of the wood stocks in a region (according to the FSSS database "Regions of Russia" (Rosstat, 2013b), Fig. 5a);

– on the basis of the annual allowable cut (Fig. 5b).

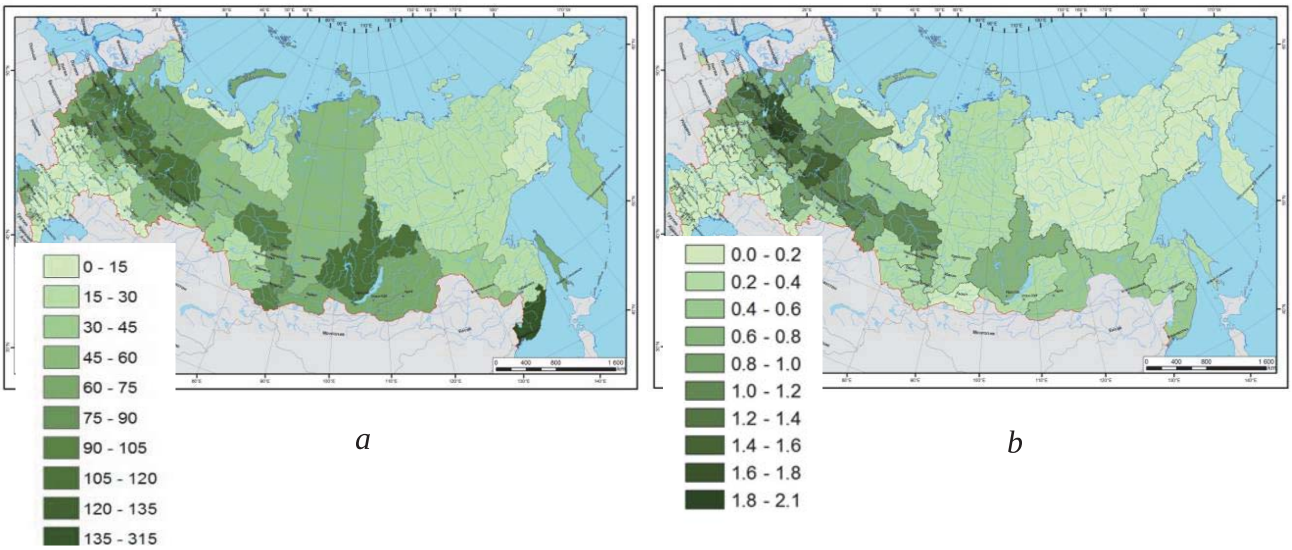


Figure 5. Volume of the wood production ES supplied by ecosystems:
a) wood stocks per unit of area of the region (m^3/ha);
b) annual allowable cut per unit of area of the region (m^3/ha/yr)

It is obvious that the assessment of the supplied ES by the annual allowable cut is more accurate, since it shows the wood volume the harvesting of which will not undermine wood reproduction. This indicator may also be directly compared with the actual amounts of wood taken from ecosystems.

Table 5 describes the trend in the area of forested lands and timber stocks in the forests of Russia from 1988 through 2008. One can note a trend toward the increase in both the area of forests and wood stocks in them.

Table 5. Dynamic of areas and wood stocks in Russian forests (Zamolodchikov et al. 2011)

Category	*Characteristic*	*Accounting year*				
		1988	*1993*	*1998*	*2003*	*2008*
All forests	Area, kha	758715.7	750953.1	763826.0	767473.6	787147.8
	Stock, million m^3	81123.1	79504.3	80797.9	81153.0	82378.2
Commercial forests	Area, kha	388453.0	351095.9	331461.0	329788.9	345449.3
	Stock, million m^3	47595.2	43466.8	40279.4	39629.6	40813.6

Not all forests are accessible for exploitation, however. Main fellings are prohibited in protected forests, including forests of specially protected natural areas. Forests are reserved if they are not to be exploited within the next 20 years. In 2008, 43.9% of forest area and 49.5% of timber stocks were assigned to exploitable (commercial) forests. Note the reduction in the area of exploited forests and wood stocks in them in 1988–2003 (Table 5). This trend is related to the large-scale reclassification of forests as protected. After 2006 the trend reversed itself because of the expedited reclassification of reserve forests as exploitable.

Wood stocks in forests are an important characteristic, but to establish an acceptable amount of forest use one should begin with the productive properties of the forests. According to criteria for sustainable forest use, wood losses as a result of felling must be compensated by an increase in the remaining forests. Therefore, given restrictions with respect to forest use categories, annual allowable cuts, i.e., annual timber felling limits, have been set for territorial forest management units (now forest districts). In 1995 the total annual allowable cut for Russia equaled 545.6 million m^3; in 2004, 495.3 million m^3. This reduction corresponds to a decrease in timber stocks in exploitable forests from 1993 to 2003 (Table 5).

The consumed ES volume is expressed as the volume of timber felled – both commercial and for firewood. The assessment based on the FSSS database "Regions of Russia" (Rosstat, 2013b) is shown in Fig. 6.

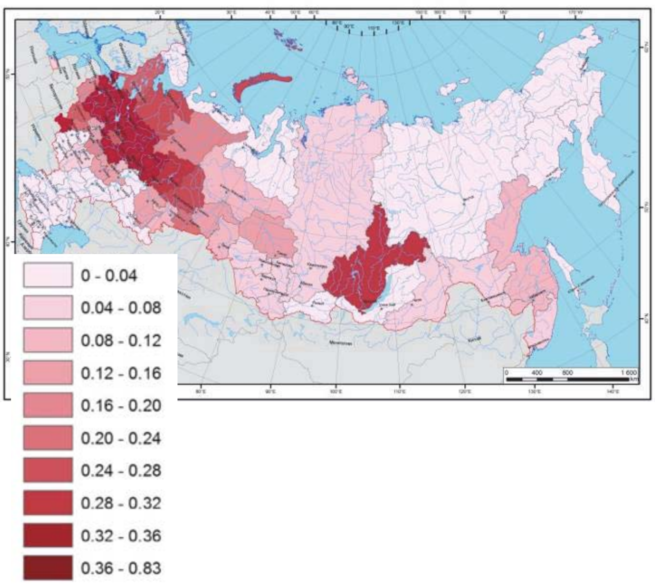


Figure 6. Consumed volume of the wood production ES: timber felling per unit of a region's area (m^3/ha/yr)

The volume of legally felled timber is documented in statistical reports of the Federal Forestry Agency and the Federal State Statistics Service (FSSS). Archival information on the volume of felled timber for 1946–1995 has been published (VNIIClesresurs, 1996). In the 1960s–1980s the total volume of felled timber in Russia came to about 350–370 million m^3 per year (Fig. 7). During the socioeconomic reforms (1990–1998) it dropped to 130–160 million m^3 per year, and in the 2000s it varied in the range of 160–180 million m^3 per year. Annual felling of about 350 million m^3 of timber from the mid 1950s to the late 1980s contributed to the formation of a sustainable forest age class structure, in which the annual amount of timber harvested was compensated by an annual increment. When logging declined, the wood increment began to exceed the harvest, which led to a growth in forest area and in wood stocks (Table 5).

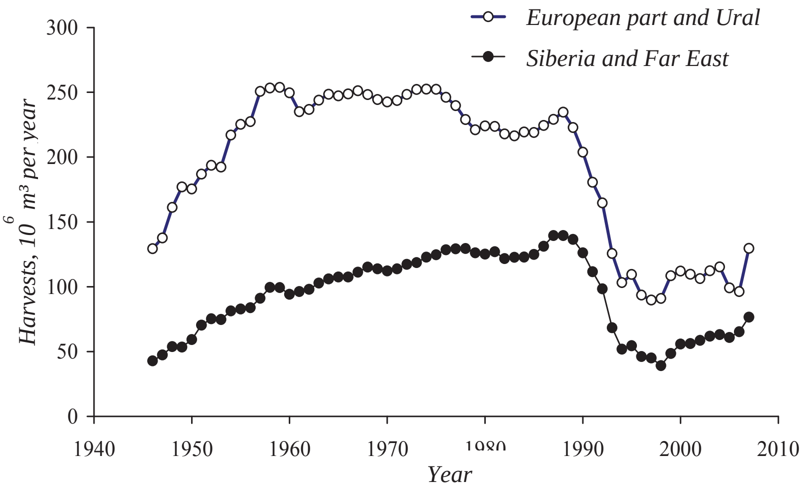


Figure 7. The dynamics of timber felling in the Europe-Ural region and in the Asian part of Russia (Zamolodchikov, 2012)

The graphs shown in Fig. 7 represent legal fellings in Russia. A full assessment of the consumed ES volume requires the addition of illegally harvested timber, the amount of which can usually be defined only on the basis of indirect attributes. If illegal forest harvesting by the local population for its own needs comes to about 2% (Gryaznov et al., 2011), then, according to various estimates, legal entities illegally fell 10–25% of the total amount of timber (Ptichnikov & Kuritsyn, 2011) or more. For example, in 2009 timber felling in the Northwest Federal District in violation of felling codes constituted 35% of total felling (Gryaznov et al., 2011). In the early 2000s, the amount of commercial timber of dubious origin in Krasnoyarsk Krai came to 14–16% of the total timber consumption and export; in Irkutsk Region, 9–18%; and in Khabarovsk Krai, 35% of timber consumption and export or 56% of the official felling amount (Kotlobay et al., 2006).

Comparison of the supplied and consumed ES volumes

As an indicator of the degree of the use of this ES, we assessed the unused remainder of allowable cut per unit of a region's area (the difference between annual allowable cut and timber felled), i.e., the unused portion of the supplied ES ($V_{supplied} - V_{consumed}$). This indicator was largest in the forest regions of European Russia and West Siberia, and in only one region (Rostov Oblast) did timber felled exceed the allowable cut, i.e., the consumed ES volume exceeded the supplied volume (Fig. 8) for 2012 according to the Federal Forestry Agency.

Data required to assess and monitor the ES

To assess the supplied volume: annual allowable cut, which should account for the objective of preserving biodiversity and the entire set of ecosystem functions of forests.

To assess the consumed volume:

– the volumes of legal felling of commercial timber and firewood;

– credible volumes of illegal cuttings.

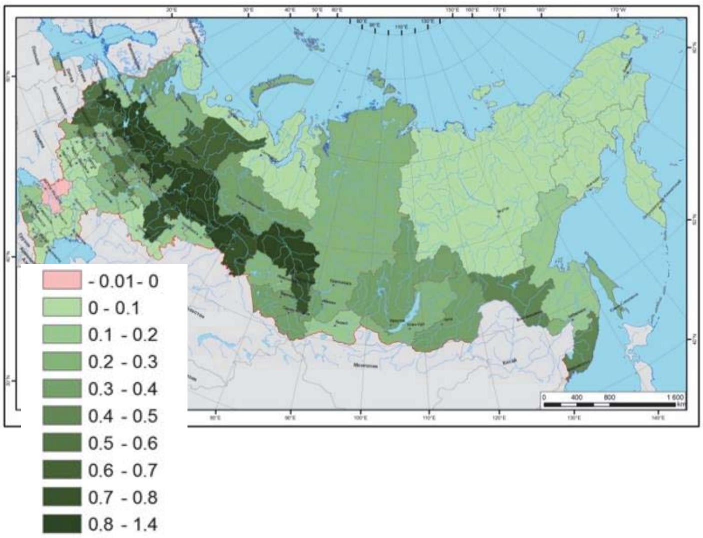


Figure 8. Volume of unused allowable cut in 2012 (m^3/ha). Negative values indicate that timber felling exceeded the allowable cut

Non-wood production of the forest and other terrestrial ecosystems

Non-wood resources of the forest and other terrestrial ecosystems comprise a great variety of products primarily of plant origin, excluding wood raw materials for manufacturing. Non-wood products include stumps and roots of trees and shrubs, brushwood, wood forage, fir, pine, and spruce boughs, Christmas trees, edibles (berries, nuts, wild fruits), medicinal, nectar-bearing, technical and other economic groups of plants and edible mushrooms. The value of non-wood resources to society is significant. Part of these resources people enjoy free of charge, for example by visiting forests to collect mushrooms and berries for their own needs. Another part is harvested for sale and successfully monetized. Non-wood resources are not treated as separate resources, but are classified as byproducts of forest use. Their value in certain categories of forests may, however, exceed the value of the timber (Laptev, 2009). For city dwellers, harvesting mushrooms and berries has not only commercial but also recreational value.

In the second half of the 1980s, the total mean multiyear harvest of edible fungi in Russian Federation was about 8,000 tons, the maximum annual harvest reached more than 16,000 tons. The total mean multiyear harvest of cranberries was more than 5,000 tons, the maximum annual harvest reached more than 10,000 tons. In the 1990s, the system of centralized procurement collapsed, and harvest volumes were minimal. However, at present, the anthropogenic load on wild plants and mushrooms has increased dramatically, and in some regions their resources are being used almost completely. Near populated areas and highways, many species are overexploited (Egoshina, 2005).

Assessment of non-wood resources is part of forestry management, but these resources are classified as byproducts of forest use, and detailed records are not kept. Inasmuch as government statistics on the procurement and consumption of non-wood forest resources are currently absent, in our work we used estimations of the harvest and stocks of mushrooms and berries in the second half of the 1980s from the study by T. L. Egoshina (2005).

The ES volume supplied by ecosystems was assessed on the basis of mushroom and berry stocks in nature. Examples for mushrooms and lingonberries *(Vaccinium vitisidaea)* are shown in Fig. 9.

The consumed ES volume corresponds to the volume of product harvested. Examples for mushrooms and lingonberries are shown in Fig. 10.

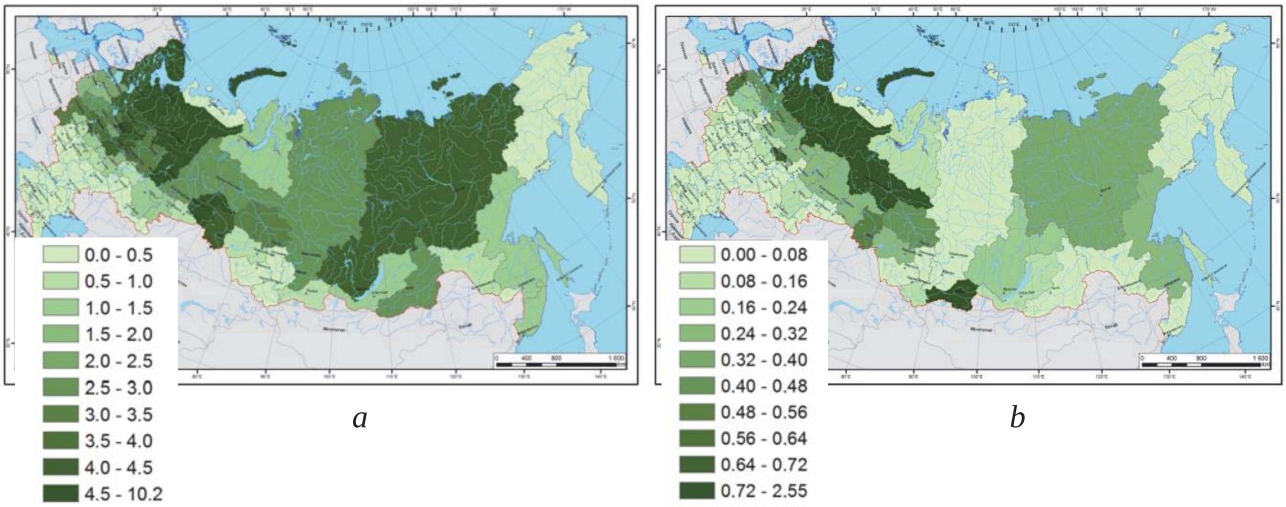


Figure 9. Examples of the supplied volume of non-wood production ES:
a) biological stock of edible mushrooms per unit of area of a region (kg/ha);
b) biological stock of lingonberry fruits per unit of area of a region (kg/ha)

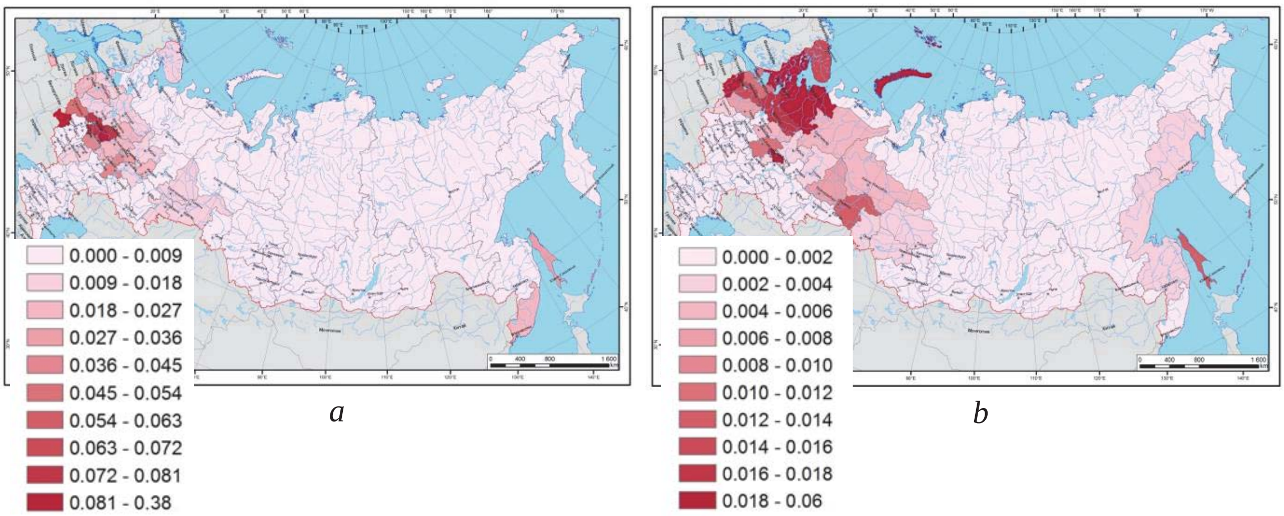


Figure 10. Examples of the consumed volume of non-wood production ES:
a) mushroom harvest per unit of area of a region (kg/ha/yr);
b) harvest of lingonberry fruits per unit of area of a region (kg/ha/yr)

Comparison of the supplied and consumed ES volumes

The degree of ES use was assessed using harvested bioresources as a proportion of their stock in nature (by weight). As shown in Fig. 11a, the percentage of harvested mushrooms does not exceed 10% of their stock. It is highest in a number of regions of the Central Federal District and of south Siberia. It is obvious, however, that locally this resource may be used far more intensely. The harvest of lingonberries in the majority of regions is also in the single digit percentages (Fig. 11b). The largest volumes are harvested in Smolensk Oblast (23% of the biological stock), Kamchatka Krai (14%), and Magadan (9.8%), Sakhalin (9.8%), and Novgorod (7.5%) regions.

Data required to assess and monitor the ES

To assess the supplied volume: volumes of the allowable harvest of all basic kinds of non-wood resources, considering objectives for their sustainable reproduction and the preservation of biodiversity and of the entire set of ecosystems functions.

To assess the consumed volume: volumes of legally and illegally harvested non-wood resources (in particular in protected areas).

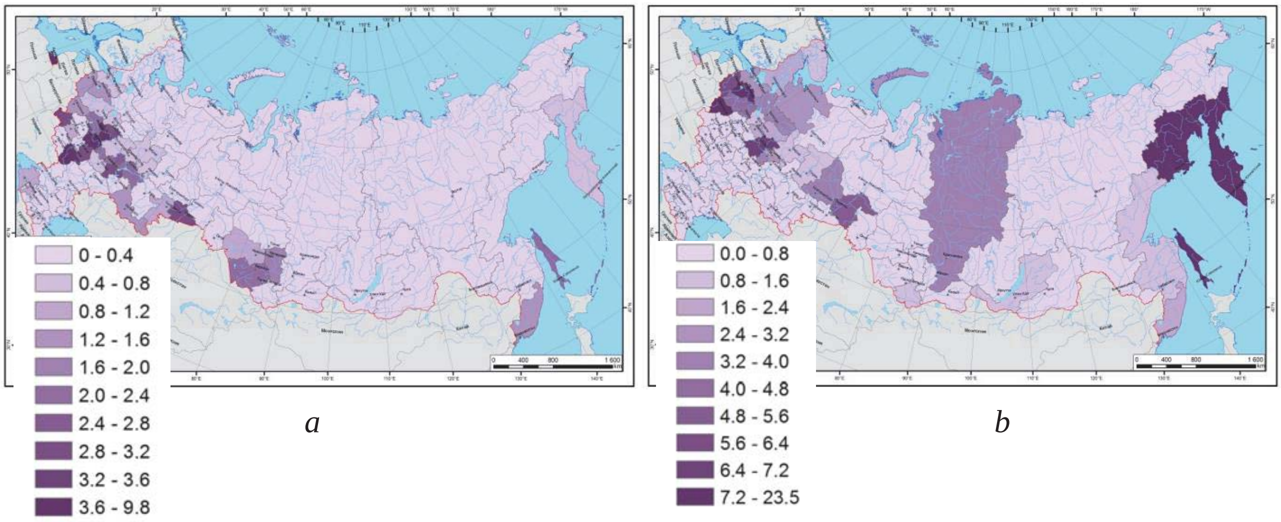


Figure 11. Examples of the degree of non-wood production ES use:
a) harvested mushrooms as a percentage of the biological stock (%);
b) harvested lingonberries as a percentage of the biological stock (%)

Production of fodder on natural pastures

This ES is important primarily on the local and regional levels of management, since it provides the fodder resources of hayfields and pastures for local communities, including the indigenous reindeer herding population of the North.

Russia does not have a uniform system for collecting data on the productivity of natural pastures and the consumption of their resources. For this reason, the assessment of this ES was based on the conversion of data from the FSSS database "Regions of Russia" (Rosstat, 2013b) and digital maps from "Land Resources of Russia" (Stolbovoi & McCallum, 2002).

The ES volume supplied by ecosystems equals the quantity of fodder plant biomass that natural pastures annually produce. This indicator was assessed in the following way (Fig. 12).

1. Four zones of natural pasture use (reindeer herding, livestock grazing on plains, livestock grazing in mountains, and relative extensive farming) were identified using the map of agricultural regions from the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002).

2. The production of natural pastures (kgC/m^2/yr)[1] was determined within these zones using the map of net primary production (kgC/m^2/yr) from the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002).

3. The productivity of the pastures within the regions (kg/ha/yr of fodder unit) was determined given that 1 kg of meadow hay equals 0.5 fodder units (Mesjatz, 1989), and 2 kg of dry hay contains 1 kgC. Therefore 1 kgC corresponds to 1 fodder unit. The result is a map of the number of fodder units that natural pastures produce per year per 1 ha of a region's area, which is considered an indicator of the ES volume supplied by ecosystems.

[1] Hereinafter, weight measures with the symbol "C" (kgC, tC, GtC, MtC) denote the weight of carbon contained in biomass, wood or soil.

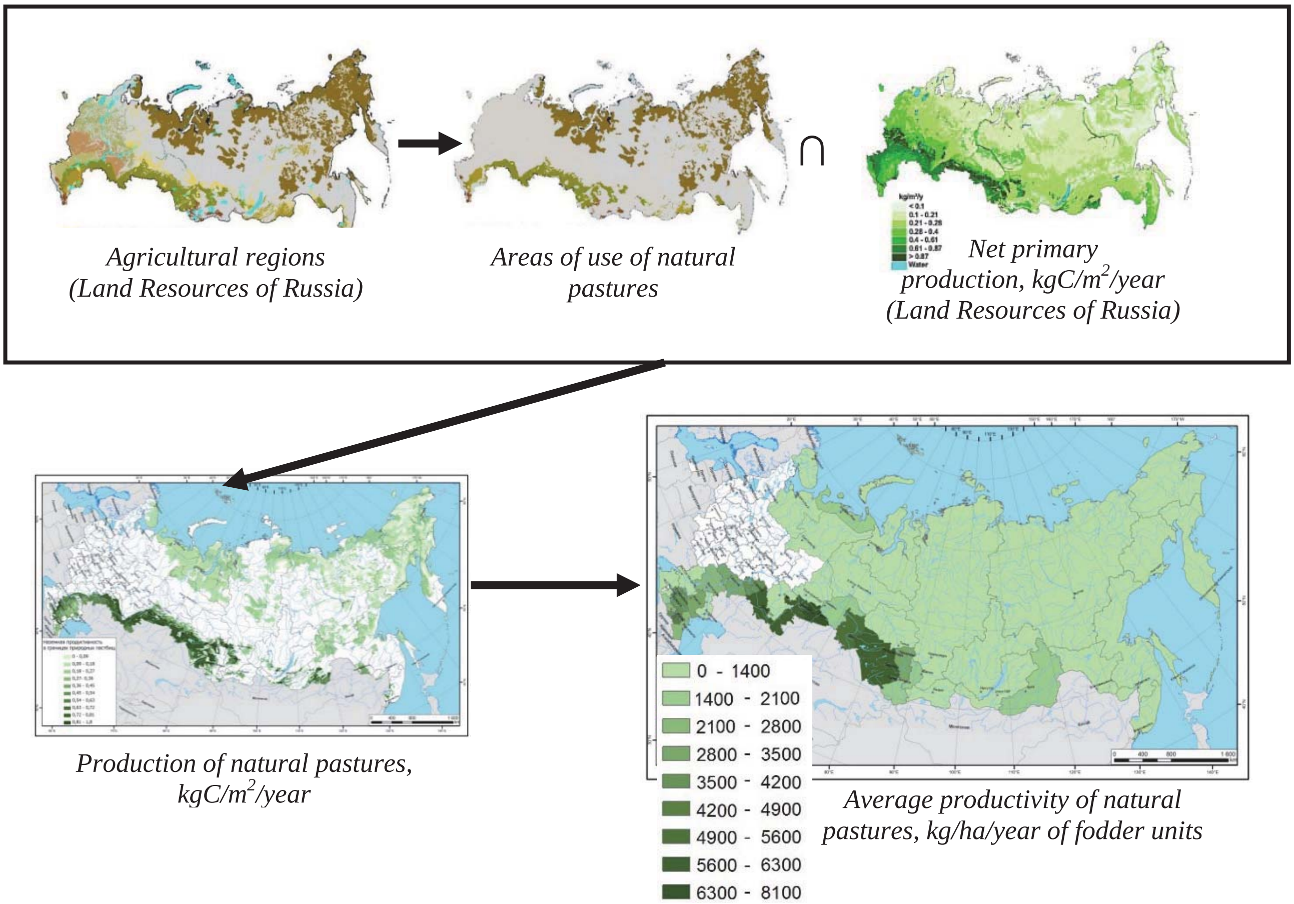


Figure 12. Supplied volume of the ES of fodder production on natural pastures – mean productivity of natural pastures per unit of area of a region (kg/ha/yr of fodder unit) and how it was determined. "0" (white) corresponds to regions in which livestock mainly don't graze on natural pastures according to the database "Land Resources of Russia"

The consumed ES volume is determined by the amount of fodder from natural pastures that is eaten by domestic livestock. The estimate was carried out as follows (Fig. 13).

1. The numbers of livestock units in the regions were determined by adding up the numbers of cattle, sheep, goats, deer and reindeer according to the FSSS database "Regions of Russia" (Rosstat, 2013b) with the following multipliers: 1 for cattle, 0.1 for sheep and goats, 0.6 for deer and reindeer[2].

2. The percentage of livestock eating fodder from natural pastures was determined. On the basis of the previously identified zones of natural pasture use, the percentage of area on which livestock feeds on natural pastures was calculated for each region. This figure was used as an indirect estimate of the percentage of livestock that consume natural fodder.

3. The amount of fodder eaten by livestock from natural pastures was determined by multiplying the number of livestock in the region, the percentage of livestock grazing on natural pastures and fodder consumption rates per livestock unit (2900 kg of fodder units per year)[3]. Thus, the indicator of consumed ES was assessed.

[2] www.gks.ru/free_doc/new_site/metod/sx/metkor_y.doc

[3] www.gks.ru/bgd/regl/b13_38/Main.htm

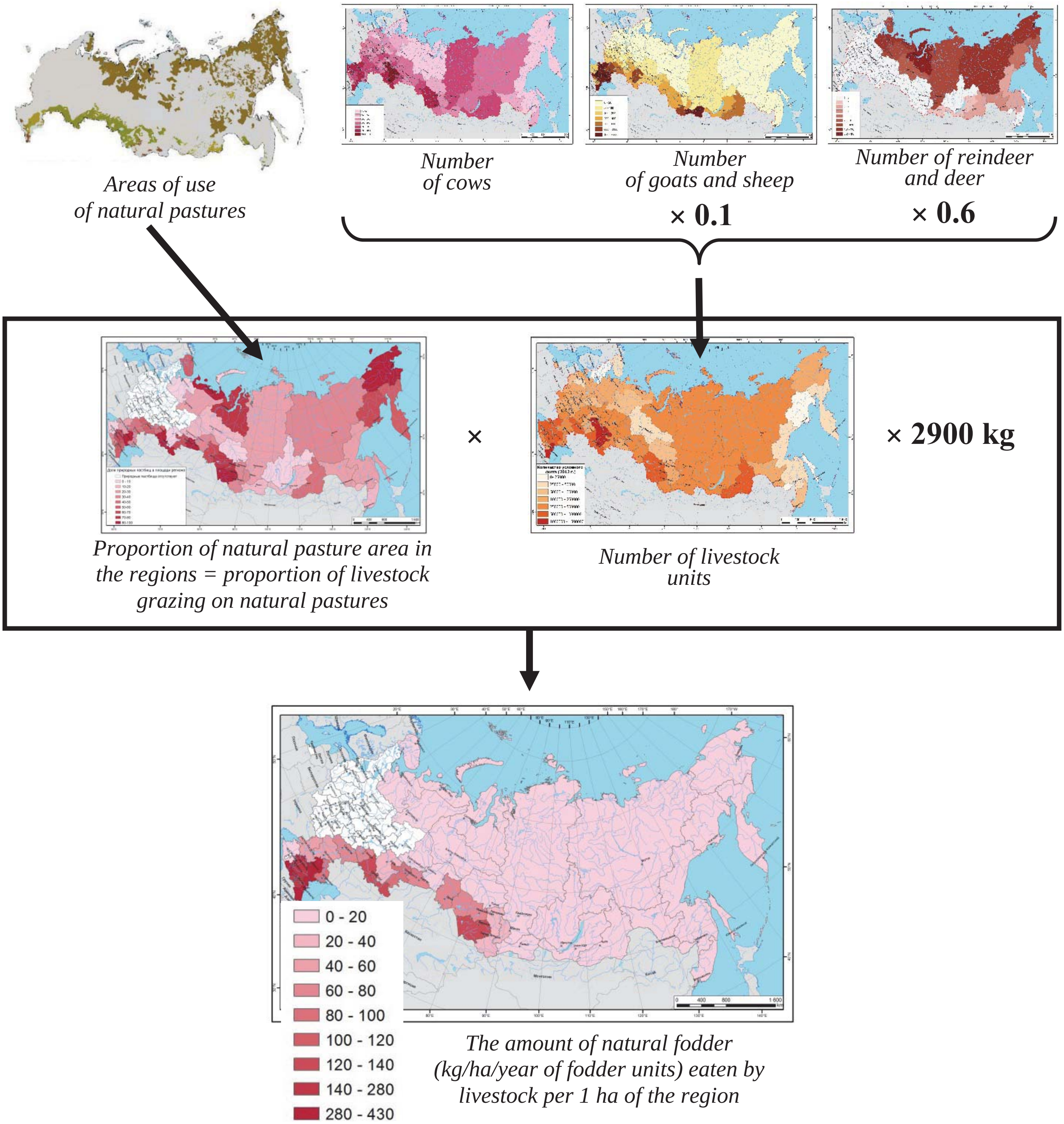


Figure 13. Consumed volume of the ES of fodder production on natural pastures – amount of natural fodder eaten by livestock per 1 ha of a region's area (kg/ha/yr of fodder units) – and how it was determined. "0" (white) corresponds to regions in which livestock mainly don't graze on natural pastures according to the database "Land Resources of Russia"

Comparison of the supplied and consumed ES volumes

As shown in Fig. 12 and Fig. 13, the consumed ES volume is far less than the supplied volume. In this instance, the use of the unconsumed ES volume as an indicator (by analogy with the wood production ES) is inappropriate, since its distribution will largely replicate the supplied ES volume. The percentage of natural fodder eaten by livestock was therefore used as the indicator of the degree of ES use (Fig. 14). Throughout a large portion of the country this figure does not exceed 4%; only in the north Caucasus regions and Kalmykia is it between 6 and 19%.

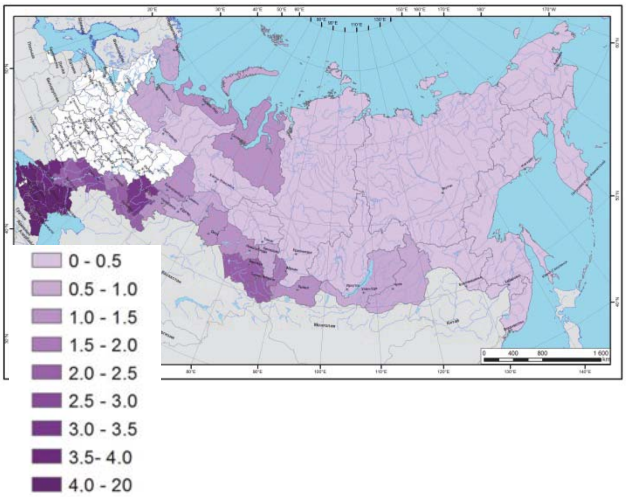


Figure 14. Percentage of natural fodder eaten by livestock (%). White corresponds to regions in which, according to the database "Land Resources of Russia", livestock mainly do not graze on natural pastures

The results are obviously inaccurate and demonstrate only one possible methodological approach to assessing the ES. Moreover, a correct assessment of the consumed ES volume will require more accurate data on the area of the natural pastures and on the livestock grazing on them. The agricultural regions map from the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002) that we used reflects only the relative dominance of a particular type of agriculture in the zones identified by the authors, which does not mean that other types (proportions of which are unknown) are not present. Thus, natural pastures were not considered in regions where grain or livestock farming prevails. These regions were classified as having no natural pastures (white in Fig. 14), although it is obvious that a certain portion of livestock in them graze on natural pastures.

Overall, the resulting assessment seems significantly understated. Most likely the usage of pastures in black soil regions and the forest belt of European Russia (which are classified as regions without pastures) comes to a few percent, while in Kalmykia and Dagestan it may be close to 50%, which is the upper limit for the possible mean multiyear removal of terrestrial primary production.

Data required to assess and monitor the ES

To assess the supplied volume:

– the area of natural pastures and hayfields in the regions (they must be mapped);

– data on the productivity of natural pastures and hayfields;

– the amount of biomass that can be removed from pastures and hayfields without detriment to their sustainability and ecosystem functions (the "capacity" of pastures and hayfields).

To assess the consumed volume:

– number of livestock in the region consuming natural fodder;

– consumption of natural fodder by different species of livestock.

Production of freshwater ecosystems, primarily fish

Statement of the task of ES assessment

A large portion of Russia's water bodies are exposed to various anthropogenic impacts. The ecosystems of the majority of major rivers have been altered by hydraulic engineering structures. For example, as a result of the construction of canals in the last 200 years the Volga River is linked with the Black, Caspian, White and Baltic seas and has 9 major reservoirs. Hydraulic construction radically transformed river ecosystems and the diversity, quality and quantities of fish resources. The development of reservoirs led to an increase in primary production and the production of a number of commercial fish species and to an expansion of their spawning grounds, but many other species (e.g., sturgeons) lost access to their spawning grounds. Fluctuations in water level (especially in the spawning season) typical for reservoirs created unstable conditions for fish reproduction. A similar situation, but to a lesser degree, is typical for the basins of the Ob, Yenisei and Amur rivers. The construction of canals between basins contributed to the invasion of alien fish species and other aquatic life.

The USSR was a world leader in commercial fishing with a total annual catch of 11.5 million tons. But after 1991 the fishing industry experienced two major declines. The first (1991–1994) was related to economic problems and the disintegration of the USSR. The second (1997–2004) was caused by a decline in fish stocks and ineffective laws on fishing. Recently the total catch in Russia, including in freshwater, has grown a little. In 2011, the total catch in all freshwater bodies was 178,000 tons. The maximum catch (55%) was obtained in rivers, 29% in lakes and 16% in reservoirs. The composition of the catch over the last 20 years has changed substantially. The stocks of valuable commercial species such as sturgeon, pike perch, bream, catfish, hake, gar and asp have dropped sharply. Today anadromous species make up a large part of Russian freshwater catch.

One of the major factors in the contraction of freshwater fish stocks is overfishing, caused by illegal, unreported and unregulated fishing (IUU fishing). For example, IUU fishing for Volga-Caspian sturgeons many times exceeds legal fishing. The IUU fishing for other fish species is usually from 20 to 100% of the official catch. In some places, recreational fishing accounts for a significant portion of IUU fishing. Local fishing regulations in many regions of Russia allow recreational fishers to use any kind of fishing gear, including nets and traps. More than 15 million people take part in this fishing. Many people in the regions use fish as their primary source of food because of current economic problems (unemployment, low wages).

The ES volume supplied by ecosystems corresponds to fish stocks.

The consumed ES volume corresponds to the fish catch.

It was impossible to estimate the volume of the service of producing freshwater ecosystems for Russia's regions on the basis of open source statistics. Published statistical abstracts contain data on marine fish stocks and catches or on categories of freshwater bodies, but they are not broken down by Federation constituents, which we needed to assess this ecosystem service.

Data required to assess and monitor the ES

In a more detailed analysis the service may be assessed on the basis of information on the stocks and commercial harvesting of basic species of freshwater bioresources from basin administrations of the Federal Agency for Fishery and sectoral research organizations.

The following materials are needed to develop a comprehensive system for assessing and monitoring the ecosystem service:

– data on the commercial harvest of the entire range of freshwater bioresources;

– credible information on IUU fishing;

– an assessment of bioresource stocks by modern methods (hydroacoustic surveys, mathematical modeling of changes in fish populations, etc.).

Game production

Game products (fur, meat, trophies, hides, feathers, down, etc.) are obtained as a result of game management, commercial, recreational and trophy hunting, game farming, etc. Hunting and game management are important conservation and socioeconomic fields for Russia. Russia has the world's largest hunting grounds (about 1.5 billion ha). Game animals (228 species) are an integral part of the natural environment and biodiversity. Tens of millions of people engage in recreational hunting and fishing to one degree or another. For hundreds of thousands of people, especially the indigenous peoples of the North, hunting and fishing are the basis of existence and a traditional way of life. More than 80,000 people are permanently or temporary engaged in game management in Russia, and the total annual trade turnover is estimated at RUB 80–100 billion (Strategy for the development of the hunting industry of the Russian Federation until 2030, 2014).

The annual production of the most abundant game animals is tens and hundreds of thousands of individuals. For example, in the season of 2013/14 the production was about 40 thousand wild reindeer, 56 thousand wild boars, 28 thousand moose, 36 thousand roe deer, 14 thousand beavers, almost

237 thousand sables, 167 thousand squirrels, 176 thousand foxes, 155 thousand mountain hares, 200 thousand brown hares. In 2014, at the St. Petersburg International Fur Auction, more than half a million sable skins were sold (Ministry of Natural Resources and Environment of the Russian Federation, 2015a).

Estimates of the volumes of this ES are based on data from the statistical compendium "The state of game resources in the Russian Federation in 2008–2010 (Lomanova, 2011).

The ES volume supplied by ecosystems was assessed based on the population of game animals. Figure 15 presents examples for the elk separately and for four ungulates (red deer, elk, roe deer, boar) as a group. It is obvious that a more correct assessment of the supplied ES volume is given by the size of the annual harvest of animals that does not undermine their reproduction in the wild and does not disrupt the population structure. These corrections must be incorporated into future estimates.

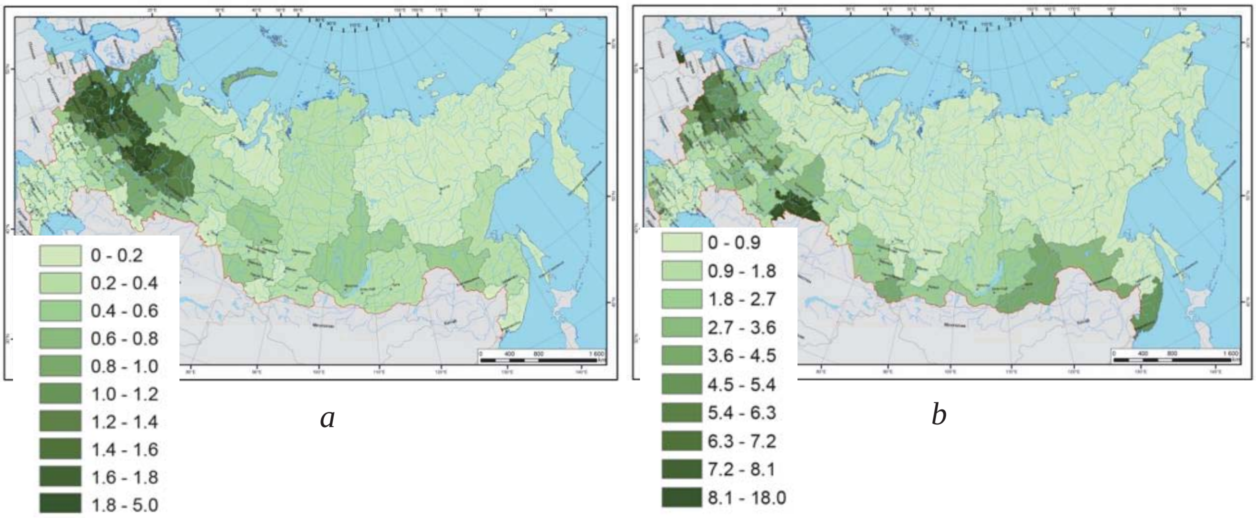


Figure 15. Supplied volume of the game production ES: a) density of elk (individuals/ha); b) total density of four ungulates (red deer, elk, roe deer, boar, individuals/ha)

The consumed ES volume equals the catch of game animals. Examples are shown in Fig. 16.

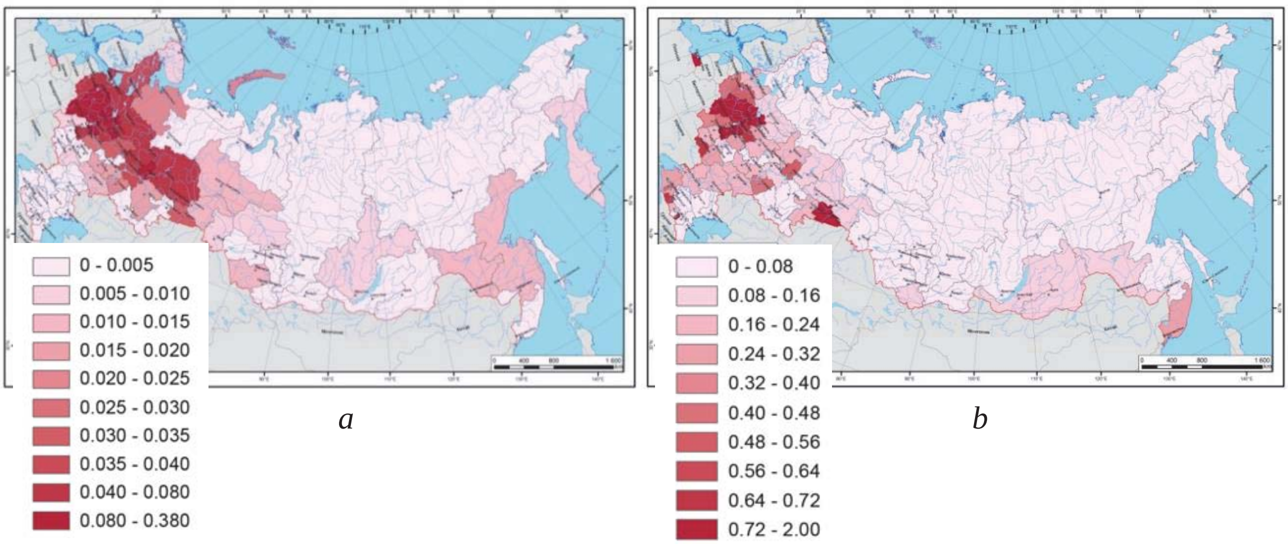


Figure 16. Consumed volume of the game production ES: a) catch of elk per unit of area of a region (individuals/ha/yr); b) total catch of four ungulates (red deer, elk, roe deer, boar) per unit of area of a region (individuals/ha/yr)

Comparison of the supplied and consumed ES volumes

The lack of data on the allowed catch of game animals, i.e., of a direct assessment of the supplied volume of game production ES and the lack of credible information on IUU hunting allows only a relative comparison of the supplied and consumed ES volumes. Figure 17 shows the percentages of shot elks and ungulates (total for 4 species). This indicator is a few percent for the elk; for the four ungulates it is far higher (up to 30% in regions in the southern European part of the country), which is attributable to the high intensity of boar hunting.

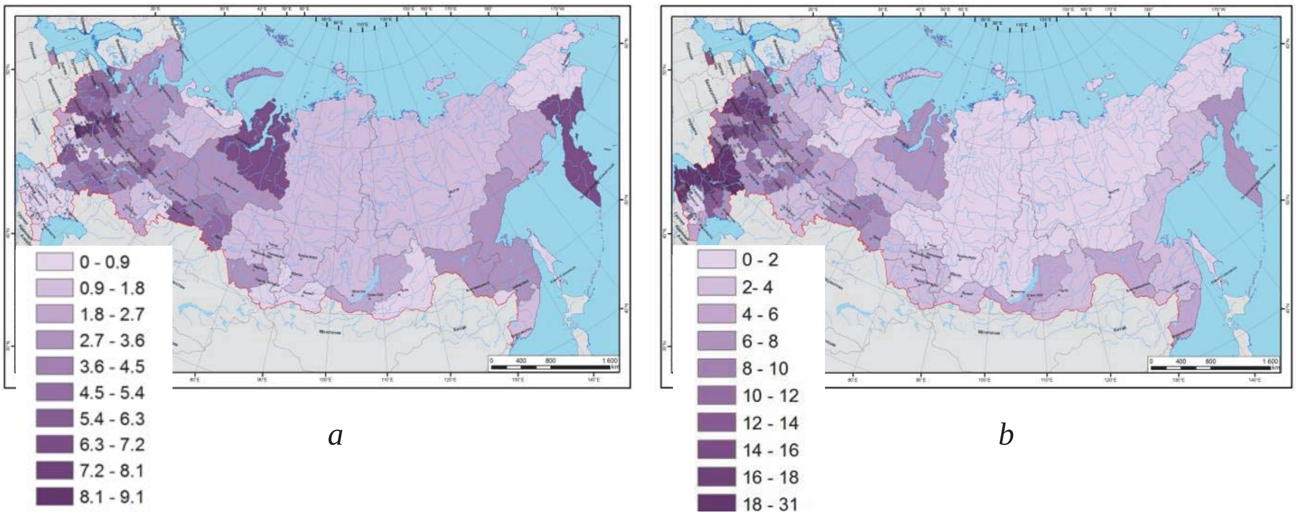


Figure 17. Examples of the comparison of the supplied and consumed volumes of the game production ES: a) shot elk as a percentage of the population (%); b) shot number of four species of ungulates as a percentage of the total population (%)

Data required to assess and monitor the ES

To assess the supplied volume: volumes of the allowable harvest of game animals.

To assess the consumed volume: volume of legal hunting; credible volumes of IUU hunting.

Production of honey in natural areas

Statement of the task of ES assessment

The ES of honey production includes only honey that was collected in natural areas (meadows, steppes, forests). This honey yield is essentially determined by the biomass that was produced by the natural ecosystems and taken from them by domestic bees.

The ES volume supplied by ecosystems can be assessed as the potential amount of honey that can be collected in natural areas. Quantification of this indicator requires knowledge of the size of the areas from which honey is collected and their potential productivity with respect to honey.

The consumed ES volume is the amount of honey collected from natural areas. The FSSS database “Regions of Russia” (Rosstat, 2013b) contains information on the total amount of honey produced in the regions of Russia. But assessing the ecosystem service requires extracting the amount of honey collected only in natural areas from this quantity.

ENVIRONMENT-FORMING SERVICES

Climate and atmosphere regulation

Biogeochemical climate regulation

Regulation of greenhouse gas flows

Russia does not keep an official comprehensive record of the carbon balance in terrestrial ecosystems. The exception is forests, reports on which are generated by the Federal Service for Hydrometeorology and Environmental Monitoring and are submitted to agencies of the UN Framework Convention on Climate Change (UNFCCC). Greenhouse gas sinks in managed forests are included in the national greenhouse gas budgets under the UNFCCC and the Kyoto Protocol. Every year the Russian Federation submits the appropriate reports to UNFCCC agencies. Tha area of managed forests in Russia is about 700 million ha (about 73% of the total forest area).

Estimates of the carbon sink in Russian forests by different authors vary within 100–800 MtC/yr (Zamolodchikov, 2012; Zamolodchikov et al., 2013a; Moiseev, Filipchuk, 2009; Dolman et al., 2012). Estimates of the annual carbon sink in managed forests after 2000 range from 160 to 190 MtC/yr (National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2011, 2013a).

The contribution of different types of ecosystems to the sequestration of atmospheric carbon was estimated (Table 6) by the International Institute for Applied Systems Analysis (IIASA) (Dolman et al., 2012). The cited study presents a number of estimates based on different methodological approaches (terrestrial information system, generalization of gas exchange measurements, global vegetation models, inversion calculations) that yield a range of values for the carbon sink in Russia's terrestrial ecosystems from 199 to 761 MtC/yr. We used the most spatially detailed set of estimates from this study (Table 6) to obtain values for the regions.

Table 6. Contribution of different ecosystems to CO_2 sequestration (after Dolman et al., 2012, with simplifications). Positive values correspond to carbon absorption by ecosystems, negative to its release

Ecosystem type	*Area, million ha*	*Carbon balance, MtC per year*
Forests	820.9	691.9
Wetlands	144.6	53.4
Abandoned arable lands	29.9	46.1
Meadows	24.0	28.5
Cropland and pastures	145.8	25.0
Fallows	19.0	4.2
Grass-shrub ecosystems	315.7	–15.0
Burned lands	23.7	–20.8
Open forests	85.1	–40.3
Other lands, including water bodies	101.1	–11.8
Total ecosystems of Russia	1709.8	761.2

Forests make the largest contribution to carbon sequestration, not only because of their large area, but also because of their current condition. Russia's current forest cover largely consists of secondary forests of different ages, which makes it highly active in atmospheric carbon sequestration. According to other estimates (Zamolodchikov et al., 2013b), the carbon sink in Russia's forests in the early 1990s was about 50 MtC per year. It grew to 250 MtC per year by the mid-1990s and with some variations remained on this level until 2005, after which it started to decline. This trend is related to the trend in timber cutting, which fell sharply (almost threefold) during the socioeconomic reforms. The drops in carbon sequestration by forests in 1998 and 2003 are explained by the high level of forest fires in Asiatic Russia. The significant difference in these estimates of the carbon sink in Russia's forests in Table 6 is related to the difference in methodological approaches, which demonstrates the need to revise them and select a single basis for assessing and monitoring this ES in Russia.

Grass and shrub ecosystems (primarily zonal and mountain tundras), which rank second in area, are a weak carbon source, which is related to the adverse impact of warming.

Wetlands are a significant carbon sink. Many wetland ecosystems have not yet completed their long successional sequence after the last glaciation. The modern atmospheric carbon sink in peat bogs is 37.6–53.4 MtC/yr (Dolman et al., 2012; Inisheva et al., 2013) depending on the source.

Per unit of area, abandoned arable lands absorb carbon most actively. A large-scale abandonment of arable lands in the non-black earth zone of European Russia occurred in the 1990s during the socioeconomic reforms. Ecosystems recovering on land retired from agriculture use now absorb 43 MtC per year (Kurganova et al., 2014).

The total multi-year carbon sink potential with long-term fixation in steppe ecosystems is estimated at 75 MtC/yr (Smelyansky, 2012). It must be noted that the productivity of steppe ecosystems may vary more than tenfold depending on the degree of wetting and other climate factors. Therefore, their carbon functions are also very different.

The ES volume supplied by ecosystems was assessed on the basis of carbon balance data according to the IIASA land information system (Dolman et al., 2012; Shvidenko & Shchepashchenko, 2014). Figure 18a shows the annual absorption or release of carbon in the regions.

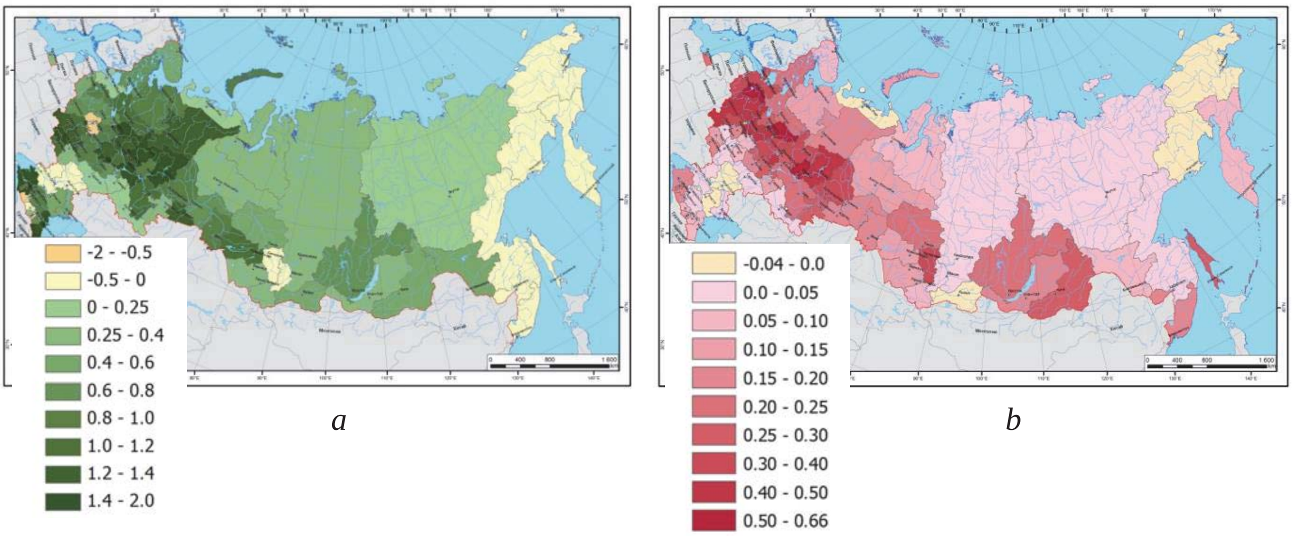


Figure 18. Supplied and consumed volumes of the ES of regulating greenhouse gas flows: a) carbon balance of terrestrial ecosystems per unit of area of a region, tC/ha/yr; b) carbon balance per 1 ha of managed forests, tC/ha/yr. Positive values correspond to carbon absorption, negative ones to carbon emission

The consumed ES volume was assessed according to current best practices. This indicator is governed by the amount of CO_2 absorbed by forests as a result of their purposeful management by man for use on carbon markets. Russia has no commitments in the second Kyoto Protocol round and is not participating in international carbon markets such as emissions trading or joint carbon projects. Nor has a national carbon market been developed. Nonetheless, responsibility for maintaining carbon sinks in managed ecosystems was included in the UNFCCC. The Russian greenhouse gas inventory report (National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for

1990–2011, 2013a) includes estimates of the carbon budget for managed forests covering 600 million ha. An appendix to the report (National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2011, 2013b) contains data on the carbon balance in Russia's managed forests, which can be considered the consumed ES volume since Russia officially declares the existence of management in this forest category for UNFCCC purposes (Fig. 18b).

Comparison of the supplied and consumed ES volumes

The degree of ES use was assessed using the percentage of the regional carbon balance attributed to managed forests (Fig. 19).

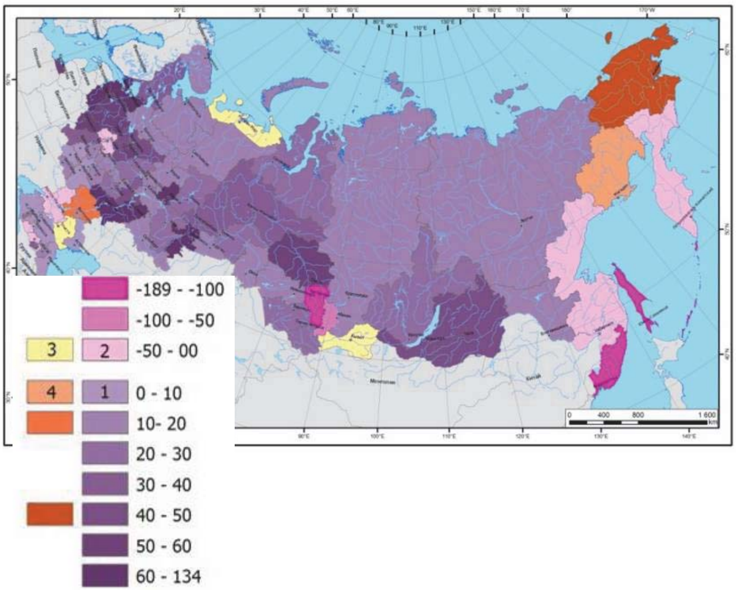


Figure 19. The degree of use of the ES of regulating CO_2 flows: percentage of the regional carbon balance attributed to managed forests:
1 (purple spectrum) – positive balance in terrestrial ecosystems and managed forests;
2 (pink spectrum) – negative balance in terrestrial ecosystems, positive balance in managed forests;
3 (yellow spectrum) – positive balance in terrestrial ecosystems, negative balance in managed forests;
4 (orange spectrum) – negative balance in terrestrial ecosystems and managed forests

The resulting estimate divides the regions into four groups depending on the sign of the carbon balance in all terrestrial ecosystems (including all forests) according to the IIASA land information system and, separately, in managed forests according to the Russian greenhouse gas inventory report.

1 – (purple spectrum in Fig. 19) – the carbon balance both in terrestrial ecosystems and in managed forests is positive, i.e., both managed forests and terrestrial ecosystems absorb carbon. This group includes the majority of regions in Russia. The darkest color shows the regions where most of the balance is attributed to managed forests (in Leningrad Oblast the balance for managed forests exceeds that for all terrestrial ecosystems, which is likely explained by differences in estimation methods used).

2 – (pink spectrum in Fig. 19) – the carbon balance of terrestrial ecosystems is negative (they release carbon), but the balance of the managed forests is positive (they absorb carbon). The brightest color (Sakhalin and Kemerovo oblasts, Primorsky Krai) corresponds to cases where the amount of carbon absorbed by managed forests exceeds the amount of carbon released by all terrestrial ecosystems.

3 – (yellow area in Fig. 19) – the carbon balance of terrestrial ecosystems is positive (they absorb carbon), but the balance in managed forests is negative (they release carbon). Kalmykia, Tyva and the Nenets Autonomous Okrug are in this group.

4 – (orange spectrum in Fig. 19) – the carbon balance both in terrestrial ecosystems and in managed forests is negative. This group includes Chukotka and the oblasts of Magadan and Volgograd.

Data required to assess and monitor the ES

To assess the supplied volume:

– amounts of CO_2 absorbed and released by terrestrial ecosystems;

– amounts of methane and other greenhouse gases absorbed and released by terrestrial ecosystems.

More adequate consumption of this ES requires that climate regulation management be applied not only to managed forests, but also to other types of ecosystems that absorb significant amounts of carbon.

Storage of carbon accumulated by natural ecosystems

Carbon stores in living and dead organic matter in the Russian forests total 49.4 GtC.

Russia's peat bogs occupy more than 140 million ha and are the most significant terrestrial reservoir of carbon. The total carbon stock deposited in Russia's peat bogs comes to 100.9–154.6 GtC (Vompersky et al., 1999; Efremov et al., 1998; Joosten, 2009; Stolbovoi, 2002). Steppes, other grassland ecosystems and their anthropogenic modifications (including fallows) in black earth and dark-chestnut soils occupy more than 220 million ha in the Russian Federation (Rozhkov et al., 1996). The area of preserved steppe ecosystems is estimated at about 500 thousand ha, and their total carbon stock (including organic and inorganic carbon of soils) is 35 GtC (Smelyansky, 2012). A unique feature of carbon deposits in steppe ecosystems is their long-term storage and high binding reliability. This follows directly from the fact that most of the carbon is preserved in the soil, where its mobility is low and the possibility of emission in undisturbed steppe ecosystems is minimal. In particular, steppe fires do not lead to significant losses of deposited carbon (Smelyansky et al., 2015), which differs sharply from fires in forests and moors. Significant carbon emission is observed only when anthropogenic disturbances occur – primarily as a result of plowing. The preservation of steppe ecosystems against plowing ensures (a) the fixation of about 1.5 t/ha per year of carbon from the atmosphere and (b) long-term (multi-century) preservation of about 700 tC/ha of carbon (Smelyansky, 2012).

The Russian Federation's tundra occupies 280 million ha (16% of the country's territory). Carbon stores in soils in the various types of tundra range within 100–200 tC/ha. The total carbon store in Russia's tundra soils is estimated at 28.6 GtC (Ministry of Natural Resources and Environment of the Russian Federation, 2015b).

The ES volume supplied by ecosystems was assessed according to the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002). An estimation of total carbon stocks in the regions (Fig. 20) was obtained by summing up data on carbon stocks in phytomass and soil.

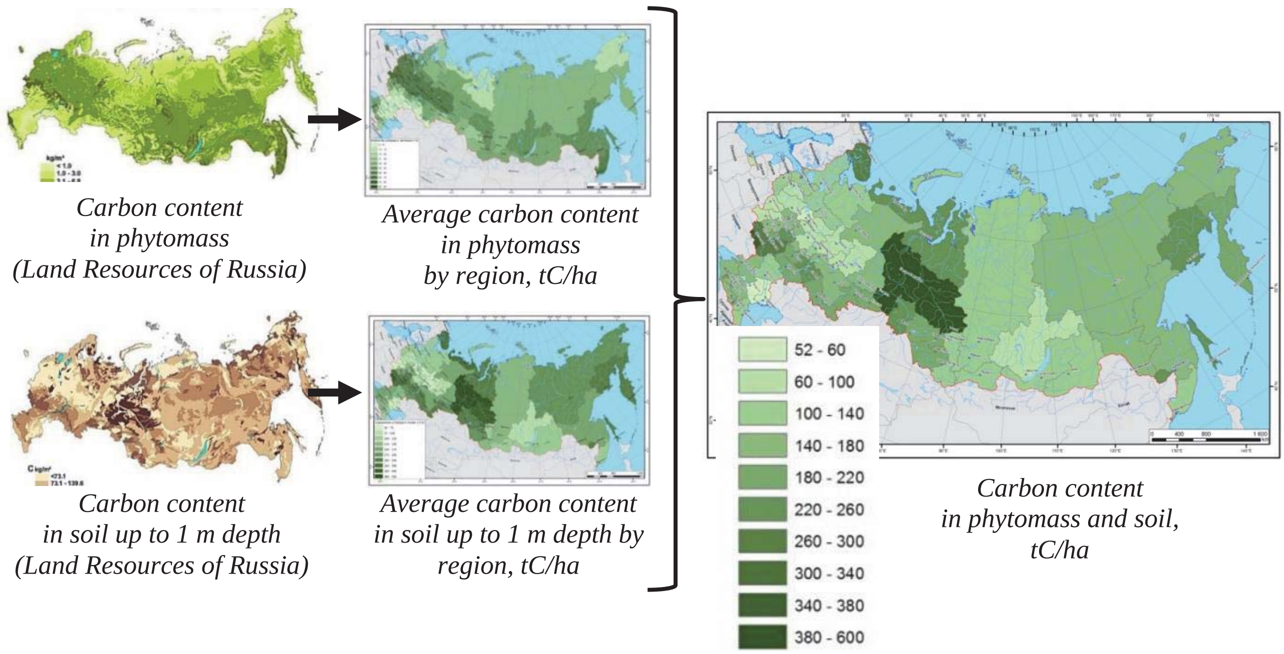


Figure 20. Supplied volume of the carbon storage service: total carbon content in phytomass and soil (tC/ha) and how it was derived

The consumed ES volume was assessed as for the previous service on the basis of data on carbon stores in Russia's managed forests. The Appendix to the National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2011 (2013b) contains data on the carbon content in the biomass, dead wood, ground litter and a 30-cm layer of soil in managed forests for Russia's regions. This amount of carbon can be considered the consumed ES volume, since Russia officially declares management for UNFCCC purposes in this forest category.

Figure 21 shows the consumed ES volumes in the regions. A number of northern (e.g., Nenets Autonomous Okrug) and southern (e.g., the oblasts of Astrakhan and Volgograd) regions have very low values of this indicator, despite the fact that they are located in tundra and steppe zones where there are large carbon stores in the soils. However, there is no ecosystem management to support "carbon services" in non-forest ecosystems. This produces a tremendous discrepancy between the spatial distribution of the supplied and consumed volumes of the carbon storage service. Obviously, implementing the UNFCCC in Russia requires preservation and restoration of tundra, steppe and wetland ecosystems that store large carbon stocks.

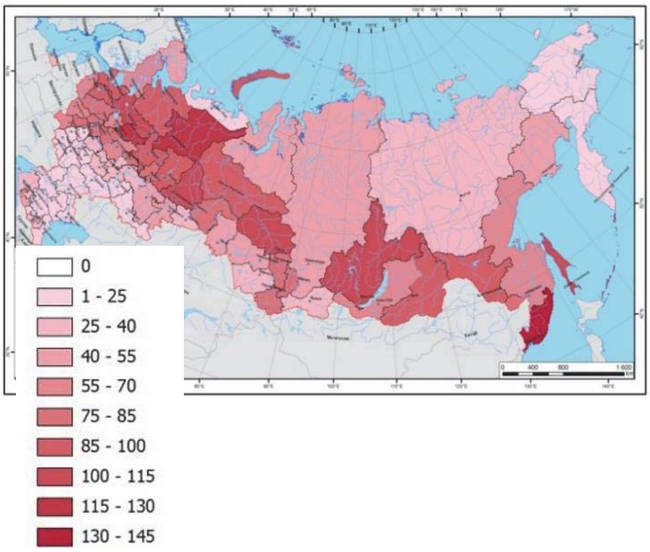


Figure 21. The consumed volume of the carbon storage service: carbon stores in managed forests (tC/ha)

Comparison of the supplied and consumed ES volumes

The degree of ES use was assessed using the percentage of the regional carbon store attributed to managed forests (Fig. 22).

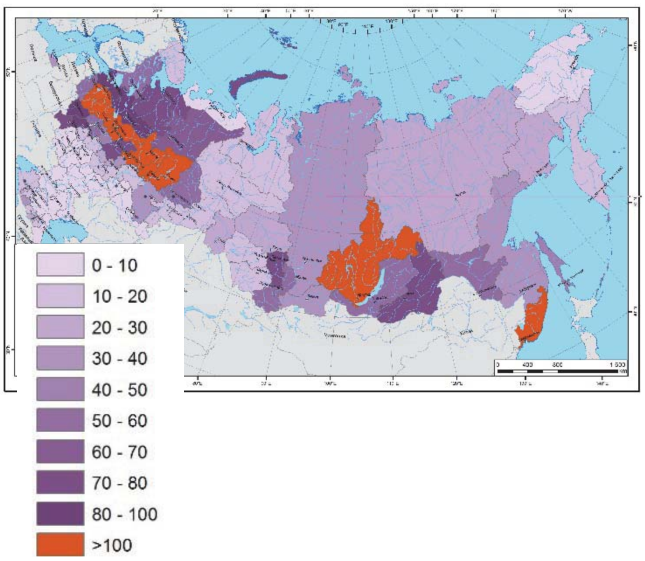


Figure 22. The degree of use of the carbon storage ES: percentage of the regional carbon store (%) attributed to managed forests

This indicator shows that the service is most fully used in a number of forest regions (oblasts of Yaroslavl, Kirov, Irkutsk, Primorsky Krai), where a significant proportion of the carbon store is located in managed forests. According to the Appendix to the National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2011 (2013b), in some of these regions the carbon store in managed forests even exceeds the total terrestrial carbon stock calculated according to the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002) (the values exceeding 100% in Fig. 22). At the same time, in the northern and steppe regions of the European part of the country and in the Western Siberian low plains, which have large carbon stores in soils and peat, the carbon storage service is used very little (less than 20%), since non-forest ecosystems are not under climate regulation management.

Data required to assess and monitor the ES

To assess the supplied volume: carbon stores in all terrestrial ecosystems, including soils.

More adequate consumption of this service requires that climate regulation management be applied not only to managed forests, but also to other types of ecosystems that store significant amounts of carbon (tundra, wetlands, steppes).

Biogeophysical climate regulation

Statement of the task of ES assessment

This group of mechanisms includes the regulation of energy flows between the Earth's surface and atmosphere (albedo, heat flows, wind velocity); a reduction in wind force by vegetation and reduction of damage from hurricanes and storms; regulation of moisture flows between the surface and atmosphere (regulation of cloud formation and the amount of precipitation). The biogeophysical climate-regulating functions of ecosystems have a substantial impact on both the regional and the global climate, but as the Intergovernmental Panel on Climate Change (IPCC) notes, the level of scientific understanding of these processes is still low.

The global importance of the biogeophysical climate-regulating functions of Russian ecosystems is largely determined by the size of the country, the world's longest coastline and the northern location in an area of stable winter snow cover. Changes in surface albedo are very important in regions with a long snow season. Under these conditions there is a positive feedback between an increase in the area of woody and shrubby vegetation, which substantially lowers the albedo, and an increase in regional temperatures, especially in spring. The impact of this relationship on the climate intensifies even more if the region borders the ocean. In this case there is another positive relationship between an increase in regional temperatures on land and the shrinkage of ice on adjacent waters. This in turn reduces the ocean's albedo. These conditions are typical for the Russian Arctic, which makes the impact of this region on continental and global climate extremely powerful.

The changes in the size and condition of natural ecosystems caused by integrated anthropogenic and climate factors will have a serious impact on the climate system.

Air purification by vegetation

The ecosystem function of air purification by vegetation is of local and regional scale. It operates primarily in settlements, urban areas and industrial zones, providing people with clean air. This ES is important for preventing the contamination of farm fields and watersheds in industrial regions. At this stage of research the ES was assessed only with respect to the trapping of pollutants from stationary sources by suburban forests, since there is no information on other types of pollution in the FSSS database "Regions of Russia" (Rosstat, 2013b).

The ES volume supplied by ecosystems was assessed as the maximum amount of pollution that vegetation can capture. Forests capture pollution most efficiently; thus, the supplied ES volume was assessed on the basis of forest area. Inasmuch as air pollution from industrial facilities is heaviest within the first few kilometers from the pollution source (Kravtsova et al., 2014; Lobanova, 2009), forests in an area 5 km from towns were included in the assessment.

The assessment was made as follows.

1. The area of forests within a 5-kilometer zone around cities was determined. Urban areas were identified on the map of terrestrial ecosystems of Russia (Bartalev et al., 2004) (Fig. 23a). Then, all population centers with a population greater than 100,000 people according to the 2010 National Census were selected (more than 150 cities). 5-km buffer zones were plotted around these cities (Fig. 23b), and the forest area within these suburban zones was calculated for each RF constituent (Fig. 23c).

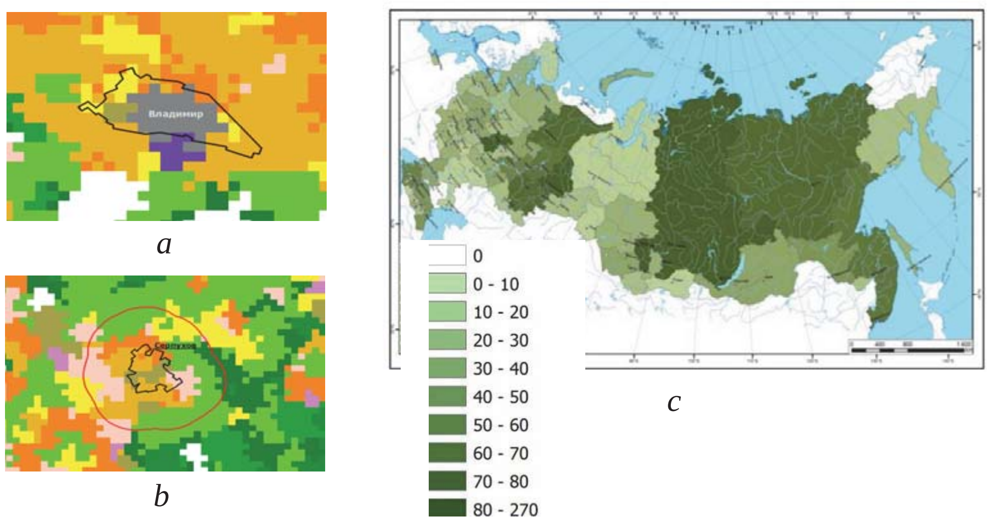


Figure 23. Forest area within suburban 5-kilometer zones by region (thousand ha) and how it was calculated

2. The maximum amount of toxic gases that can be absorbed by suburban forests was determined. Available data on the amount of gaseous sulfur, nitrogen, chlorine, and fluorine compounds that can be absorbed by trees over the growing season without critical harm to them shows that this figure is in the tens (Kulagin, 1974; Tarabrin et al., 1984; Chernyshenko, 2001) or hundreds of kilograms, not exceeding 1000 kg per 1 ha (Artamonov, 1986; Vorobiev, 1985). Simultaneous exposure to several toxic gases reduces the gas resistance and gas-absorbing capacity of trees. Thus, the maximum amount of toxic gases that vegetation can absorb was set at 1 t/ha per year. This figure was used to determine the maximum amount of toxic gases that suburban forests can absorb (Fig. 24).

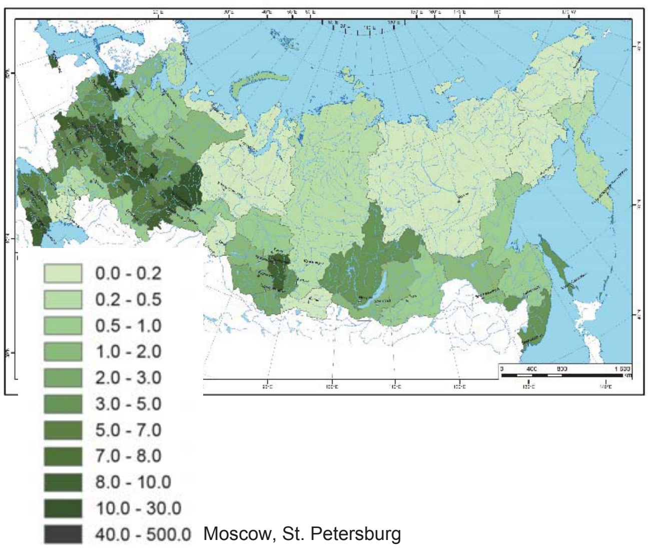


Figure 24. Volume of the air purification ES supplied by forests: maximum amount of toxic gases that can be captured by suburban forests per unit of area of a region (kg/ha/yr)

The demanded ES volume was defined as the amount of air pollution emissions from stationary sources according to the FSSS database "Regions of Russia" (Rosstat, 2013b) (Fig. 25). Later, this figure will have to be calculated more accurately as the difference between the amount of pollutant emissions and their maximum permissible concentrations.

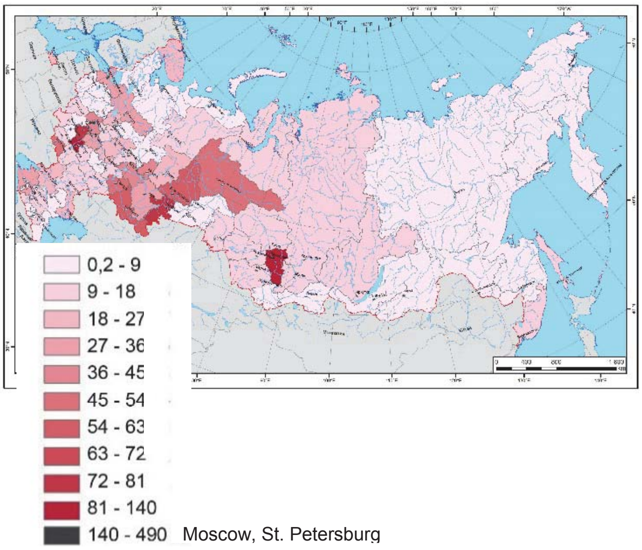


Figure 25. Demanded volume of the air purification ES: amount of pollutant emissions from stationary sources per unit of area of a region (kg/ha/yr)

The consumed ES volume must be assessed as the amount of pollutants that are actually absorbed by suburban forests under the present conditions in the region. The actual absorption volume can differ from the maximum potential volume due to a variety of factors (relief, climate, amount of pollutants, etc.). The difference between these two indicators needs to be clarified in future assessments. It is obvious that a precise assessment requires data from direct measurements of pollution absorption by forests depending on their species and age structure, climate, relief and other local and regional conditions. As finding these data was not part of the project's objective, we used a mean indicator obtained for city parks in the United States and Europe of 0.1 t/ha/yr (Nowak et al., 2006; Baro et al., 2014) (Fig. 26). This is 10 times less than the maximum gas-absorbing capacity of trees established for the most polluted locations.

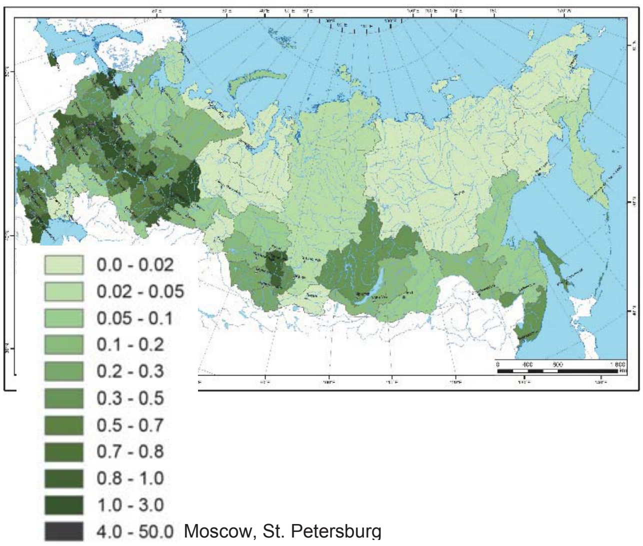


Figure 26. The consumed volume of the air purification ES: amount of pollutants absorbed by suburban forests per unit of area of a region (kg/ha/yr)

Comparison of the supplied, demanded and consumed ES volumes

The indicator of the actual satisfaction of the demand for the service ($V_{consumed} / V_{demanded} \times 100\%$), i.e., the percentage of regional pollutants absorbed by suburban forests, shows that pollution is not completely absorbed in any region (Fig. 27a). In the majority of regions, less than 10% of emissions are absorbed (light purple in Fig. 27a), and in only a few regions where there are many natural forests, but low emissions, the indicator ranges from 10% to 58% (dark purple).

The figure for the potential satisfaction of the demand for the ES ($V_{supplied}$ / $V_{demanded}$ × 100%), i.e., the maximum percentage of emissions that can potentially be captured, shows that the maximum gas-absorbing capacity of suburban forests exceeds the actual emissions only in a few regions (green spectrum in Fig. 27b, 27c). In the majority of regions, even the maximum gas-absorbing capacity is insufficient to neutralize emissions. Many regions have a maximum capacity below 50% (light purple in Fig. 27b). They will therefore have a significant amount of unabsorbed pollutants under any conditions ($V_{demanded}$ – $V_{supplied}$, red spectrum in Fig. 27c). The greatest amount of unabsorbed pollutants is in regions with large pollutant emissions (dark red color).

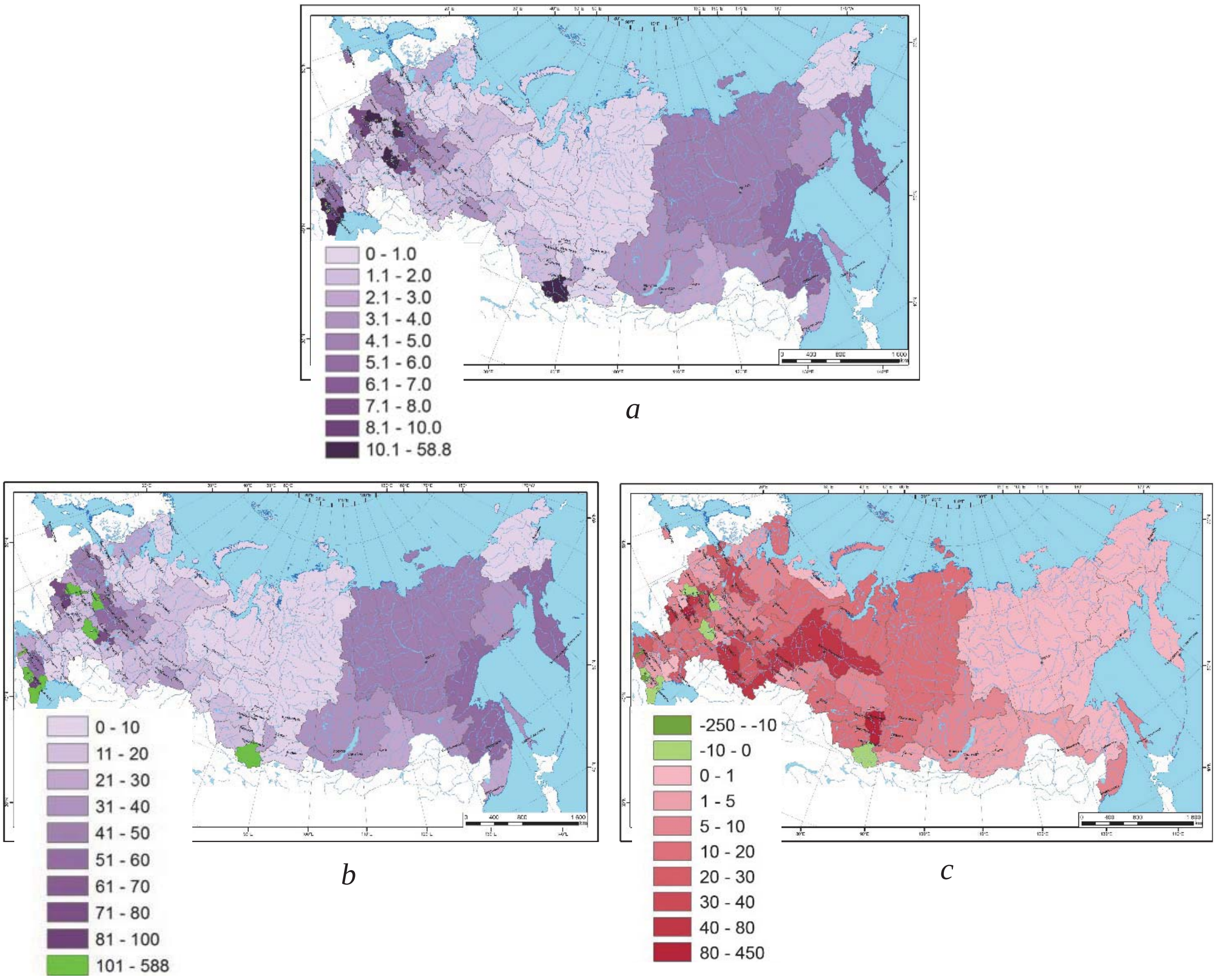


Figure 27. Satisfaction of the demand for the air purification ES:
a) percentage of pollutants absorbed by suburban forests (%),
b) maximum percentage of emissions that can potentially be absorbed by suburban forests (%);
c) remaining emissions that cannot be absorbed by suburban forests, per unit of area of a region (kg/ha/yr).
Regions where all emissions can potentially be absorbed by suburban forests are shown in green in maps b and c.

Data required to assess and monitor the ES

To assess the supplied and consumed volumes:

– amount of toxic gases, aerosols and dust absorbed by different types of vegetation with allowance for the regional and local conditions (vegetation characteristics, climate, relief);

– the amount of toxic gases, aerosols and dust absorbed by different types of soil with allowance for regional and local conditions;

– the area of different types of vegetation in suburban zones; for forests: the species and age structure, area of suburban and urban forests (Fig. 28);

– the correspondence between pollutant chemicals in data on pollutant emissions and data on absorption capacities of plants.

To assess demanded volume:

– amount of toxic gases, aerosols and dust from stationary sources, the migration distance for different pollutants;

– amount of toxic gases, aerosols and dust from transport, the migration distance for different pollutants.

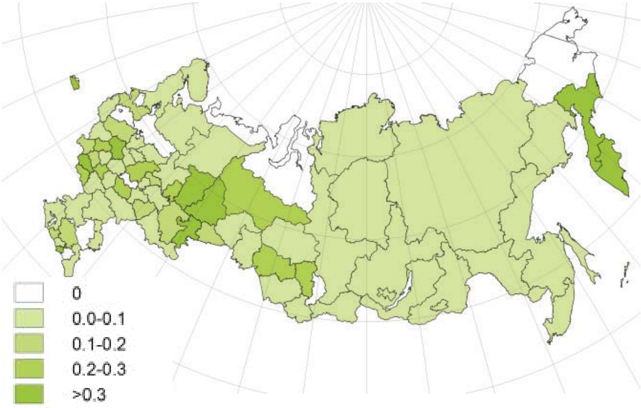


Figure 28. Area of settlement forests according to the State Forestry Registry (% of the area of the region)

Hydrosphere regulation

The ecosystem services of water regulation include four main components:

a) water protection (water saving) services, i.e., regulation of runoff volume;

b) regulation of the variability of runoff, i.e., runoff stabilization, including the reduction of the intensity of and damage from floods;

c) assurance of water quality by terrestrial ecosystems, i.e., removal of various pollutants from runoff due to terrestrial ecosystems functioning;

d) assurance of water quality by freshwater ecosystems, including dilution and the neutralization of pollutants.

In the present report, water regulation ES are considered on the scale of the constituents of the Federation, since we used the data from FSSS databases. It is obvious that future assessments of these ES should be based on the basin approach (see the section “Scale of Ecosystem Services”). The flow direction should also be taken into account because ecosystems in the upper course of a river supply downstream regions.

Regulation of runoff volume

Water enters the land surface as a result of precipitation, due to the melting of ice and snow, and from groundwater. Moisture returns to the atmosphere through evaporation from the ground or water surface. The flow of entering water is redistributed by ecosystems: A portion of the precipitation is intercepted by vegetation and evaporated by it. A portion evaporates from the soil surface. A portion seeps into the soil. A portion forms surface runoff. Soil moisture is absorbed by plants and evaporates from plant surfaces during transpiration. The moisture remaining in the soil seeps into deeper strata through infiltration, forming delayed runoff. The water balance is diagrammed in Fig. 29a.

The water balance equation (Lvovich, 1963) considers the water balance on a certain surface over a specific time. In its most general form it may be written as follows:

$$P = R + ET + \Delta S, \qquad (1)$$

where the only input is precipitation *(P)*. Precipitation is redistributed by ecosystems between runoff *(R)*, evapotranspiration *(ET)* and moisture stock in biomass and soil *(ΔS)*. The sum of evapotranspiration *(ET)* and the change in moisture stock in ecosystems *(ΔS)* can be regarded as the total impact of ecosystems on the water balance. A change in this sum affects the runoff volume: the more moisture is evaporated and the more moisture stock is replenished, the less runoff there will be and vice versa. The runoff volume is therefore the result of the redistribution of atmospheric precipitation by ecosystems.

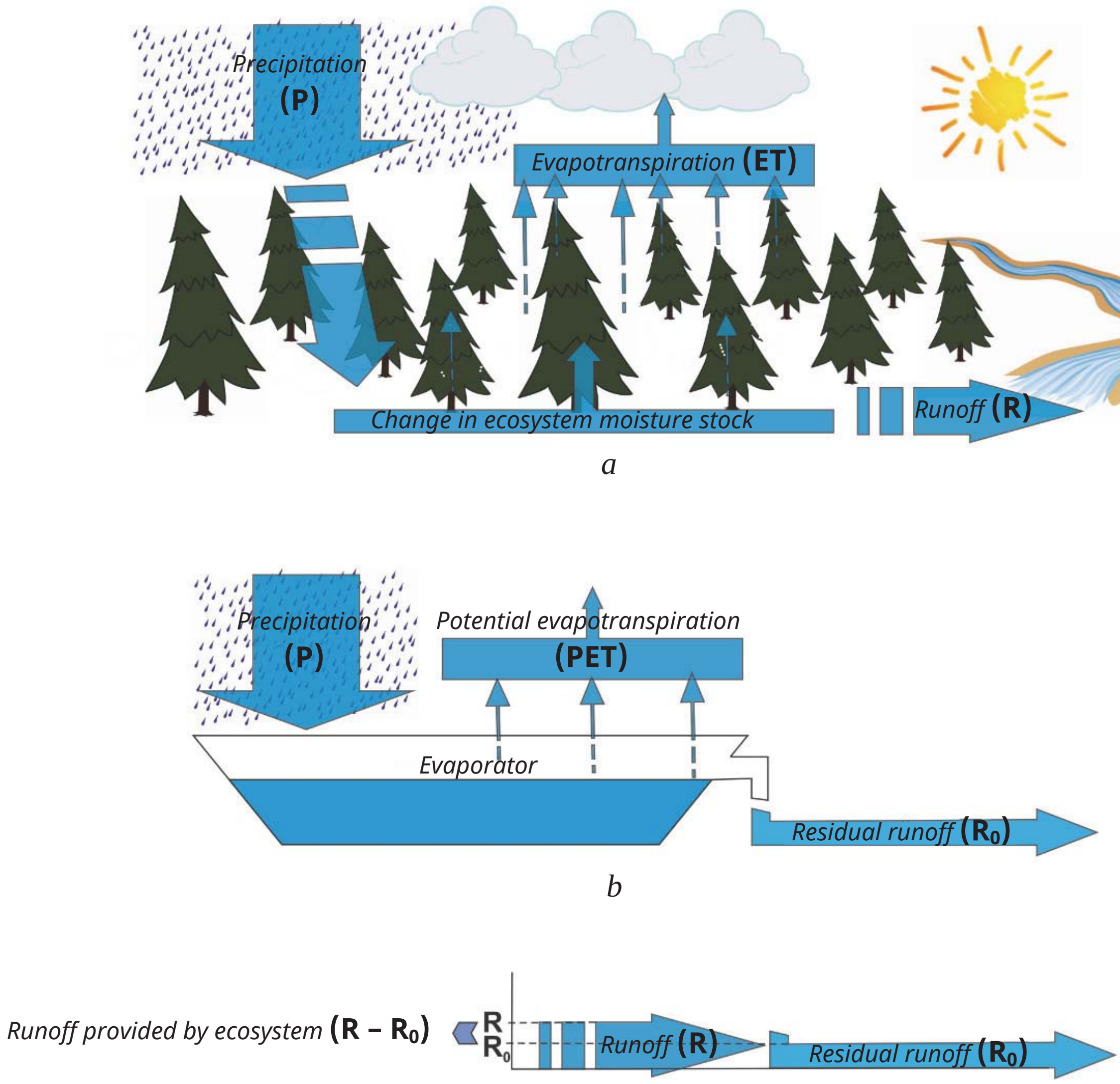


Figure 29. The role of ecosystems in water balance and runoff formation:
a – the impact of ecosystems on runoff;
b – hypothetical model with evaporator;
c – scheme for estimating runoff volume provided by ecosystems

The ES volume supplied by ecosystems was assessed on the base of a comparison of the actual runoff with a hypothetical case where ecosystems are not involved in runoff redistribution. This requires the introduction of one more term – the potential evapotranspiration *(PET)*, that is, the maximum possible evaporation in an evaporator under existing atmospheric conditions that is not limited by water reserves. In the hypothetical case where the assessed area is regarded as an evaporator (Fig. 29b), in regions with normal and excess moisture (where the amount of precipitation exceeds *PET*), evaporation will be equal to *PET*, but in arid regions (where the amount of precipitation is less than *PET*) evaporation will be less than *PET*. When the evaporator's reservoir is completely filled, the difference between the amount of precipitation and *PET* is residual runoff (R_0) outside the evaporator. The water balance equation for an evaporator may be written in the form:

$$R_0 = P - PET \text{ if } P > PET \text{ and } R_0 = 0 \text{ if } P \leq PET \quad (2)$$

In regions where the amount of precipitation is less than *PET*, the residual runoff equals zero. The difference between the observed surface runoff (*R*) and the hypothetical residual runoff (R_0) from the evaporator is considered as the runoff volume provided by ecosystems (Fig. 29c), i.e. the supplied ES volume. Surface runoff (*R*) was determined by subtracting underground runoff from total runoff and the hypothetical residual runoff (R_0) was determined by subtracting *PET* from precipitation according to the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002).

In the first step, the regions with insufficient moisture were identified through calculation of the moisture factor (*P/PET*). A large portion of regions has insufficient moisture[4] (moisture factor less than 1.0, Fig. 30). In these regions, the amount of precipitation is less than *PET*, and $R_0 = 0$. The observed surface runoff (*R*) is treated as the sum of the runoff volume provided by ecosystems and the residual runoff (R_0) (Fig. 29c). Thus, ecosystems in these regions provide the formation of 100% of surface runoff.

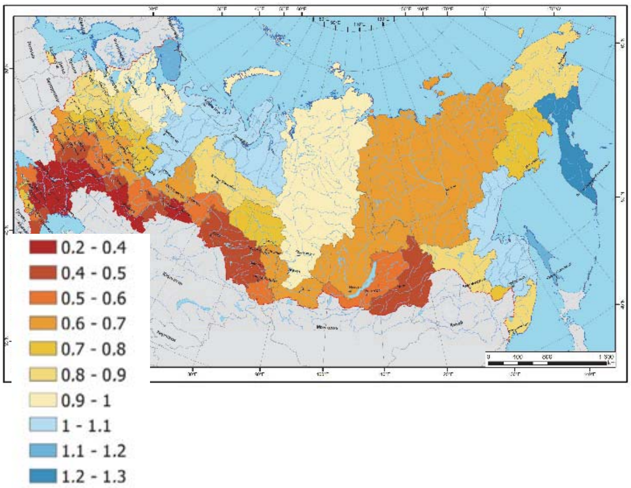


Figure 30. Moisture factor by regions

Moisture has sublatitudinal zoning and decreases from north to south. In regions located in the Central and Western Caucasus, however, moisture is higher. There is extremely insufficient moisture in the Caspian lowland (Republic of Kalmykia and the oblasts of Astrakhan and Volgograd). In these areas, potential evapotranspiration significantly exceeds the amount of precipitation.

Areas with normal and excess moisture (moisture factor equal to or greater than 1.0) tend to be in the northern parts of European and Asian Russia and in an area exposed to monsoon circulation in the Far East. For example, in Kamchatka Krai the amount of precipitation exceeds potential evaporation by an amount that is by 33% more than surface runoff. In these regions, the residual runoff (R_0) is greater than zero, and thus, the role of ecosystems in the formation of surface runoff is less than 100% because observed surface runoff (*R*) is regarded as the sum of the runoff provided by ecosystems and the residual runoff (Fig. 29c).

For arid regions where ecosystems form 100% of the runoff, the amount of runoff volume provided by ecosystems was set equal to the long-term values for surface runoff. For regions with moderate and high moisture, where ecosystems form less than 100% of runoff, runoff volume provided by ecosystems equals their contribution to the total surface runoff (Fig. 31).

---

[4] Tundra, forest-tundra and part of boreal forests – areas with excessive moisture. However, for some Siberian and Far Eastern regions this is not shown on the map due to their very large areas that include both nortern and southern ecosystems. – *Note. Ed.*

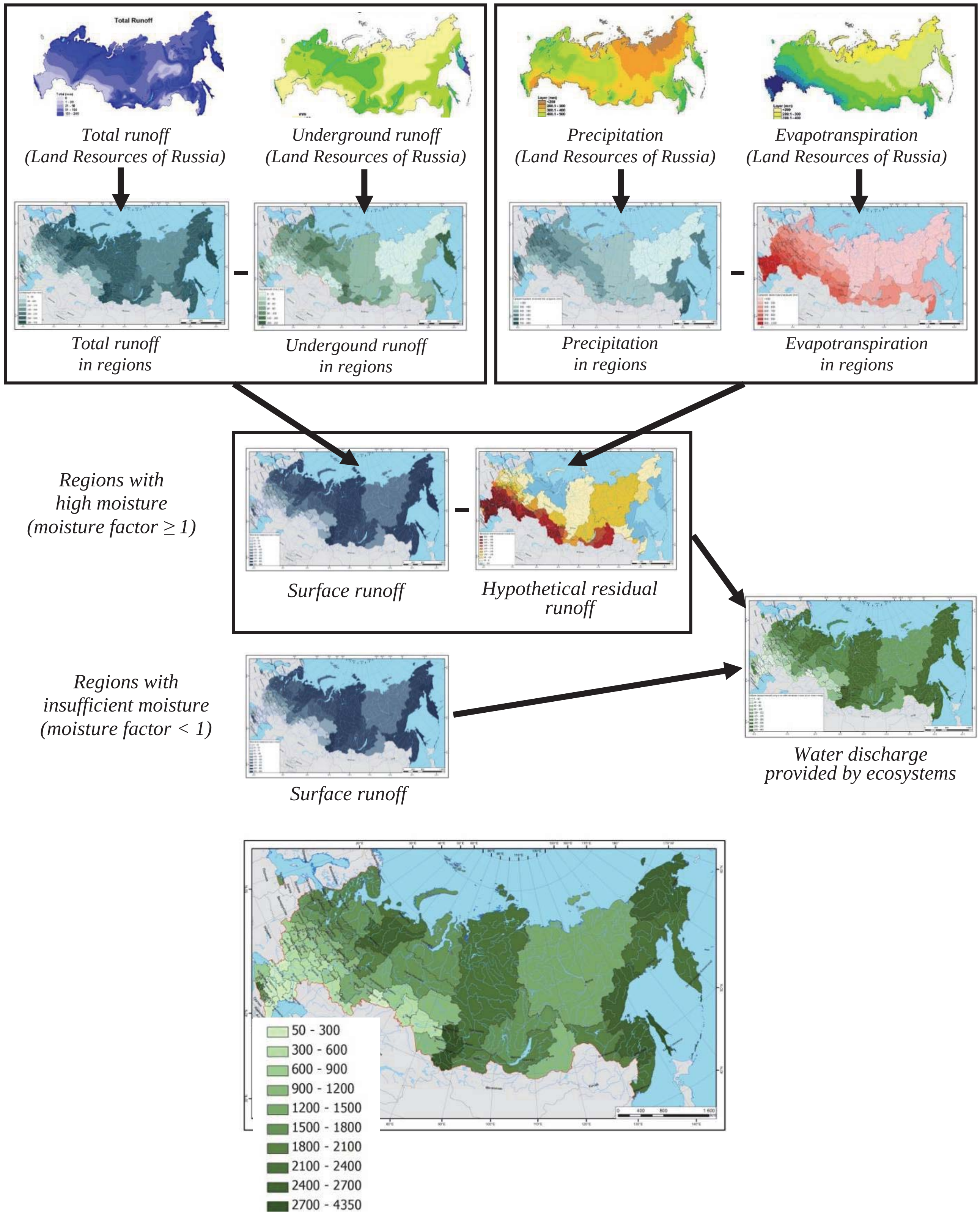


Figure 31. The volume of the ES of regulation of runoff volume supplied by ecosystems (m^3/ha/yr) and how it was assessed in regions with insufficient and excess moisture

The runoff volume provided by ecosystems, i.e. supplied ES volume, varies from 50 m^3/ha/yr (Astrakhan Oblast) to 4350 m^3/ha/yr (Altai Republic). The majority of regions have ecosystem-provided runoff of about 200 mm. The largest supplied ES values are typical primarily for regions with normal and excess moisture and for mountainous areas – Altai Republic, Khakassia, Kemerovo Oblast and the Karachay-Cherkess Republic.

Table 7 presents examples for three regions with different ratios of precipitation and evaporation.

Table 7. Parameters for assessing the ES of runoff volume regulation in selected Federation constituents

Parameter, mm/year	*Tyva Republic*	*Saratov Oblast*	*Sakhalin Oblast*
Precipitation	393	362	620
Total runoff	268	56	605
Underground runoff	80	12	137
Surface runoff	268 – 80 = 188	56 – 12 = 44	605 – 137 = 468
Potential evaporation	557	887	498
Hypothetical residual runoff	393 – 557 = –164	362 – 887 = –525	620 – 498 = 122
Ecosystem contribution	188 – (–164) = 352	44 – (–525) = 569	468 – 122 = 346
Supplied ES – runoff volume provided by ecosystems	188 (100% surf. runoff)	44 (100% surf. runoff)	346 (73% surf. runoff)

Example 1 – Tyva Republic. On average, the republic receives 393 mm of precipitation annually. The mean annual water discharge equals 268 mm, of which 80 mm is supplied by groundwater inflow. Potential evaporation comes to 557 mm. Replenishing the moisture shortage requires 164 mm of precipitation. However, the steppe and forest-steppe vegetation and the divided terrain result in the formation of a 188 mm surface runoff. The contribution of ecosystems to runoff volume is therefore 188 mm – (–164 mm) = 352 mm. The ecosystem component in the actual surface runoff equals 100%, i.e., 188 mm. Consequently, the role of ecosystems in providing runoff volume lies in the redistribution of precipitation as follows: 352 mm, i.e., 89% of precipitation is retained by ecosystems and 11% of precipitation evaporates. The entire surface runoff (188 mm) is formed from precipitation retained by ecosystems.

Example 2 – Saratov Oblast. The mean annual precipitation totals 362 mm. Of the 56-mm water discharge, 21% (12 mm) is supplied by underground runoff. Surface runoff totals 44 mm. With the potential evaporation of 887 mm the moisture shortage is 525 mm. The sum of moisture shortage and surface runoff (525 + 44 = 569) exceeds the mean annual precipitation. Consequently, the ecosystems of Saratov Oblast form the entire surface runoff from 12% of precipitation (44 mm / 362 mm), while 88% of precipitation is retained by ecosystems and evaporates.

Example 3 – Sakhalin Oblast. The region receives 620 mm of precipitation, while the observed water discharge totals 605 mm. Surface runoff is 468 mm. Potential evaporation is 498 mm, that is, less than the amount of precipitation. Therefore, ecosystems provide 468 mm – (620 mm – 498 mm) = 346 mm of water discharge, which is 73% of surface runoff. Consequently, in Sakhalin Oblast surface runoff (468 mm) forms from 75% of precipitation, and 73% of runoff is provided by ecosystems, while 27% is formed directly as a result of precipitation events, which is probably related to the prominence of the mountainous terrain. The remaining 25% of precipitation (152 mm) replenishes ecosystem moisture stock that forms underground runoff.

The consumed ES volume was assessed as the volume of freshwater used, i.e., water intake from various natural sources (except returned water and reused gray water) according to the FSSS database "Regions of Russia" (Rosstat, 2013b) (Fig. 32). In all RF constituents except Moscow and Saint Petersburg the amounts of freshwater used are in the tens or hundreds of m^3/ha/yr. In Moscow and Saint Petersburg water consumption is measured in thousands of m^3/ha/yr.

Comparison of the supplied and consumed ES volumes

As shown in Fig. 31 and 32, the supplied and consumed ES volumes are comparable. The indicator of unused/overdrawn ES $(V_{supplied} - V_{consumed})$ is therefore sufficiently informative for assessment of the degree of ES use (Fig. 33).

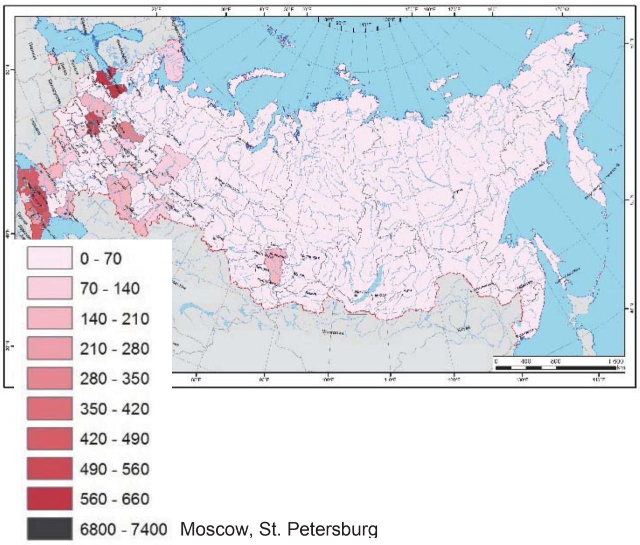


Figure 32. Consumed volume of the ES of runoff volume regulation: use of freshwater (m^3/ha/yr)

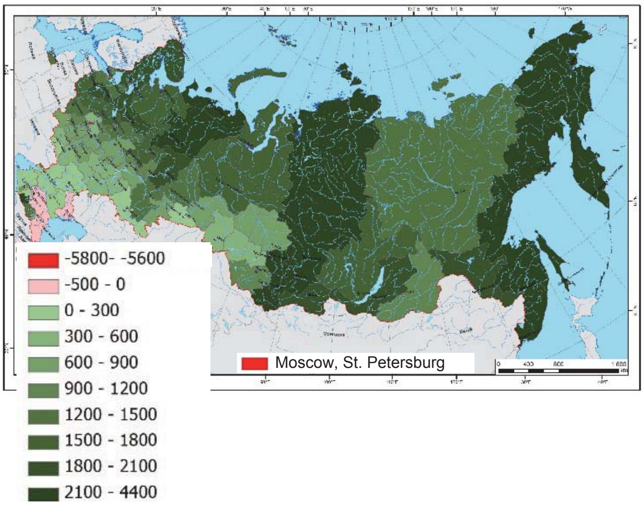


Figure 33. The degree of ES use – runoff volume provided by ecosystems and unused by man (positive values) or excess of water use over runoff provided by ecosystems (negative values), m^3/ha/yr

Throughout almost all of Russia the use of freshwater does not exceed runoff volume provided by ecosystems (green color in Fig. 33). In Moscow Oblast, the southern regions of European Russia and West Siberia, runoff volume provided by ecosystems is almost entirely used (light green in Fig. 33). The excess of water use over runoff volume provided by ecosystems (up to 500 m^3/ha/yr) is seen in Stavropol Krai, Astrakhan Oblast, the Chechen Republic and Dagestan (pink in Fig. 33). In Moscow and Saint Petersburg, this excess (5000–6000 m^3/ha/yr) is larger than the highest figures for ecosystem regulation obtained in the entire country (4350 m^3/ha/yr in the Altai Republic).

Figure 34 presents the number of regions with different ratios of supplied and consumed ES volumes. It shows that the majority of regions are grouped in the upper left corner of the chart, which corresponds to an excess of supplied ES over consumed ES because of relatively high runoff volume provided by ecosystems and low water consumption.

Data required to assess and monitor the ES

The method used to assess the ES is effective only on the macro-regional scale. Averaging the data by region lowers the accuracy of the assessment. To account for the specific features of catchment basins, in future assessments it will be necessary to plot all intermediate maps with isolines and only in the last stage average the data for RF constituents. It is necessary to account for actual evaporation and the amount of moisture retained by different types of ecosystems. Inter-regional interactions in the field of water-protecting ES should be based on the basin approach. Necessary data to assess the supplied ES volume:

– amount of precipitation, actual and potential evaporation, maximum water storage in snow over a year measured at weather stations;
– the water discharge measured at gauging stations;
– the measured contributions of snow, rain, ice and underground runoff towards total runoff.

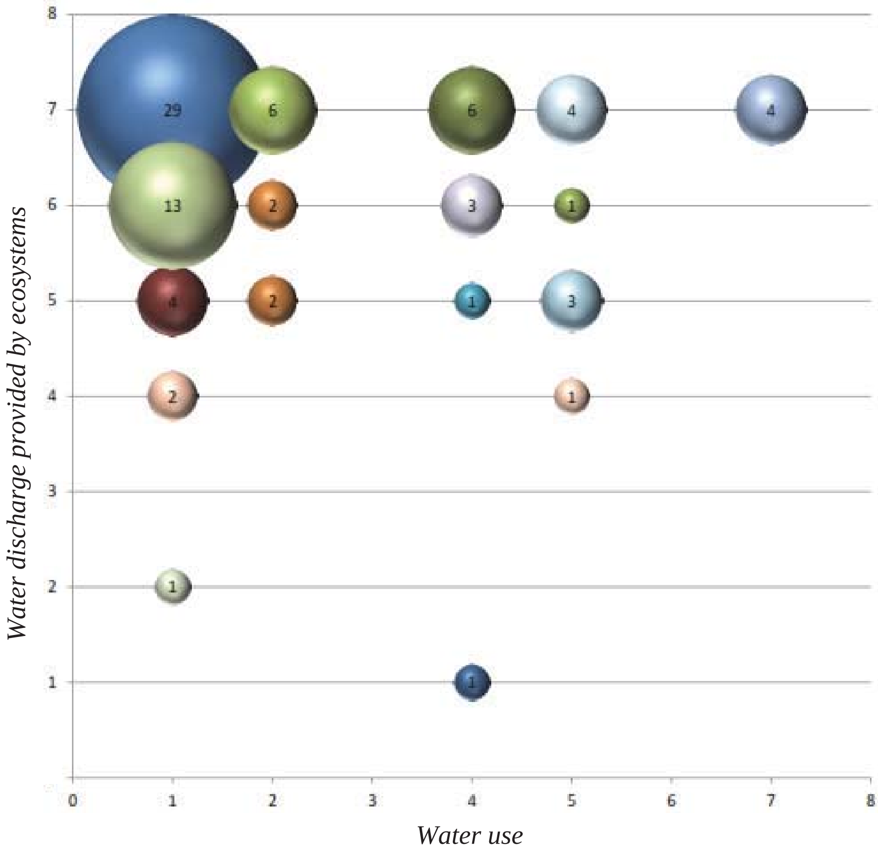


Figure 34. Groups of regions by ratio of supplied and consumed ES volumes: 1 — 0–0.005; 2 — 0.005–0.0075; 3 — 0.0075–0.01; 4 — 0.01–0.02; 5 — 0.02–0.05; 6 — 0.05–0.1; 7 — 0.1–0.75 million m^3/km^2. The size of a bubble and the number in it correspond to the number of regions with a certain combination of supplied and consumed ES

Regulation of runoff variability

Runoff undergoes intra- and inter-year changes. Results of this variability might be changes in water level, changes in the rate of water intake replenishment, drying of stream beds, droughts, and catastrophic floods. Ecosystems have a direct role in runoff regulation through the redistribution of the amount of precipitation. The Prototype Report assesses only one component of the integrated water regulating services, namely, the influence of ecosystems on minimum and maximum annual runoff figures.

Runoff regulation by ecosystems was assessed using cartographic data on the mean annual total runoff and its variation coefficient (C_v), i.e. the ratio of the standard deviation to the mean long-term value (Fig. 35), according to the database “Land Resources of Russia” (Stolbovoi & McCallum, 2002). The runoff variation coefficient for RF constituents is on average 0.36, with a spread from 0.14 (Yamalo-Nenets Autonomous Okrug) to 1.09 (Astrakhan Oblast). By these data, maximum and minimum runoff over a multiyear period and the deviation of the runoff value from the mean multiyear value (dispersion) were determined (Fig. 35).

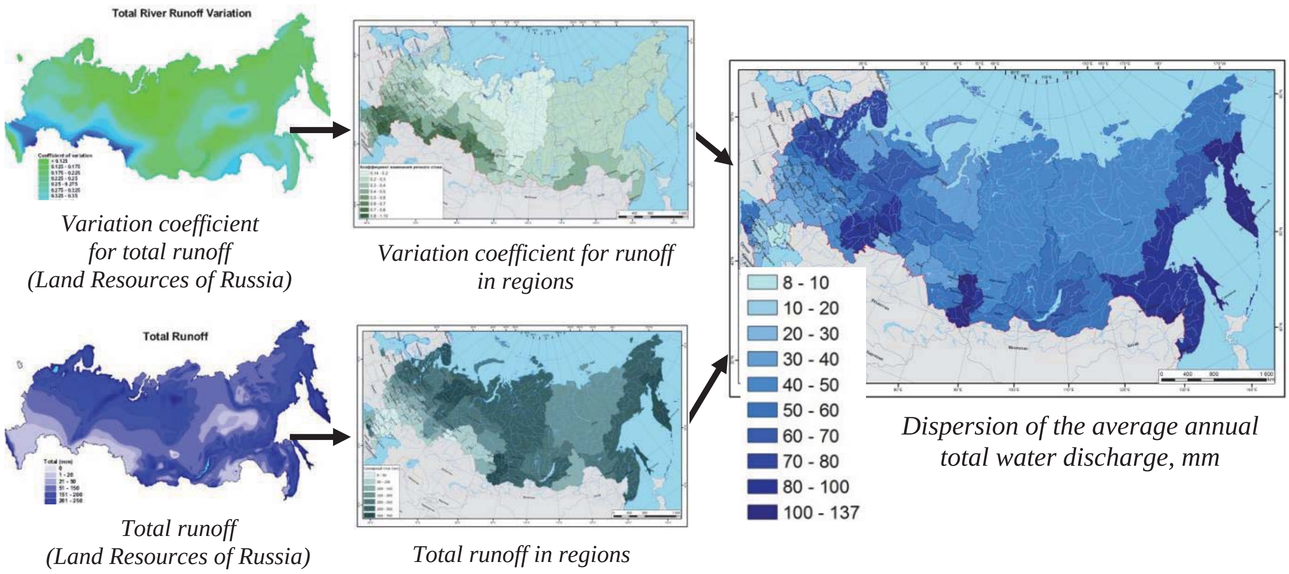


Figure 35. Dispersion of the average annual water discharge (mm) and how this indicator was obtained

The distribution throughout Russia of the absolute values of the amplitude of runoff fluctuations differs from the distribution of the runoff variation coefficient. A large portion of regions are characterized by a water discharge variability of 60 mm. Higher figures are typical for northwestern regions of the European part of Russia and in the Urals, the Karachay-Cherkess Republic, the Altai Republic, the Republic of Khakasia, Kemerovo Oblast, the Buryat Republic, the southern Far East, Kamchatka Krai and Magadan Oblast. There is a high correlation (r = 0.84) between the absolute values for runoff variability and runoff amount. It is roughly the same for total runoff and for surface runoff and somewhat smaller (r = 0.69) for underground runoff, from which one can draw the following conclusions:

– the greater the mean annual runoff, the greater the absolute indicators of its multiyear variability;
– variations in total runoff are determined primarily by surface runoff.

The ES volume supplied by ecosystems. Data on the multiyear variability of runoff were compared with the variability of precipitation for the same period (1961–1990) to determine the regulation of runoff by ecosystems. Data on total precipitation over a year were obtained by processing data from the reanalysis of observations at weather stations in Russia in the 3D model CRU-TS v. 3.23 (Harris et al., 2014). Processing involved determining the precipitation variation coefficient with the formula

$$C_v = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}}{\bar{x}}, \qquad (3)$$

where x_i is annual precipitation over year i in the interval 1961–1990, n = 30, with averaging of the variation coefficient in the squares of a 0.5° × 0.5° grid within each region though GIS analysis.

Then the difference in dispersions of precipitation and surface runoff for the period 1961–1990 was found. The physical meaning of this operation is as follows. Ecosystems regulate surface runoff in an annual cycle. Underground runoff is also regulated through the redistribution of subsurface runoff, but this takes place over longer time scales and under the influence of factors related primarily to lithologic, not biological conditions.

Ecosystems regulate water inflow into water bodies by redistributing precipitation between runoff and evaporation. The inter-year variability of surface runoff is explained in part by the variability of precipitation. We found the mean multiyear magnitude of this regulation in absolute terms (mm of water discharge) by determining the difference in the dispersions of precipitation and runoff (Fig. 36).

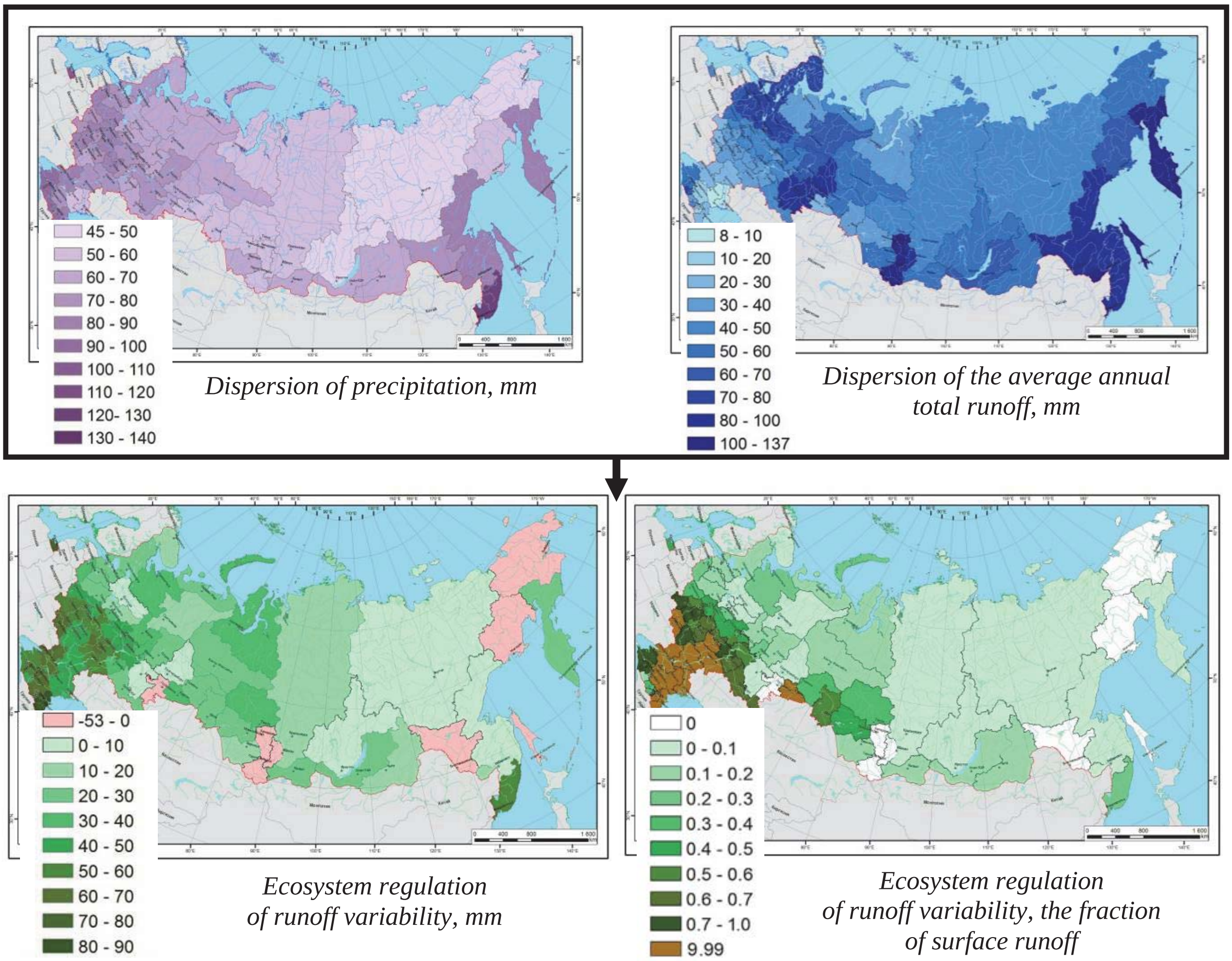


Figure 36. Absolute and relative indicators of the ecosystem regulation of runoff variability

The variability of precipitation exceeds the variability of runoff across most of Russia. The difference in the variability of precipitation and runoff may reach 90 mm. Negative values are also encountered, indicating regions in which the variability of precipitation is less than the variability of runoff. This may be attributable to runoff factors other than ecosystems that play a role greater than ecosystem regulation. These might include, for example, a change in underground or glacial runoff or the over-regulation of rivers through the organization of reservoirs. Such regions include: Amur Oblast, Kemerovo Oblast, Magadan Oblast, Altai Republic, Republic of Khakasia, Sakhalin Oblast, Chelyabinsk Oblast and the Chukotka Autonomous Okrug – largely mountains glacial regions or overly moist areas.

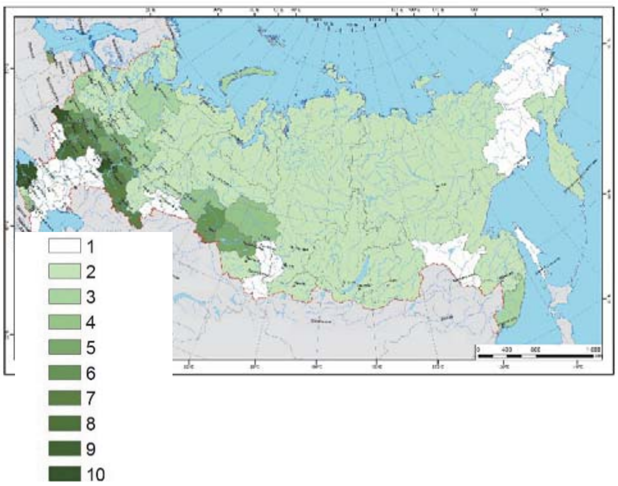


Figure 37. The score for the supplied volume of the ES of regulating runoff variability. White indicates regions where there is no ecosystem regulation of runoff variability

The relative contribution of ecosystems to runoff regulation in regions was determined by calculating the extent of ecosystem runoff regulation as a fraction of surface runoff. There is one more category of regions, in which the difference in the dispersions of precipitation and runoff exceeds the annual water discharge (9.99, brown on the map). The regions in which this effect is observed are located in the steppe zone of the European part of Russia, the Volga area and the Urals, the Caspian area and the North Caucasus, i.e., mostly in arid areas in which ecosystems provide practically no runoff and, consequently, do not regulate it.

An estimation of the score of the supplied ES volume was obtained on the basis of the relative indicator of the supplied ES (Fig. 37).

The consumed ES volume was preliminarily assessed on the basis of the regional GDP per hectare (Fig. 38). This indicator was used as an assessment of possible damage from runoff fluctuations not regulated by ecosystems. It is assumed that the service is used less in regions with lower GDP.

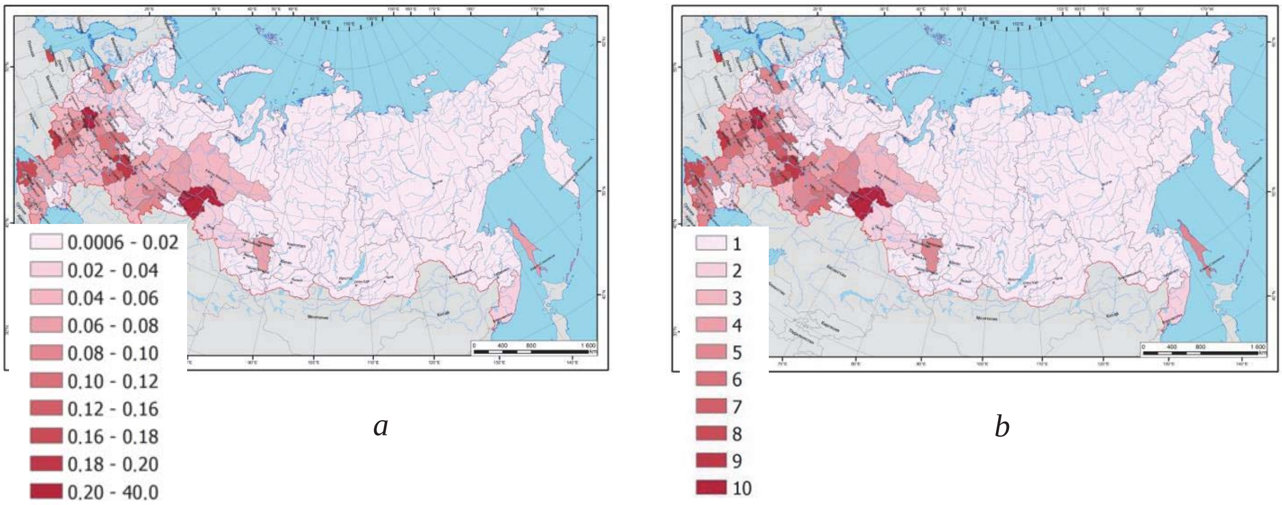


Figure 38. Assessment of the consumed volume of the ES of regulating runoff variability: a) regional GDP per unit of area of a region (RUB/ha/yr); b) score of the consumed ES

Comparison of natural and socioeconomic factors that determine the supplied and consumed ES volumes

Comparing the scores for the supplied and consumed ES volumes *($V_{supplied}$ – $V_{consumed}$)* shows that in the majority of northern and Asian regions the effect of natural and socioeconomic factors is either in balance (white, “0” in Fig. 39), or natural factors dominate slightly (light green in Fig. 39).

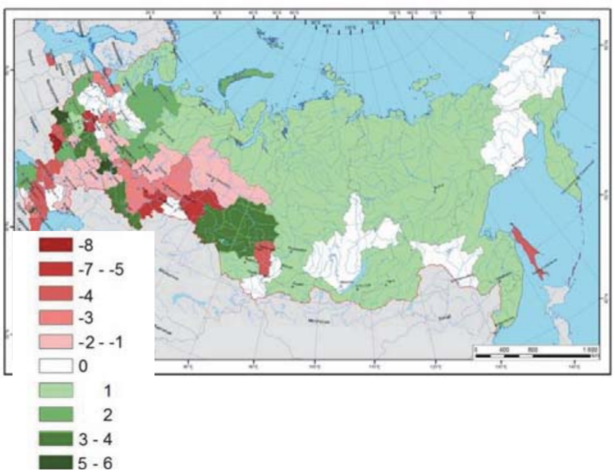


Figure 39. Difference in the scores for supplied and consumed ES volumes

Relative prevalence of factors governing a demand for and consumption of the service (red in Fig. 39) is found primarily in regions with relatively high GDP per unit of area (oblasts of Tiumen, Moscow, and Belgorod). It is obvious that the use of possible damage from intense runoff fluctuations to assess other indicators, for example, the cost of key assets, may alter the picture.

Data required to assess and monitor the ES

Correct assessment of the supplied ES volume must be based on calculations in ecosystems, not administrative units. Averaging data for the regions lowers the accuracy of the assessment. To account for the specific features of catchment basins, in future assessments it will be necessary to plot all intermediate maps with isolines and only in the last stage average the data for RF constituents. For calculations on a larger scale it will be useful to analyze the variability of precipitation in connection with the variability of runoff and to quantify the runoff retention time, i.e., the amount of moisture retained in ecosystems.

Assessing the consumed ES volume for extremely large runoff (i.e. prevention of flood damage) requires data on the cost of damage from high water, for which the cost of land in flood zones is needed. To assess the regional scale, it will be helpful to know the distribution of GDP with respect to absolute elevation. The consumed ES for extremely small runoff (i.e. prevention of damage from lowering the water level) may be assessed on the basis of water consumption figures.

Runoff is regulated, among other things, by human water management activities. Both water consumption and the net volumes of reservoirs should be taken into account in the regulation of runoff and in the generation of its mean multiyear variations. Inter-regional interactions in the field of water-regulating ES should be based on the basin approach.

Assurance of water quality by terrestrial ecosystems

Many kinds of economic activity in watersheds lead to the formation of pollutants and their infiltration into the environment. Some of these pollutants enter water bodies and adversely affect them. Anthropogenic sources of pollutants in water bodies can be divided into two groups. The first includes industrial enterprises, livestock farms and other business entities, pollution from which enters water bodies and water courses with wastewater. These sources are called point sources. Ecosystem services associated with the dilution of wastewater and neutralization of pollutants in water bodies are discussed in the section "Water purification in freshwater ecosystems".

The second group of pollution sources is dispersed over the catchment area, and pollutants initially end up on the surface environment (buildings, roads, vegetation, soils, snow cover) and are then washed into water bodies with meltwater and rainwater. These pollution sources are called "non-point," and pollution from them is called "diffuse" (Kalinin, 2008). The process by which diffuse pollution migrates is greatly affected by the nature of the surface. Water runoff from asphalt and concrete surfaces of towns and roads and from freshly plowed and eroded lands ensures almost complete transport of pollutants to water bodies. The presence of vegetation, especially woody vegetation, leads to an increase in the infiltration of meltwater and rainwater and the subsequent incorporation of pollutants in biogeochemical cycles or their accumulation in components of terrestrial ecosystems. These processes support the ES of water purification by terrestrial ecosystems.

In this section only one component of the ES – absorption of pollutants by ecosystems – is considered. The other ES component related to preventing runoff of soil and dirt into the water bodies is discussed on the level of the problem statement in the section "Soil protection from erosion".

Two empirical-statistical methods are used to assess diffuse pollution at a specific watershed (Mikhailov, 2000). The first method uses data on the pollutant runoff moduli. The runoff modulus is defined as the amount of a particular pollutant from a unit of catchment area per unit of time. The best known spreadsheet data for the runoff moduli for certain pollutants are found in the summaries of G. Jolankai (1983, 1992). The second method is called the "constant concentrations method". In this case spreadsheet values of concentrations for particular pollutants are calculated for different runoff variations. The constant concentrations method was used in the "Guidance on calculation of fees for unorganized discharge of pollutants into water bodies" (1998). Table 8 presents information from this source on pollutant concentrations in surface runoff from developed areas.

Fishery MACs are presented for comparison of the importance of particular pollutants in Table 8 (The list of fishery management standards: the maximum permissible concentrations (MPCs) and the approximately safe levels of exposure (ASLE) of harmful substances for water bodies that are of fishery importance, 1999; Water quality standards for water bodies of fishery importance, including standards for maximum permissible concentrations of harmful substances in the waters of water bodies of fishery importance, 2010). Suspended solids are the most significant pollutant of surface water in developed areas. Their concentration exceeds the MAC in rainwater by a factor of 1000 and in meltwater by a factor of 14,000. Petroleum products rank second, exceeding the MAC by a factor of 200 and 600, respectively. The high levels of pollution by these substances stand to reason – dust (suspended particles) and petroleum products are typical consequences of activity in developed areas, in particular, construction and transportation. On average, concentrations of pollutants in meltwater exceed those for rainwater by a factor of 3.84, which is related to the long exposure of snow under conditions of pollution. The multiplier 3.84 will later be used to convert the amount of polluted rainwater into the amount of polluted meltwater, in order to use the universal unit of the volume of the ecosystem service of water purification by terrestrial ecosystems.

Table 8. Concentrations of basic pollutants in surface runoff from developed areas, maximum allowable concentrations (MAC) for fishery water bodies and their ratios

Pollutant	*Concentration, mg/L*			*Ratio of concentration to MAC*	
	rainwater	*meltwater*	*MAC*	*rainwater*	*meltwater*
Suspended solids	250	3500	0.25	1000.0	14000.0
Petroleum products	10	30	0.05	200.0	600.0
BOD	30	90	3	10.0	30.0
Sulphates	100	500	100	1.0	5.0
Chlorides	200	1500	300	0.7	5.0
Ammonium nitrogen	2	4.3	0.5	4.0	8.6
Nitrates	0.08	0.17	40	0.0	0.0
Nitrites	0.08	0.17	0.08	1.0	2.1
Calcium	43	113	180	0.2	0.6
Magnesium	8	14	40	0.2	0.4
Iron	0.3	1.7	0.1	3.0	17.0
Copper	0.02	0.076	0.001	20.0	76.0
Nickel	0.01	0.02	0.01	1.0	2.0
Zinc	0.3	0.55	0.01	30.0	55.0
Phosphorus	1.08	1.08	0.15	7.2	7.2

An important source of initial information for this ES assessment was information on chronically polluted lands in Russian Federation constituents (Prokacheva & Usachev, 2004). In this study the area of polluted lands was estimated by two methods. The first consisted in direct determination of polluted areas under snow cover on the basis of remote sensing data. Chronic technogenic pollution turns snow darker in comparison with clean or slightly polluted areas. As a result, sources of pollution (primarily developed areas) are surrounded by a dark aureole of dirty snow. As the authors have shown, the size of the aureole correlates well with a number of socioeconomic indicators of the polluter, in particular the population and the industrial and economic functions of the town. For areas where aureoles were not plotted on the basis of satellite images, polluted areas were estimated on the basis of the correlation found. In a similar way (either by decoding satellite information or by calculation), the aureoles of pollution from roads and railways were estimated.

Figure 40 shows the distribution of the percentage of persistently polluted area for regions on the basis of data from Prokacheva and Usachev (2004). The highest percentage of polluted area was in Moscow Oblast (60%), the lowest in Chukotka Autonomous Okrug (0.1%).

For further calculations it was assumed that all runoff from persistently polluted lands is polluted. The total and spring runoff (meltwater) were determined from digital maps from "Land Resources of Russia" (Stolbovoi & McCallum, 2002). The amount of meltwater from the polluted area of a region was estimated as the product of the mean spring runoff (mm) and the area of polluted land. The remaining portion of total runoff was regarded as rain runoff.

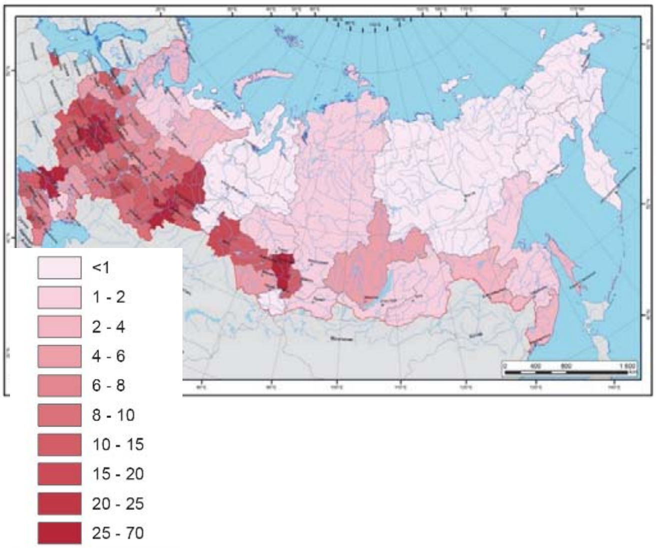


Figure 40. Percentage of polluted area by Russian Federation regions (%)

The demanded ES volume was assessed by final figures for polluted runoff (Fig. 41). In fact, it is the amount of polluted water running off of the persistently polluted lands. The figure for polluted runoff is directly proportional to the area of polluted land and is also a function of the amount of spring and total runoff.

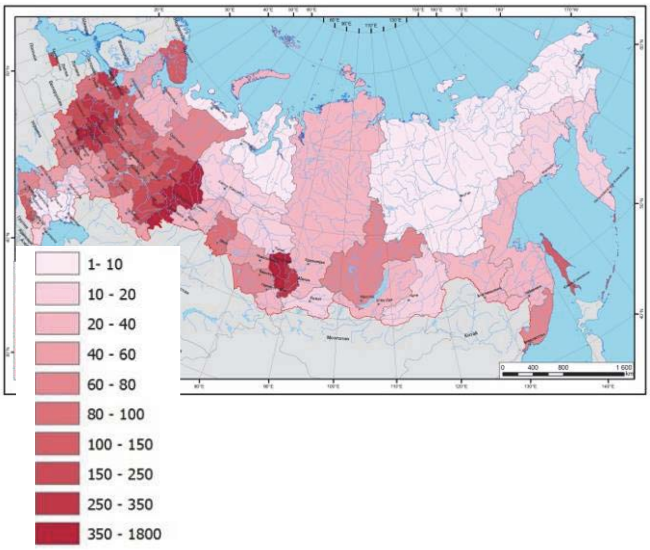


Figure 41. Demanded volume of the ES of water quality assurance by terrestrial ecosystems: volume of polluted runoff per 1 ha of region area, m^3/ha/yr

The total polluted runoff in the Russian Federation equals 95,949 million m^3. The highest intensities of polluted runoff are typical for highly polluted regions – those surrounding Moscow and Saint Petersburg, the Southern Urals, Kemerovo Oblast and Khakassia. The maximum polluted runoff (9820 million m^3) is observed in Kemerovo Oblast because of the large polluted area and quite a high runoff. The lowest polluted runoff intensities are found in the northern and central oblasts of Siberia and the Far East. The minimum (8 million m^3) is in the Republic of Kalmykia, with a moderate polluted land area and low water runoff.

The consumed ES volume was assessed as the amount of pollutants absorbed by terrestrial ecosystems. The aureole of persistent pollution may be found on different types of land: urbanized areas, arable lands, lands with different kinds of perennial vegetation (forests, meadows, tundras, steppes, wetlands, etc.). These types of cover interact in different ways with water runoff and pollutants in the runoff. The pollutant runoff modulus is highest for urbanized and arable lands, intermediate for pastures, and minimum or close to zero for forested lands (Jolankai, 1983, 1992). Unfortunately, the significant variations in estimates of the runoff moduli for different kinds of land use and the limited number of pollutants considered prevented the direct use of Jolankai's estimates to identify the quality of runoff for different kinds of land use. N. I. Balakay (2011) presents information on the ability of different agricultural plant covers to retain rainwater pollutants. With zero plant cover (complete fallow) there is no retaining ability (100% of pollutants are washed away); with 20–30% plant cover, 35%; with 40–60% plant cover, 10%; and with 60–80% cover, 4% of pollutants are washed away. Bearing these estimates in mind, we deemed it possible to use the following values for pollutant flushing: urbanized and arable lands – 100% of pollutants are washed away; all types of grassy ecosystems (meadows, tundras, steppes, etc.) – 40% of pollutants are washed away (60% runoff purification); all types of forest ecosystems – 10% of pollutants are washed away (90% runoff purification).

The satellite "Map of Terrestrial Ecosystems of Northern Eurasia" (Bartalev et al., 2004) was used to describe the distribution of polluted lands by land cover types. All land cover categories were grouped into 4 types: 1) urbanized lands; 2) arable lands; 3) forests; 4) other ecosystems. It was assumed that a region's urbanized lands are fully included in the persistently polluted area, while the remaining polluted area is distributed among arable land, forests and other ecosystems in the proportion typical for the given region. This assumption probably results in an overestimate of the percentage of polluted forests and other ecosystems as arable lands tend to be concentrated around population centers.

The total polluted runoff (in terms of meltwater) was distributed over the types of land cover (urbanized lands, arable lands, forests, other ecosystems) in proportion to their area. Then purification factors were applied to the runoff: 0 for runoff from urbanized and arable lands, 60% for runoff from other ecosystems, and 90% for runoff from forests. The sum of the values of purified runoff from all land cover types is the total purified runoff in a region. This figure is directly proportional to the figure for polluted runoff (the more polluted water, the more of it can be purified) and is a function of the proportions of the types of land cover in the polluted areas.

Figure 42 shows the intensity of runoff purification (i.e. volume of purified runoff per year per area) by terrestrial ecosystems for regions. The distribution of purified runoff resembles that for polluted runoff (Fig. 41), but there are differences determined by the distribution of polluted areas by type of land cover. The intensity of purification is therefore somewhat higher in the forest zones of the Russian Federation. The maximum amount of purified runoff occurs in Krasnoyarsk Krai (6581 million m^3), inasmuch as, given the comparatively large amount of polluted runoff (8885 million m^3) the percentage of forest on polluted areas there is extremely high (51.6%). The minimum amount of purified runoff is found in the Republic of Kalmykia (4 million m^3), inasmuch as there is extremely little polluted runoff there.

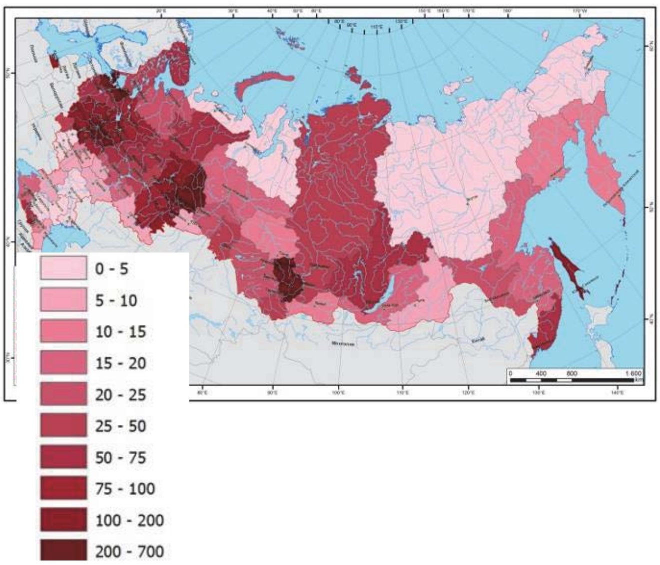


Figure 42. The consumed volume of the ES of water quality assurance by terrestrial ecosystems: volume of purified runoff per 1 ha of area of a region, m^3/ha/yr

The volume of the ES supplied by ecosystems was defined as the ecosystems' potential ability to purify runoff. This estimate was made using the same procedure as for the consumed ES volume (actually purified polluted runoff), but instead of the polluted area, the entire area of a region was evaluated. The maximum potentially purifiable runoff is attributed to Krasnoyarsk Krai (341,144 million m^3) because of its large size and a high proportion of forest in the region's area. The minimum potentially purifiable runoff is attributed to Kursk Oblast (56 million m^3) because of its small size, low forestation and low runoff. The total potentially purifiable runoff in the Russian Federation is about 2 triillion m^3. The volume of potentially purified runoff is maximum in the forest and tundra zones (Fig. 43). A forest is the most effective purifier of polluted runoff, while the tundra zone has a relatively small proportion of urbanized and arable lands.

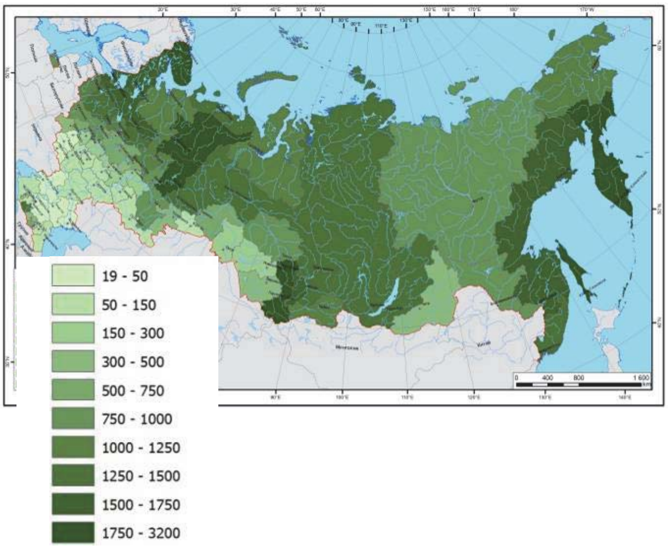


Figure 43. The volume of the ES of runoff purification supplied by terrestrial ecosystems: volume of potentially purified runoff per 1 ha of a region's area, m^3/ha/yr

Comparison of the supplied, demanded and consumed ES volumes

A unique feature of this ES is that the demand for the service cannot be entirely satisfied. Persistently polluted areas include urbanized and arable lands on which the runoff purification service is not provided or is extremely limited. Further, terrestrial ecosystems are not capable of completely purifying polluted runoff, especially during the snow melt period. All regions therefore have residual unpurified runoff $(V_{demanded} - V_{consumed})$, i.e., the demand for the service is not satisfied anywhere (Fig. 44a).

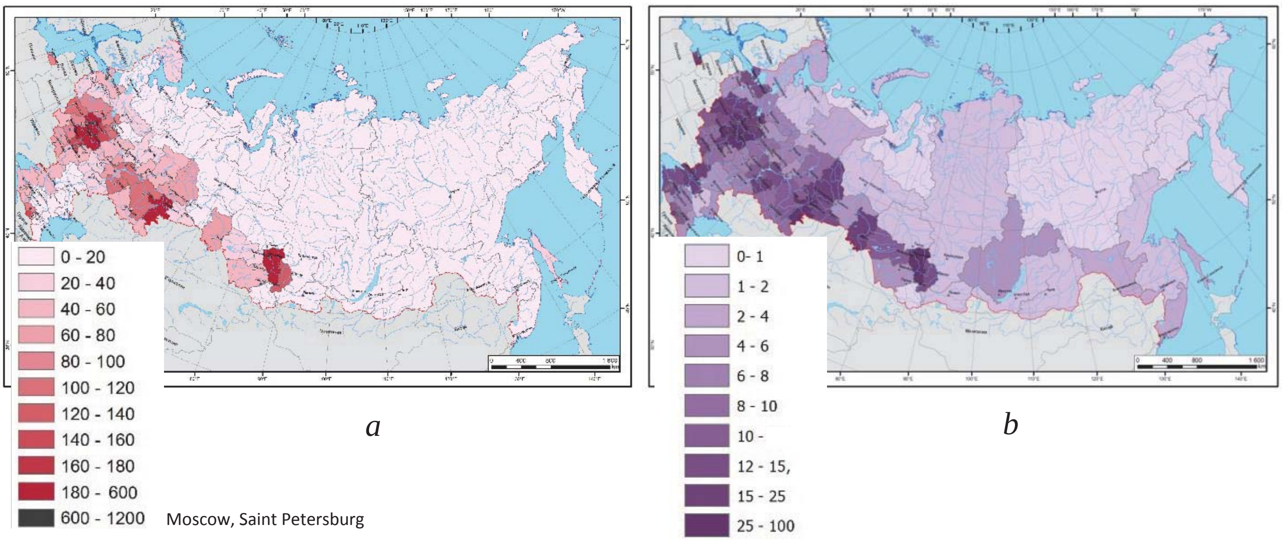


Figure 44. Satisfaction of the demand for the ES of water quality assurance by terrestrial ecosystems and the degree of ES use: a) residual unpurified runoff (m^3/ha/yr); b) actual purified runoff as a percentage of potentially purified runoff (%)

Another informative indicator is the degree of ES use, i.e., the ratio of the actual amount of purified runoff to the potential amount of purified runoff: ($V_{consumed}$ / $V_{supplied}$ × 100%). Figure 44b shows that in the most industrially developed regions the degree of ES use exceeds 25% (in the oblasts of Moscow and Tula it exceeds 50%). In many other regions of European Russia, the Urals and Western Siberia it exceeds 10%, but in the northern and central regions of Siberia and the Far East it does not exceed 2%.

Data required to assess and monitor the ES

The following data are necessary to assess the supplied, demanded and consumed ES volumes:

– data on the actual distribution of polluted areas by types of land cover, which may be obtained using local digital maps of the polluted areas (Prokacheva & Usachev, 2006, 2010, 2011);

– more precise values for the degree of runoff purification by different types of terrestrial ecosystems;

– detailed data on the concentrations of pollutants in the runoff from different types of land cover (similar to those presented in Table 8 for urbanized areas) for converting the amount of polluted runoff into the total quantities of pollutants.

Assurance of water quality by freshwater ecosystems

This ES, which assures the population and the economy of clean water, is most important on the local and regional (basin) level. The service includes two main components: dilution of pollutants to safe concentrations and conversion of pollutants into harmless substances due to the functioning of aquatic ecosystems. Thus, the ES efficiency depends on the amount of clean water in natural water bodies and the condition of aquatic communities of plants, animals and microorganisms able to convert pollutants into harmless substances. Transformations of aquatic communities lead to a modification of their water purification functions.

At present the most important factors that impact this ES are the pollution of water bodies, hydraulic construction, and invasions of alien species. Russia's rivers and lakes in economically developed regions are heavily polluted. Among Russia's main rivers, the ones with the greatest environmental problems are the Volga, Don, Kuban, Ob, and Yenisei. They are rated as "polluted" or "extremely polluted." Their major tributaries: Oka, Kama, Tom, Irtysh, Tobol, Miass, Iset and Tura are rated as "heavily polluted" (Nikanorov, 2012). Hydraulic construction has converted the majority of major rivers into chains of standing water bodies with variable water level and severely disturbed ecosystems with depressed flora and fauna. The establishment of alien species is also changing the structure and functioning of aquatic ecosystems. Accordingly, the ability of disturbed ecosystems to perform the ES of water purification has changed.

The demanded ES volume is defined as the amount of wastewater annually discharged into water bodies. It was assessed according to the FSSS database "Regions of Russia" (Rosstat, 2013b) (Fig. 45). "Polluted wastewater" is defined as industrial and domestic (sewer) runoff discharged into surface water bodies without treatment (or after insufficient treatment) and containing pollutants in quantities that exceed the approved maximum allowable discharge. It does not include collector and drainage water removed from irrigated lands.

The intensity of wastewater discharge (m^3/ha/yr) was estimated by dividing the total annual wastewater discharge in the regions by their area (Fig. 45). The intensity of wastewater discharge is maximum throughout almost all of European Russia and the Urals (except the northeast), where the figure exceeds 20 m^3/ha/yr. The distribution of the intensity of wastewater discharge is determined primarily by population density and the location of industrial facilities.

Wastewater entering natural water bodies is diluted by natural water. The degree of dilution depends on the ratio of wastewater to natural water and on the concentration of pollutants. To determine pollutant concentrations in wastewater, we used information from the government report "On the State and Protection of the Environment of the Russian Federation in 2013" (Ministry of Natural Resources and Environment of the Russian Federation, 2014) (Table 9).

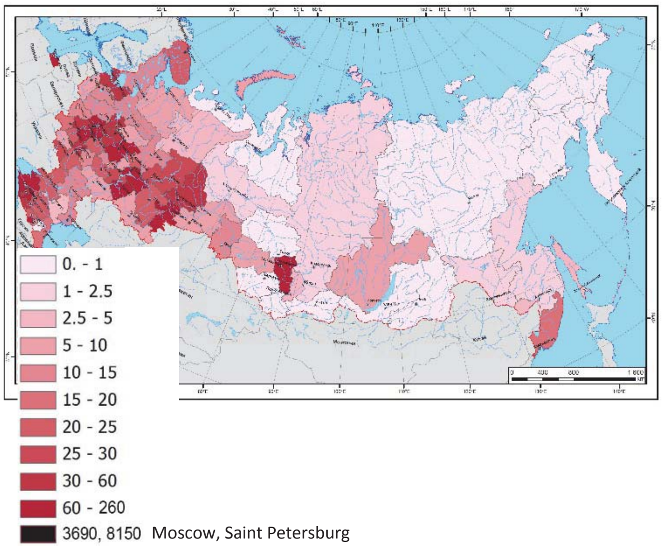


Figure 45. Demanded volume of the ES of assurance of water quality by freshwater ecosystems: discharge of polluted wastewater per unit of area of a region (m^3/ha/yr)

For further calculations it was assumed that all pollutants are discharged into water bodies with polluted wastewater, the total amount of which in 2013 was 15,189 million m^3 (FSSS database "Regions of Russia", Rosstat, 2013b). By dividing the mass amounts of pollutant discharge by the total amount of wastewater, we obtain an estimate of the pollutant concentrations in wastewater (Table 9). Let us compare these concentrations with the corresponding maximum allowable concentration (MAC) values for fishery water bodies. For the majority of pollutants, the ratio of concentration to MAC is from 0.01 (urea) to 57 (suspended solids). The ratio for iron, 2136, is outside this range. Analysis of information on the degree of contamination of rivers in different basins (Nikanorov, 2011) shows that iron is indeed one of the most significant pollutants, but the factor by which the MAC for iron is exceeded in river water varies from the single to the double digits. In view of this contradiction (the volume of discharge of iron is not supported by information on pollutant monitoring in river water), iron was not included in the further assessment of the ES.

The standard-setting practice for pollutant discharge requires that the sum of the ratios of the pollutant concentrations to the corresponding MACs must not exceed 1 (Vladimirov & Orlov, 2009):

$$\frac{C_1}{MAC_1} + \frac{C_2}{MAC_2} + \ldots + \frac{C_n}{MAC_n} \leq 1, \qquad (4)$$

where C_i is the concentration of substance i in a water body, and MAC_i is its maximum allowable concentration. The value calculated using the data in Table 9 according to the left-hand side of the inequality (4) equals 130. This in fact means that discharged wastewater must be diluted by a factor of 130 to achieve a safe content of pollutants in water bodies. Recall that this assessment does not include discharges of iron. Otherwise the required dilution factor would equal 2267.

The ES volume supplied by ecosystems is defined as the amount of wastewater that an aquatic ecosystem dilutes and transforms to safe concentrations. In the present report, some important components of the ES of water quality assurance are not considered, namely the movement of pollutants from the water column to bottom and floodplain deposits, biological absorption by aquatic, littoral and floodplain plant communities and the export of pollutants to outside the water body. Obviously, in future assessments these components must be taken into account.

The section "Regulation of runoff volume" covered in detail procedures for determining the water balance of an area and presented a diagram of the distribution of total runoff for the RF constituents based on information from the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002). Water runoff in a region should be viewed as the basis for the ES supplied. The more runoff, the greater the amount of wastewater that can be diluted to safe concentrations. One must take into account that about 53% of total runoff is attributable to the period of snow melt and spring flooding. Spring flooding usually lasts about 10–15 days on Russia's rivers. Assuming that the amount of wastewater is uniformly distributed over the seasons, it can be assumed that the spring runoff dilutes only 3–4% of the total wastewater volume. For this reason, spring flood runoff was excluded from total runoff in the assessment of the ES.

Table 9. Pollutant discharge (Ministry of Natural Resources and Environment, 2014), MACs for fishing water bodies (The list of fishery management standards, 1999), self-purification coefficients (Sturman, 2003) and ratios of pollutant concentrations in wastewater to their MACs

Pollutant	*Discharge, t*	*MAC, mg/L*	*Content in waste-water, mg/L*	*Ratio of content to MAC*	*Self-purification coefficient, 1/days*	*Ratio of content to MAC with allowance for pollutant transformation*
Chlorides (Cl^-)	5,724,727	300	376.90	1.26	0.1	0.56
Iron (Fe^{2+}, Fe^{3+})	3,244,813	0.1	213.63	2136.29	0.1	959.90
Sulfate anion (sulfates) (SO_4^{2-})	1,814,094	100	119.43	1.19	0.1	0.54
Nitrate anion (NO_3^-)	437,873	40	28.83	0.72	0.9	0.00
Calcium (Ca^{2+})	402,294	180	26.49	0.15	0.1	0.07
Sodium (Na^+)	374,559	120	24.66	0.21	0.1	0.09
Suspended solids	215,574	0.25	14.19	56.77	0.15	17.10
Total BOD	158,486	3	10.43	3.48	0.125	1.28
Boron (B^{3+})	102,883	0.5	6.77	13.55	0.1	6.09
Ammonium nitrate	93,544	0.5	6.16	12.32	0.9	0.01
Phosphates (P)	25,043	0.15	1.65	10.99	0.9	0.01
Magnesium (Mg) (all water-soluble forms)	34,535	40	2.27	0.06	0.1	0.03
Potassium (K^+)	36,979	10	2.43	0.24	0.9	0.00
Thiolignin	11,723	2	0.77	0.39	0.1	0.17
Nitrite anion (NO_2^-)	5,818	0.08	0.38	4.79	0.14	1.56
Ammonium lignosulfate	3,561	1	0.23	0.23	0.1	0.11
Urea (carbamide)	6,339	80	0.42	0.01	0.1	0.00
Fats/oils (of natural origin)	2,761	0.01	0.18	18.18	0.1	8.17
Fluorine (F^-)	2,259	0.05	0.15	2.98	0.1	1.34
Oil and petroleum products	2,292	0.05	0.15	3.02	0.044	2.12
OP–10, surfactants	1,517	0.5	0.10	0.20	0.3	0.02
Benzene	657	0.5	0.04	0.09	0.044	0.06
Sum of the ratios (without iron)				130.80		39.32

The dilution component of the supplied ES was assessed as the mean amount of wastewater per unit of area of a region that can be safely diluted in the water runoff of that region. The amount of runoff in a region (minus spring flood runoff) divided by 130 yields the amount of wastewater that can potentially be diluted to safe pollutant concentrations in the region. This indicator can be called the potential intensity of safe wastewater discharge (Fig. 46).

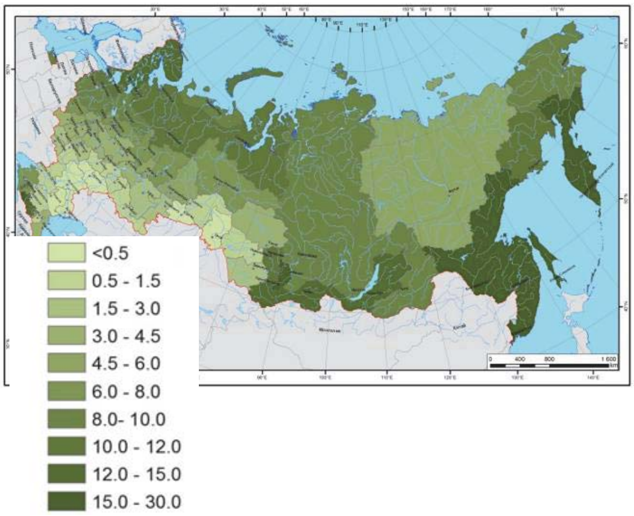


Figure 46. Supplied volume of the ES of wastewater dilution: the amount of wastewater that can potentially be diluted to safe concentrations in the region (m^3/ha/yr)

One of the specific features of supplying the service of wastewater dilution is that this dilution takes place not only in the wastewater discharge from the region, but also in the polluted water that flows from upstream regions. This "interregionality" contributes to a situation in which the need for the dilution service can substantially exceed the supplied ES volume in the region. Figure 47 illustrates the difference between the demanded and supplied volumes ($V_{demanded} - V_{supplied}$) of the service of pollution dilution. In the majority of regions of European Russia and the Urals and in southern West Siberia the demanded ES volume exceeds the supplied volume, i.e., dilution by water is unable to neutralize incoming pollution (red spectrum in Fig. 47). The values on the map for these regions show the amount of wastewater that remains hazardous after it is diluted in water bodies, i.e., the shortage of the service. Pollution can be neutralized through dilution only in the least developed regions of the country (green spectrum). In these regions there is a surplus of the supplied ES.

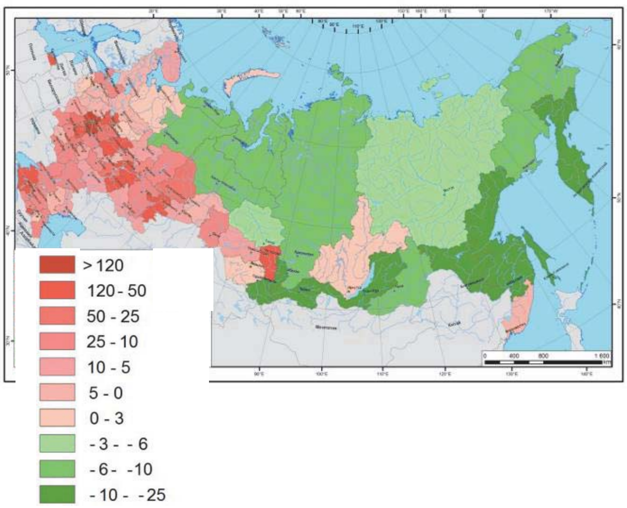


Figure 47. Deficit or surplus of the ES of wastewater dilution: untreated remainder of wastewater (negative values, red spectrum) or the unused capacities of wastewater dilution (positive values, green spectrum) per unit of area of a region (m^3/ha/yr)

The component of pollutant transformation of the supplied ES (hereinafter water self-purification) encompasses the so-called non-conservative (basically organic and biogenic) pollutants. Their concentration varies as a result of chemical, biochemical and physical processes in water bodies. The dynamics of their content in water bodies is usually described by an exponential equation (Kalinin, 2010):

$$C_t = C_0 e^{-kt}, \qquad (5)$$

where C_0 and C_t are the initial and final concentration of the substance, mg/L; t is the purification period, days; k is the self-purification constant, 1/days.

The self-purification constant for different pollutants depends on the properties of the substance, the water temperature and the conditions for oxygen to enter the water body. The self-purification constant for water courses is about 3 times higher than that for stagnant water bodies (All-Russian Research Institute of Civil Defense, 1996). In a number of sources, self-purification constants are presented for three temperature gradations: above 15°C, from 10 to 15°C, and below 15°C (Sturman, 2003). It has been shown that self-purification constants may differ significantly (by an order of magnitude) between different tributaries in the same river basin (Kalinin, 2010).

Unfortunately, published sources (All-Russian Research Institute of Civil Defense, 1996; Sturman, 2003) present self-purification constants only for a limited number of pollutants. Absent actual values for a particular substance, we used two values for self-purification constants: 1) 0.9 for phosphates and potassium as common biogenic elements; 2) 0.1 for all other substances lacking constants (chlorides, sulfates, sodium, magnesium, boron, etc.). The self-purification constants used in subsequent calculations are presented in the corresponding column of Table 9.

To calculate self-purification using the exponential Equation (5), in addition to the self-purification constant one must know the purification period, i.e., the time during which the substance is in the water undergoing decomposition. Inasmuch as the present report does not discuss marine ecosystems, the purification period may be compared with the water refresh time in rivers, which actually corresponds to the so-called “flow time” from headwaters to mouth. Flow time is a common hydrometric parameter actively used in discussing processes of pollutant dilution and purification and forecasting spring floods and other channel events on the local level. Unfortunately, we were unable to find in the literature any generalization on refresh time, flow time or the instantaneous store of water in Russia’s rivers. In this regard we used a global estimate (Bogoslovsky et al., 1984), according to which the average water refresh time in rivers is 16 days. That the procedure for this estimate is correct is supported by the modeling of basin flow time (Savichev, 2014) and direct measurements of flow time in the rivers of Tiumen Oblast (Kalinin, 2010). Inasmuch as pollution sources are found along the entire river channel, the mean purification time will equal about half the refresh (flow) time. A period equal to 8 days was therefore used to assess self-purification.

The ES component of water self-purification was evaluated as follows. Equation 5 with self-purification coefficients (Table 9) was used to calculate the decrease in pollutant concentration over 8 days (in other words, the calculation was for $C_0 = 1$ and $t = 8$). For example, with a self-purification constant equal to 0.1 the chloride concentration will equal 0.45 of the baseline after 8 days. Then the ratio of the pollutant content in wastewater to its MAC and the reduction in its concentration were calculated. These figures show the required dilution given that the substance is transformed over 8 days. Finally, inequation (4) was used to find the safe dilution of wastewater taking into account water self-purification.

The calculations show that, as a result of water self-purification, the supplied ES volume increases threefold compared with dilution alone, i.e., the required safe dilution of wastewater with allowance for the dilution and transformation of pollutants is 39 times (instead of 130 with allowance for dilution alone). Thanks to this, the supplied volume of the ES of wastewater dilution and self-purification in about half of Russia exceeds the demanded ES volume 20 m^3/ha/yr (Fig. 48) typical for regions with maximum polluted water discharge intensity.

The consumed ES volume equals the amount of pollutants actually neutralized thanks to water dilution and self-purification (Fig. 49). As stated above, in many regions the volume of wastewater discharge exceeds the ecosystems’ ability to purify them (red spectrum in Fig. 49). In these regions only the volume of wastewater that ecosystems can purify is purified, i.e., the consumed ES volume equals the supplied ES volume. In regions where the volume of wastewater discharge is less than the ecosystems’ ability to purify them (green spectrum in Fig. 49), the entire volume of discharge is purified, i.e., the consumed ES volume equals the demanded ES volume.

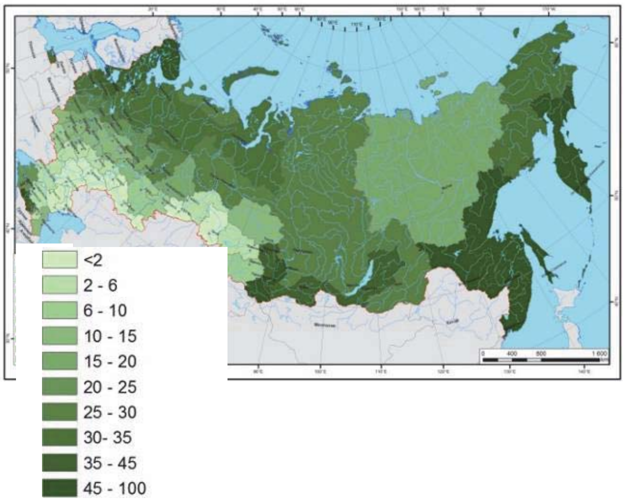


Figure 48. Supplied volume of the ES of assurance of water quality by freshwater ecosystems: the volume of wastewater that can potentially be diluted and purified to a safe concentration (m^3/ha/yr)

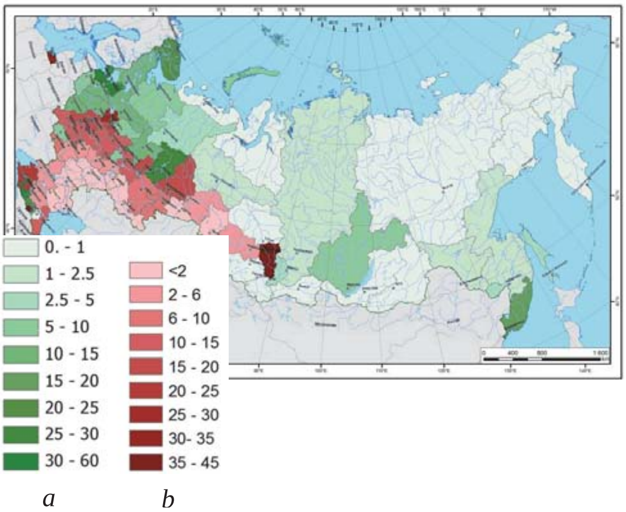


Figure 49. Consumed volume of the ES of assurance of water quality by freshwater ecosystems – volume of purified wastewater (m3/ha/yr):
a – regions where the volume of wastewater discharge is less than the capacities of ecosystems to purify it, the consumed ES volume equals the demanded ES volume;
b – regions where the volume of wastewater discharge exceeds the capacities of ecosystems to purify it, the consumed ES volume equals the supplied ES volume

Comparison of the supplied and consumed ES volumes

The indicator of the deficit or excess of the service *($V_{demanded}$ – $V_{supplied}$)* is informative in assessing this service (Fig. 50). In comparison with the ES component of wastewater dilution (Fig. 47), consideration of self-purification processes leads to a reduction in the number of regions that experience a deficit of this ES (the volume of wastewater discharge exceeds the capacities of ecosystems to purify them). These regions include those in arid areas of the southern European part of Russia and a number of industrially and agriculturally developed regions in the central and southern European part of Russia and southern West Siberia. A shortage of the ES of assurance of water quality in these regions indicates over-exploitation of river ecosystems.

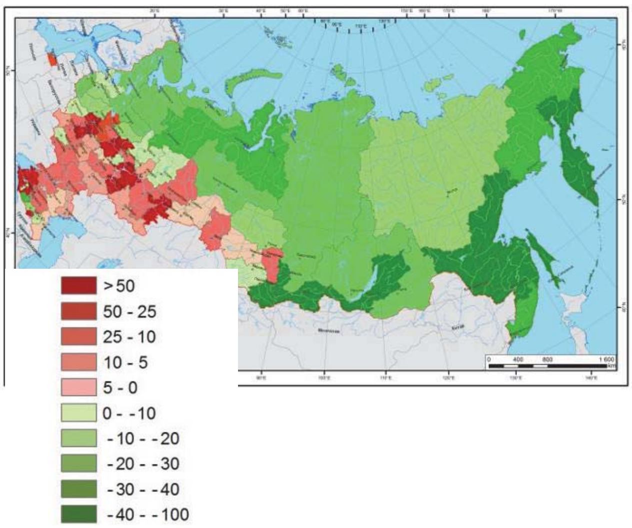


Figure 50. Deficit or excess of the ES of assurance of water quality by freshwater ecosystems: untreated wastewater remainder (negative values, red spectrum) or unused capacities of ecosystems to purify wastewater (positive values, green spectrum), m^3/ha/yr

Data required to assess and monitor the ES

The following data are necessary to assess the supplied, demanded and consumed ES volumes:

– detailed data on the content of pollutants in wastewater by region;

– the self-purification coefficients for water in water bodies with allowance for the type of water body and the zone it is in;

– the time for water to travel from headwaters to mouth for different basins.

Soil formation and protection

Soil protection from erosion

The ecosystem services of soil formation and protection are potentially the most important in three types of regions:

– agricultural regions (forest-steppe, steppe, semi-desert regions) – the important ES of forming fertile soils and protecting them from wind and water erosion;

– mountainous regions – the important ES of protecting soils from erosion on slopes and preventing landslides.

The ES of natural ecosystems in relation to the formation of soils and their protection from erosion consist in prevention of a number of negative processes: loss of agricultural and other economically important land, reduction of soil fertility and the soil's buffer function in relation to pollution, increased sediment and pollution discharge into water bodies, dust storms, landslides, mudflows, etc.

The ecosystem services of this group are extremely important for Russia, since they are key factors determining the efficiency of agriculture and the prevention of threats to infrastructure, housing and industrial facilities in mountainous areas.

The ES of formation and preservation of soil fertility has a local (point) scale of action. The ES of prevention of damage from dust storms and sediment discharge into water bodies should be considered at the regional and basin scale, as in these cases the benefit from the functioning of ecosystems is received by the population and economies located not only where erosion is prevented, but also in neighboring territories located in the direction of the prevailing winds or downstream.

Soil protection from water erosion

All terrestrial ecosystems that are natural (lightly altered by man) are considered suppliers of the ES of protecting soil from erosion.

The ES volume supplied by ecosystems can be assessed through the area protected from erosion by ecosystems. Another possible indicator is the amount of soil, the erosion of which was pre-

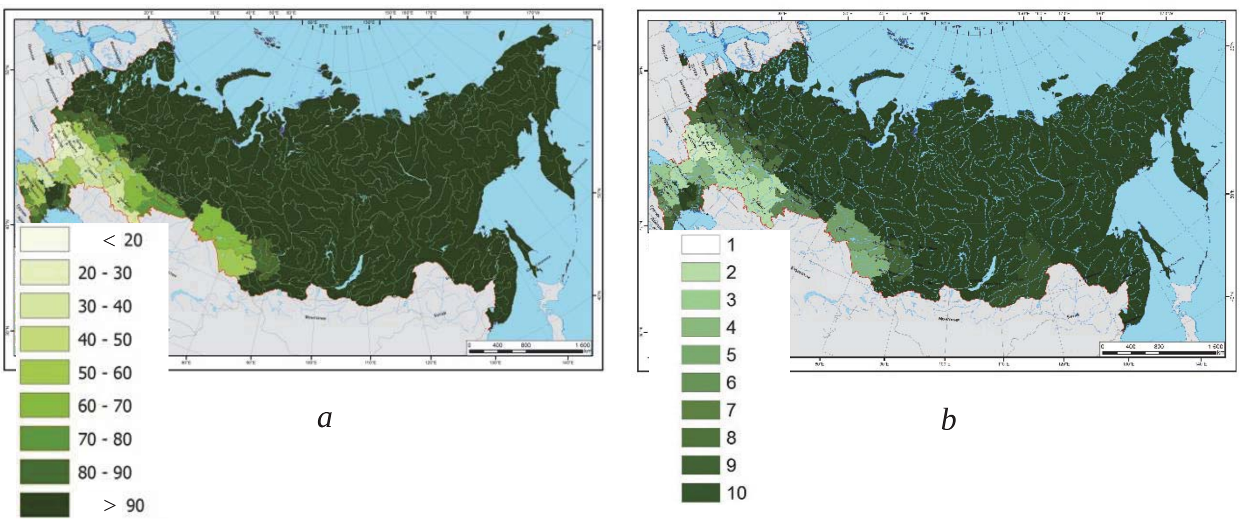


Figure 51. Supplied volume of the ES of preventing water erosion: a) percentage of natural areas in the regions (%); b) score of the supplied ES volume

vented by ecosystems. It was not possible to find data for a direct assessment of these indicators for all of Russia under this project. Inasmuch as quantification of this ES turned out to be impossible, the score of the service was estimated.

The supplied ES volume of the entire territory of the country was considered as a figure proportional to the area of the natural ecosystems in the regions. It was scored (Fig. 51) on the basis of existing data on the area of natural territories as a percentage of the area of the regions (Fig. 4).

The supplied ES volume in croplands was assessed separately. To do this, the area of natural ecosystems in 1-km zones surrounding the croplands was estimated. Croplands were identified using the map of terrestrial ecosystems (Bartalev et al., 2004) as croplands, forest–cropland complexes, and cropland–grassland complexes. After the vectorization of croplands (yellow in Fig. 52) 1-km-wide buffer zones were plotted around them (the boundaries of the zones are shown in red).

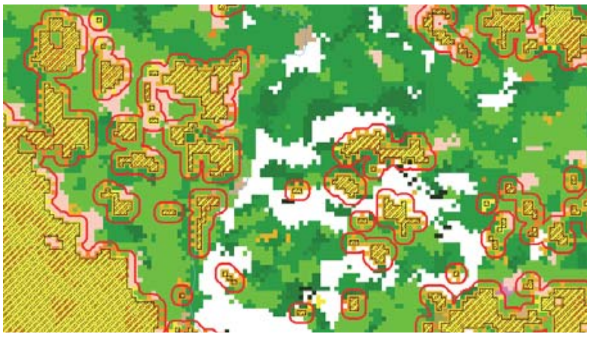


Figure 52. Highlighting of 1-km-wide buffer zones around croplands

Then the area of the buffer zones around the croplands by region *and* the area of the buffer zones as a percentage of the area of the region were calculated (Fig. 53a). On this basis a score of supplied volume of the ES of preventing cropland erosion was estimated (Fig. 53b). For future assessments, the soil-protecting ES of forests and other natural ecosystems may be quantified on the basis of the modeling of erosion processes with allowance for soil types, vegetation types, terrain, and regional climate characteristics.

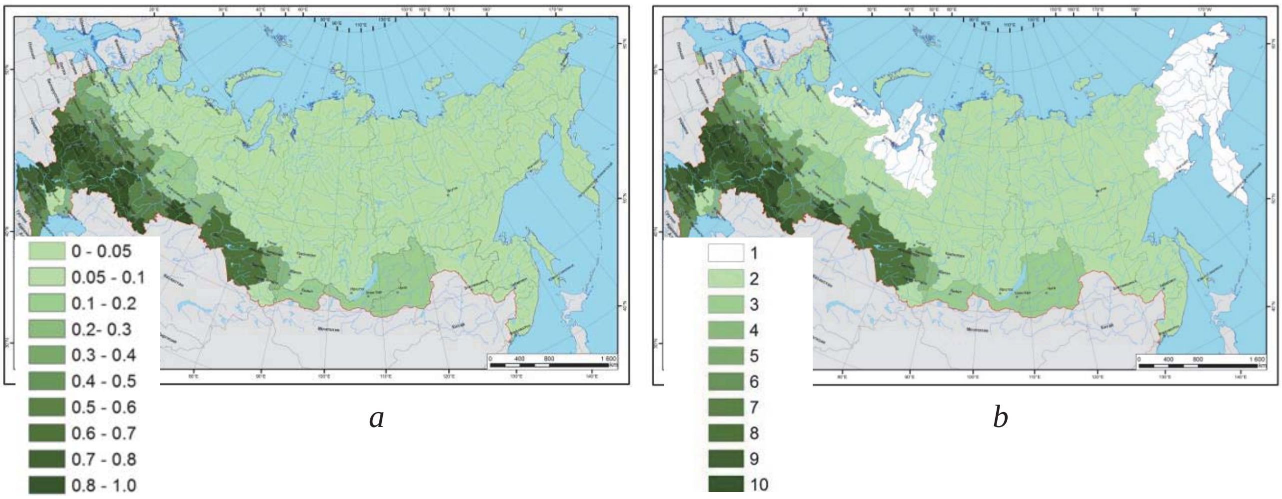


Figure 53. Assessment of the supplied volume of the ES of cropland erosion prevention: a) the area of buffer zones as a percentage of the area of the regions (%); b) score for the supplied ES volume (white indicates regions where there are no croplands according to the FSSS database "Regions of Russia")

The consumed ES volume is the amount of economic damage because of water erosion of soils that was prevented by ecosystems. At this stage of the project it is considered to be a figure proportional to two indicators: the area of croplands in the region and the degree of agricultural land erosion. The score of the first indicator was determined on the basis of data on the proportion of cropland area in the regions according to the FSSS database "Regions of Russia" (Rosstat, 2013b). The score of the second indicator was based on the map of the distribution of soil erosion in Russia (Shoba, 2011).

The combination of these two indicators yielded the score for the consumed volume of the ES of water erosion prevention (Fig. 54). The resulting assessment may also serve as the basis for the assessment of the **demanded** volume of the service.

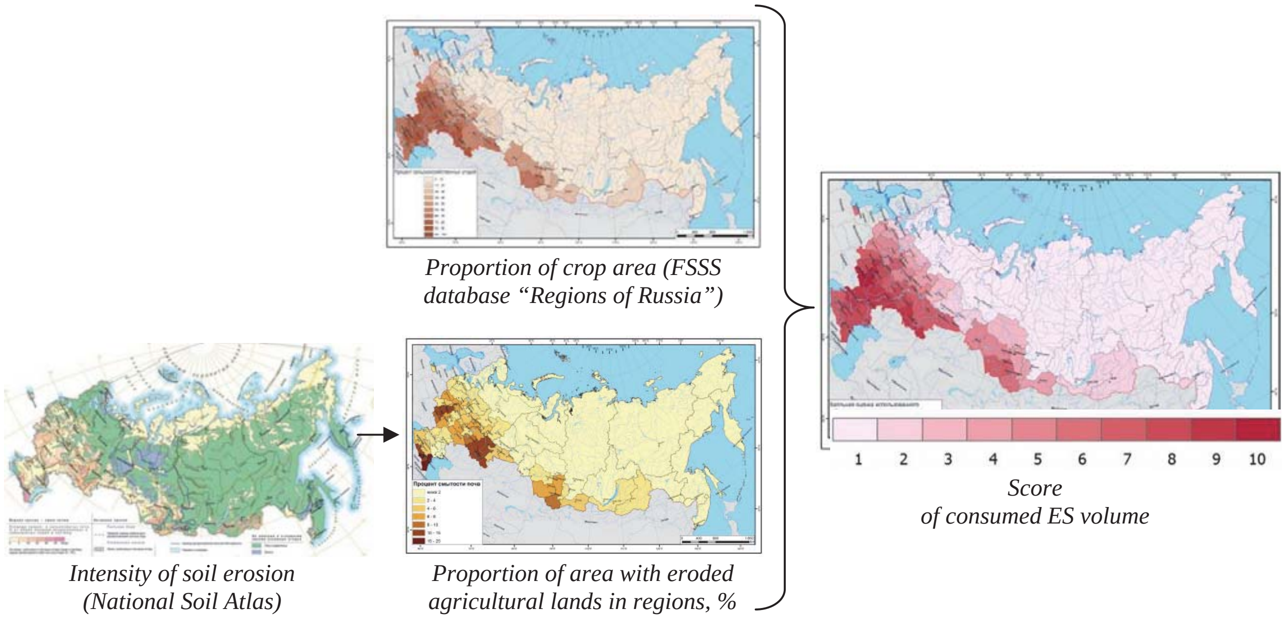


Figure 54. Estimation of the score of the consumed volume of the ES of water erosion prevention

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

Comparing the scores for the ES of water erosion prevention in the entire territory of the country ($V_{supplied} - V_{consumed}$) shows that the consumed ES volume is distributed among the regions in almost inverse proportion to the supplied volume. This result reflects only that the main reason for the reduction in the area of natural ecosystems is the agricultural use of the land and that soil erosion is most intense in the most intensely tilled regions. Figure 55a shows that in the regions of the northern half of European Russia and almost the entire Asian part of the country the natural factors supporting the service are stronger than the factors of its use (green). Socioeconomic factors for ES use are stronger

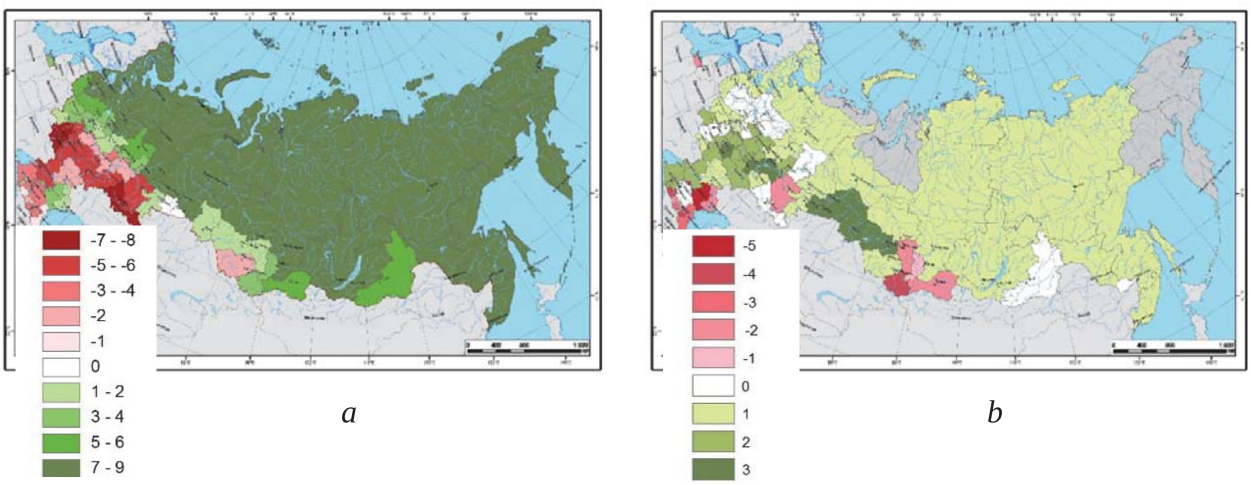


Figure 55. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of preventing soil erosion by water: a) for the entire country; b) for croplands (regions where there are no farm crops according to the FSSS database "Regions of Russia" are shown in gray)

in the agricultural regions in the southern European part of the country and Western Siberia (red). Regions where natural and socioeconomic factors are approximately equal (white) fall in the middle.

Comparing ES supplied and consumed scores $(V_{supplied} - V_{consumed})$ for croplands yields an ambiguous picture (Fig. 55b). Inasmuch as natural ecosystems adjacent to croplands in the northern, Siberian and Far Eastern regions, where farm plantings are relatively insignificant, were considered natural factors supporting the service, these factors received a low score in those regions, but still outweigh the natural factors determining the ES consumption (light green in Fig. 55b). The dominance of natural factors that support the service in the agricultural regions of the center of European Russia and in southern West Siberia is explained by the high percentage of natural ecosystem area adjacent to the croplands. Among the regions where socioeconomic factors determining the consumption of and demand for the service are dominant is the Altai Republic (dark red), where the area of washed out agricultural soils is relatively high (which increases demand for the service), while the area of croplands and, accordingly, the area of ecosystems in buffer zones is relatively small (which reduces the supplied ES volume).

Data required to assess and monitor the ES

To assess the supplied ES volume:

– the area of natural ecosystems with small and medium watersheds;

– the relationship between the percentage of the area of natural ecosystems and the percentage of eroded lands (amount of eroded soil) found for small and medium watersheds;

– data for modeling the erosion process (erosion intensity as a function of terrain, soil types, vegetation types, regional climate, etc.)

To assess the consumed (demanded) ES volume:

– the area of eroded agricultural lands;

– the area of eroded lands important for other sectors of the economy.

Soil protection from wind erosion and prevention of damage from dust storms

The ES volume supplied by ecosystems is determined in the same way as for the service of preventing water erosion (Fig. 51, 53).

The consumed volume of the ES of preventing soil erosion by wind, as in the previous case, is proportional to two indicators: the presence of soil erosion by wind in regions and the area of croplands. The score of the first indicator is based on the map of the distribution of basic types of soil erosion according to the database "Land Resources of Russia". The second indicator is assessed just as in the previous case as the percentage of cropland area according to the FSSS database "Regions of Russia" (Rosstat, 2013b). Combining these two scores yields an assessment for the consumed ES volume (Fig. 56). This resulting score may also serve as the assessment of the **demanded ES** volume.

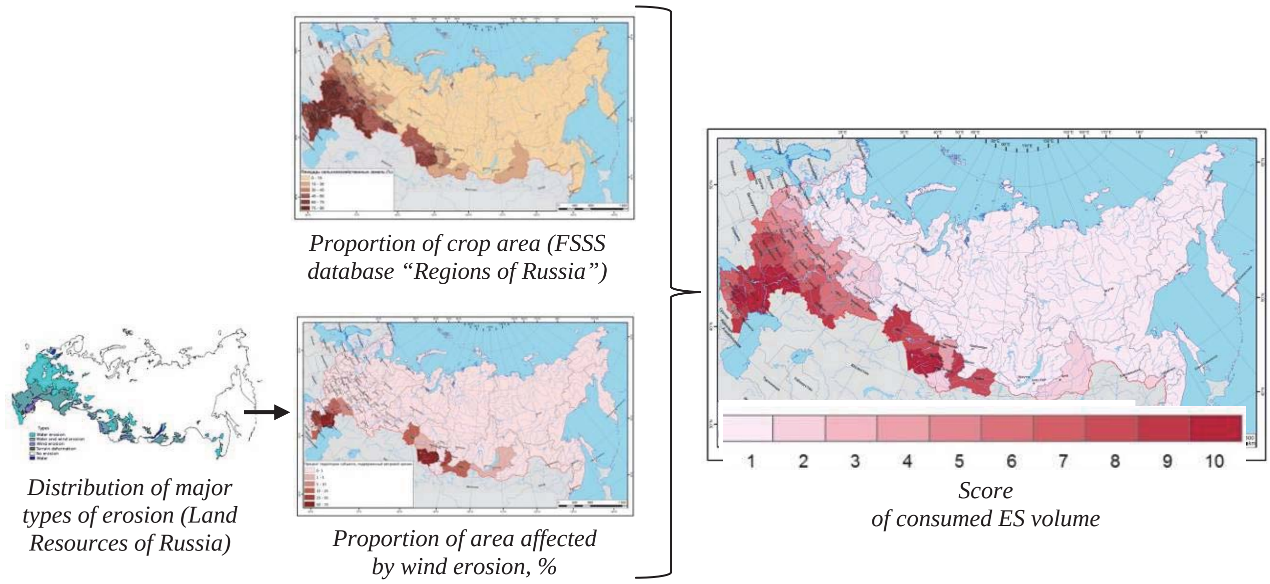


Figure 56. Estimation of the score of the consumed volume of the ES of preventing wind erosion

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

Comparing the scores of the supplied and consumed service *($V_{supplied} - V_{consumed}$)* of preventing wind erosion yields a result similar to that for water erosion. For the entire territory of the country, the consumed (demanded) ES volume was distributed among regions in almost inverse proportion to the supplied volume. Figure 57a shows that in regions of the northern half of European Russia and almost the entire Asian part of the country natural factors supporting the service are stronger than factors of ES consumption (green). Socioeconomic factors of ES consumption are stronger in the agricultural regions (red). Regions where natural and socioeconomic factors are approximately equal (white) fall in between.

Comparing supplied and consumed ES scores for agricultural lands (Fig. 57b) shows that socioeconomic factors determining the consumption of and demand for the service dominate in regions were wind erosion is common (see Fig. 56).

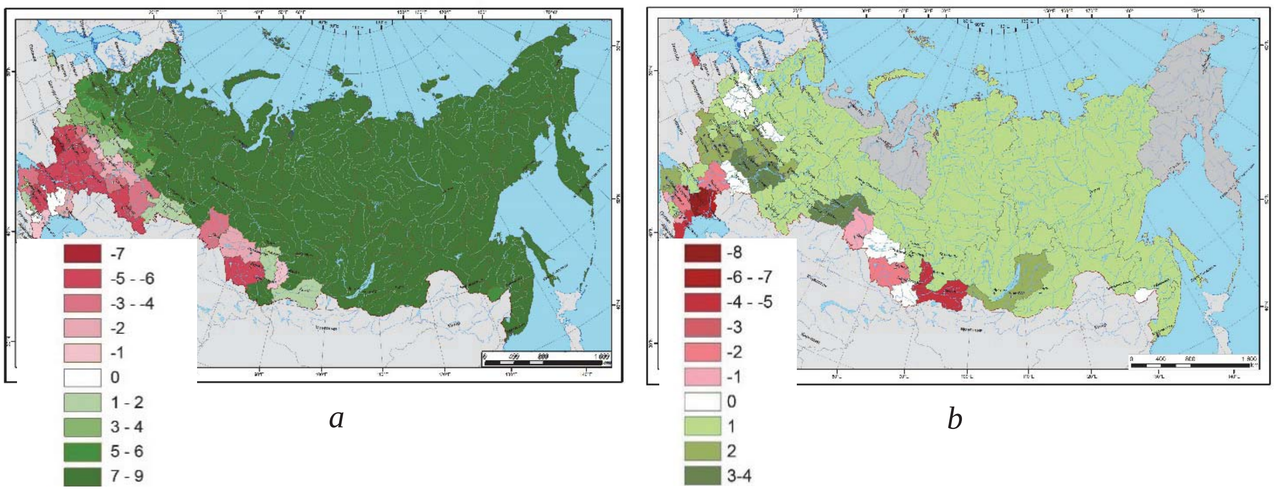


Figure 57. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of preventing soil erosion by wind: a) for the entire country; b) for croplands (regions where there are no farm crops according to the FSSS database "Regions of Russia" are shown in gray)

Data required to assess and monitor the ES

To assess the ES volume supplied by ecosystems:

– the relationship between the percentages of the area of natural ecosystems and the percentages of eroded lands (amount of wind-eroded soil);

– data for modeling the erosion process (the intensity of erosion as a function of the terrain, soil types, vegetation types, regional climate, etc.).

To assess the consumed (demanded) ES volume:

– area of eroded agricultural lands;

– area of eroded lands important to other sectors of the economy;

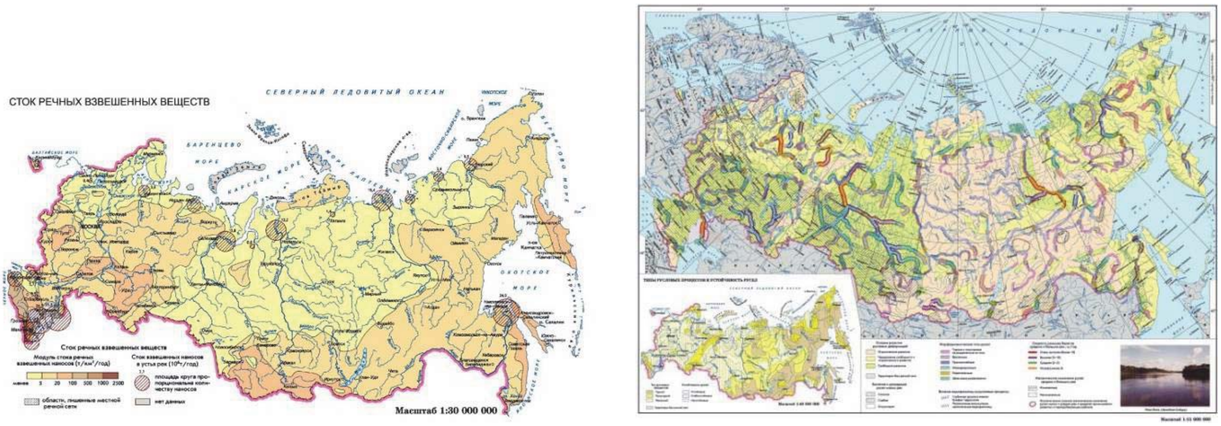
– damage from wind-borne soil and dirt.

Prevention of damage from soil washing into water bodies

Statement of the task of ES assessment

Approaches to the assessment of this service are the same as those for the service of preventing soil erosion, but this service has a non-point (non-local), but rather a basin-wide impact, inasmuch as the population and economies located downstream of the ecosystems that supply it benefit from the prevention of soil washout into water bodies thanks to the functioning of the ecosystems.

The ES volume supplied by ecosystems equals the amount of dirt washout into water bodies prevented by ecosystems. Initially the intensity of soil washout into water bodies may be assessed on the basis of the relationship between the area of the natural ecosystems in basins and the amount of soil washout, if any. Obviously the different types of terrains and soils in the regions must be taken into account. Preliminarily, the intensity of soil washing into water bodies can be estimated from the National Atlas of Russia (2004–2008) (Fig. 58).



a *b*

Figure 58. Examples of maps for assessing the supplied ES of preventing damage from soil washing into water bodies (National Atlas of Russia): a) amount of suspended matter in river water; b) channel processes, including siltation

The consumed ES volume is the amount of soil washout into water bodies causing direct economic damage that is prevented by ecosystems. If ecosystems prevent soil washout into water bodies in completely uninhabited locations where there is no population or economy, the service is not consumed there. The population using polluted water and various sectors of the economy may be damaged by soil washout into water bodies. These economic sectors include industry, farming, fishing, fish husbandry, and navigation. These components of potential damage must be considered in assessing the consumed and demanded volumes of this ecosystem service.

Prevention of damage from landslides and mudflows

Statement of the task of ES assessment

This service is provided by ecosystems first and foremost in mountainous areas and in areas with complex terrain (Fig. 59). This service may also be important in regions where intense processes of water body shore destruction are observed.

Figure 59. Areas of Russia where there is a danger of mudflows and landslides (National Atlas of Russia)

The indicator for the **supplied ES volume** is the reduction in the probability of mudflows and landslides due to natural ecosystems on the slopes and shores.

The indicator for the **consumed ES volume** is the reduction in the probability of mudflows that might directly harm people and the economy. The main factors impacting it are population density, regional GDP, and the cost of fixed assets (for example, from the FSSS database "Regions of Russia").

Establishment of soil bioproductivity

Statement of the task of ES assessment

The effect of natural ecosystems on the soils that are part of them is not considered as an ecosystem service. This is an example of the ecological processes that underlie the ecosystem functioning. Ecosystem services can be considered as the influence of natural ecosystems on the soils used (now and in the recent past) by man, and may include the following processes.

1. The effect of natural ecosystems on the bioproductivity of soils currently used by man. We know that a forest a certain distance away affects the property of soils in adjacent fields. The impact of natural ecosystems on the productivity of agricultural soils is multifaceted and includes effects on the moisture content, organic matter, the diversity of soil biota, etc.

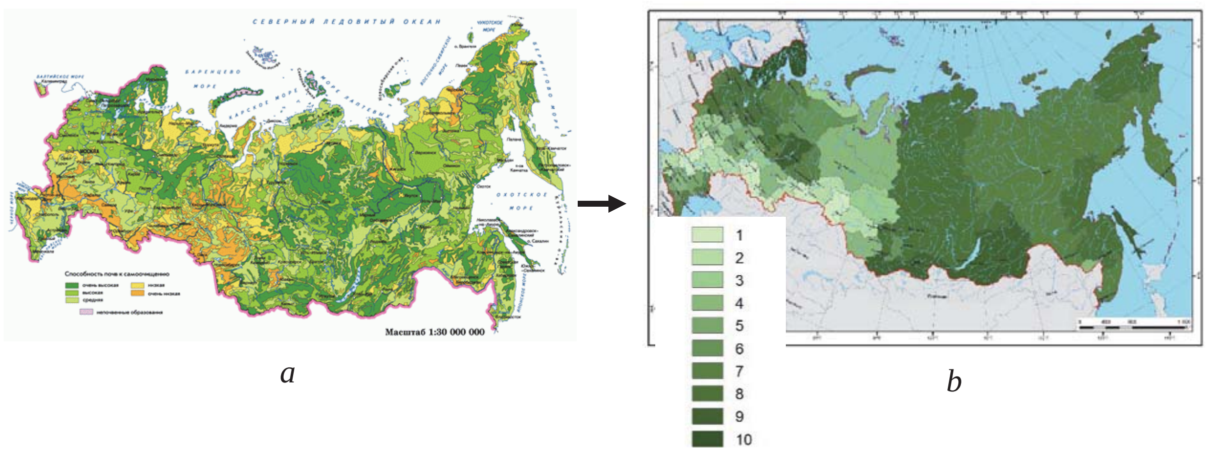
2. The establishment of the bioproductivity of soils previously unused by man but now in use, i.e., the integral natural ecosystem function becomes a service when humans till virgin soil.

3. The restoration by natural ecosystems of the bioproductivity of soils disturbed by man, in particular on fallow land and degraded pastures. In 2005 there were about 27 million ha of fallow land in just the steppe part of the country, and the area of stripped pastures was in the millions of hectares. It was primarily arable land and pastures with greatly reduced productivity that were abandoned. These areas with degraded soils measure in the tens of percents of the total area of crops and natural pastures in the country. After 10 or more years of restoring succession these soils have greatly improved basic indicators.

4. The formation of soils on technogenic substrates – mine and dredging dumps, pit walls and bottoms, debris in settling ponds and treatment facilities, etc.

Soil self-purification

The ES volume supplied by ecosystems was assessed on the basis of a map of soil capacity for self-purification from the National Atlas of Russia (2004–2008), where the soils' capacity for self-purification is assessed in a 5-point system: very high (5), high (4), moderate (3), low (2), very low (1). The map was vectorized, and the area for each value was determined in all regions. Then, the mean value for each region was calculated. The range of mean values covering integer and fractional numbers from 1 to 5 was divided into 10 classes, and a 10-point assessment of the supplied ES volume was determined (Fig. 60).



a *b*

Figure 60. Estimation of the score of the supplied volume of the ES of soil self-purification: a) map of soil capacity for self-purification (National Atlas of Russia); b) the score of the supplied ES volume

The consumed ES volume was determined by the decrease in damage from soil pollution. The main factors influencing this indicator are the following (Fig. 61):

– population density (FSSS database "Regions of Russia", Rosstat, 2013b);
– percentage of the area of farm crops in the regions (FSSS database "Regions of Russia", Rosstat, 2013b);
– percentage of the polluted area in the regions (data from: Prokacheva & Usachev, 2004).

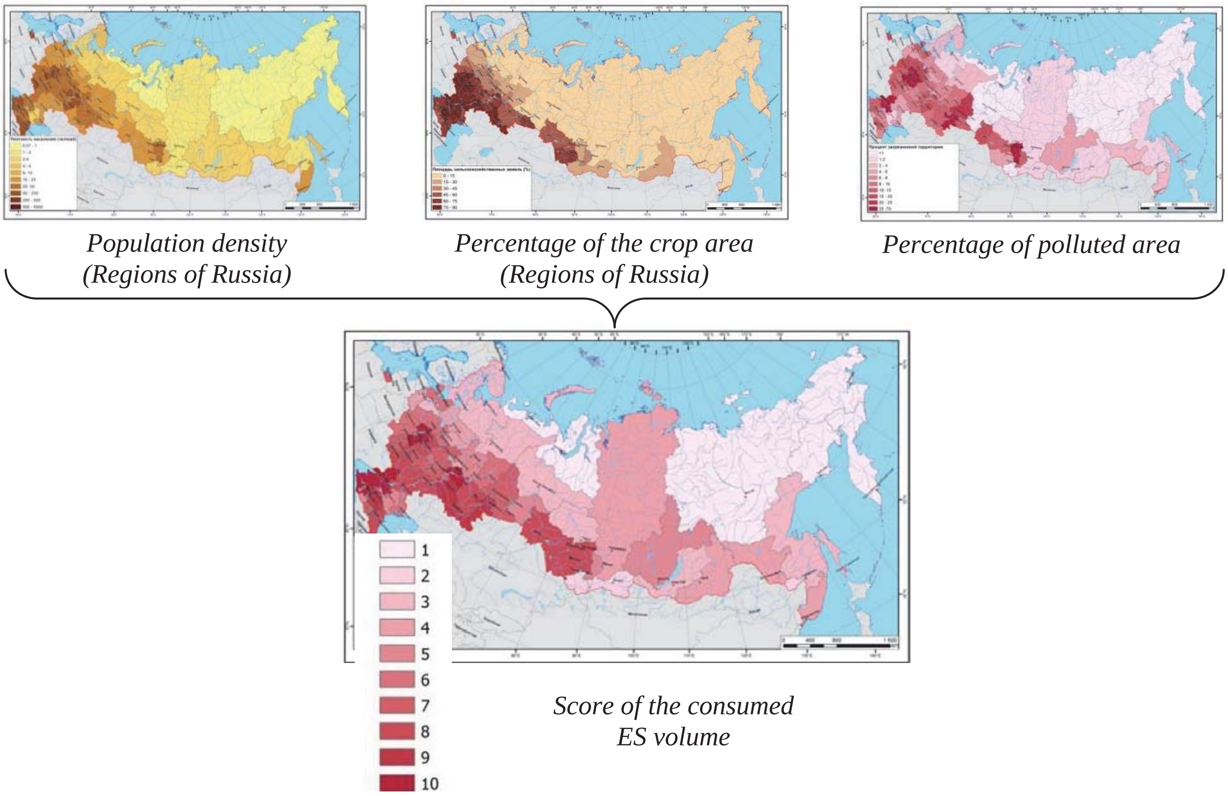


Figure 61. Estimation of the score of the consumed volume of the ES of soil self-purification

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

Comparison (Fig. 62) shows, as for other ES from the "soil" group, that the supplied and consumed volumes of the service are distributed in area in approximately inverse proportion. The maximum demand for the ES and its most intense use are seen in the farming regions of the southern belt of the country, where all three of the factors (population density, area of croplands, degree of soil pollution) have the highest values. But it is in these regions that the supplied ES volume is minimum. Soils of forest regions (except wetlands) have the maximum capacity for self-purification. But these regions need less of the service. The difference between the scores of supplied and consumed ES volumes $(V_{supplied} – V_{consumed})$

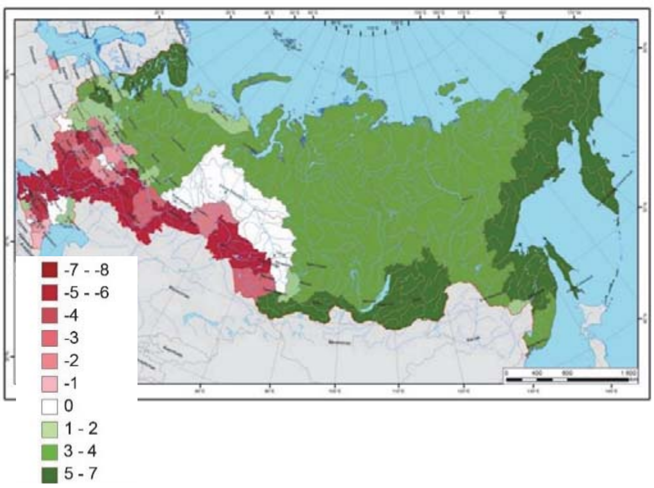


Figure 62. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of soil self-purification.

shows that in the southern regions of European Russia, the Urals and West Siberia (negative values and the red spectrum in Fig. 62) socioeconomic factors determining the high demand for the service relatively outweigh natural factors that determine the performance of the service by ecosystems. In a larger part of the country (the northern European part, the greater part of Siberia and the Far East, positive values and green spectrum in Fig. 62) natural factors supporting the service relatively outweigh socioeconomic factors for its consumption. Regions where the factors are approximately equal are shown in white.

Data required to assess and monitor the ES

Indicators of the soil capacity for self-purification and the behavior of pollutants in them from the National Atlas Russia (2004–2008) (Fig. 63) may be used to clarify the estimation of the supplied ES volume. Quantification of the supplied ES volume requires data on the rate at which different pollutants are processed in different types of soils.

Quantification of the consumed ES volume requires data on the rate at which various pollutants end up in soils. Quantification of the prevented damage requires data on the rate at which pollutants pass from the soil into farm products and on the amounts of products grown on polluted soils.

a b c

Figure 63. Examples of maps for clarifying the assessment of the supplied volume of the ES of soil self-purification: a) The capacity of soils for self-purification from oil and petroleum products; b) prediction of pesticide behavior in soils; c) conditions of migration of heavy metals in soils (National Atlas of Russia)

Regulation of cryogenic processes

Cryogenic processes are physical, physicochemical and biological processes that take place as a result of the cooling of rock to negative temperatures, their freezing and thawing (Mudrov, 2007). Cryogenic processes are present wherever there are phase transitions from water and water vapor to ice. Seasonal freezing of top layers of soil occurs in winter throughout almost all of Russia. Seasonal freezing changes the nature of the functioning of ecosystems, hydrologic behavior, and gas exchange, limiting the functioning of the majority of microorganisms. Permafrost is found in northern areas, along with seasonal freezing and thawing. Permafrost, i.e. rock which, for at least two consecutive years, has a temperature below 0 °C and contains ice (Romanovsky, 1980) occupies about 65% of the Russian Federation.

Millions of people live in permafrost areas permanently and engage in economic activity there. The specific features of permafrost dictate the importance of state regulation of construction, safety, and mineral extraction in permafrost areas. If full removal of anthropogenic heat from the rock surface is not provided, this heat one way or another changes the condition of the permafrost – its temperature and the position of the roof.

Modern climate change, with a clear trend toward the warming of summer, fall and spring in the majority of permafrost areas (Second assessment..., 2015) also results in additional entry of heat into permafrost rock. In many regions the temperature of the permafrost is rising (Romanovsky et al., 2010); in some regions there are marked trends toward an increase in the depth of the seasonal permafrost thaw (Circumpolar active layer monitoring, 2015, www2.gwu.edu/~calm). The thawing of ice horizons initiates processes of permafrost degradation – a change in the position of the permafrost roof, and a new appearance of ecosystems. The ecosystem service of regulating cryogenic processes is considered with allowance for modern trends in global climate change.

Cryogenic processes are regulated by changing the parameters of permafrost heat exchange with the environment. This pertains to engineered permafrost amelioration (Ilyichev et al., 2003), and to permafrost assessment and forecasting (Tumel & Zotova, 2014). Methods for calculating the thermal field of permafrost rock have been analyzed in detail (Kudryavtsev et al., 1974) and are included in regulatory documents.

Permafrost thaws if the temperature of the permafrost roof increases to the thawing temperature of the particular rock. This value is somewhat below 0 °C because of changes in the properties of water in the presence of rock particles, but for the purposes of this section we will set it to 0 °C. A multitude of factors affect permafrost surface temperature, including:

– the composition of the rock (because of differences in composition, moisture content, and thermophysical characteristics, thermal fluctuations on the surface are distributed unevenly into the rock);

– the snow and vegetative covers (a heat insulator between the atmosphere and the rock roof);

– the water cover (if water do not freeze completely, melt zones form in the rock;

– the terrain and exposure of the slope (determines the flow of radiation toward the rock surface);

– swampiness (because of the combination of characteristics inherent in open water bodies and the significant involvement of organic matter in the permafrost);

– the infiltration of summer precipitation (the thermal effect when warm summer precipitation penetrates the soils).

The ES volume supplied by ecosystems was assessed on the basis of the effect of the vegetative and snow covers (since they both significantly affect each other) on the temperature of permafrost.

The following is an assessment of the mean effect of snow and vegetative covers on permafrost temperature for regions (where there is permafrost), i.e., the contribution of vegetation and snow to the stabilization of permafrost temperature. The assessment is performed using a formula based on a harmonic analysis of temperature fluctuations on the surface of the cover and on the soil surface that was tested in areas in the Far North by E. D. Ershov (1971):

$$\Delta t_m = (\Delta A_1 \tau_1 - \Delta A_2 \tau_2) / \pi T, \qquad (6)$$

where: Δt_m is the mean annual difference between the surface temperature of the vegetation/snow cover and the surface temperature of the soil beneath the cover; ΔA_1 and ΔA_2 are the mean daily differences between the surface temperature of the cover and the surface temperature of the soil beneath the cover over the periods with cover surface temperatures below 0 °C and no lower than 0 °C, respectively; τ_1 and τ_2 are the lengths of the periods with cover surface temperatures below 0 °C and no lower than 0 °C, respectively; T is a period equal to a year in the same units of measure as τ_1 and τ_2. In the case of the calculations done in this chapter, the assessment was done by months and therefore T = 12. Values of ΔA_1 (cold period) are positive because the permafrost surface is warmer than the snow surface, whereas values of ΔA_2 (warm period) are negative because the permafrost surface is colder than the vegetation surface. Thus, Δt_m reflects the sum of the absolute differences between the surface temperature of the cover and the surface temperature of the soil beneath the cover in the cold and warm periods.

The effect of vegetation and snow covers was calculated using meteorological station measurements of the surface temperature of the vegetation/snow cover and the surface temperature of the soil from the public database “Basic Meteorological Data (Timeframes)” (http://meteo.ru/data/163-basic-parameters) of the Research Institute of Hydrometeorolgoical Information – World Data Center (RIHMI-WDC) of the Federal Service for Hydrometeorology and Environmental Monitoring. The assessment of the ES of regulation of cryogenic processes was based on the changes that take place in the study area, excluding the effect of ecosystems (similarly to the ES of runoff amount regulation).

Values for years in which the number of omissions does not exceed 1% (i.e., no more than 3 days) were selected from the set of meteorological data for all weather stations. The list included 238 weather stations that to varying degrees cover the period 1966–2013. The final analysis was done for years in which the number of stations at which both parameters were observed was at least 90%. Such data were available only for 1990–1992. A three-year period was sufficient for initial analysis of the effect of vegetation and snow covers using Equation (6) and for determining the standard deviation of the desired figure.

Figure 64 shows the steps in the assessment. Initially the lengths of the cold and warm periods of the year were calculated on the basis of data on the mean monthly temperature. A month was classified as warm if the mean temperature is no lower than zero. For the most part, the available data refer to regions where the cold season lasts 6–8 months. In regions where the permafrost boundary passes, the lengths of the warm and cold periods are about equal. Then the difference between the surface temperature of the vegetation/snow cover and the surface temperature of the soil during the warm and cold periods was assessed. The surface cools and heats more intensely than does the air. This is because of its greater ability to absorb and emit radiation. The greatest difference between air temperature and surface temperature in both the warm and cold seasons is typical for southern areas with permafrost, which is related to the high radiation balance values and, consequently, to the greater absorption of solar radiation. The primary contribution of ecosystems to stabilization of permafrost temperature consists in thermal insulation of the permafrost in summer. Permafrost stabilization by ecosystems is seen most starkly in the southern permafrost regions.

The mean annual difference between the surface temperature of the vegetation/snow cover and the surface temperature of the soil beneath the cover is regarded as the supplied volume of the ES of regulation of cryogenic processes (Fig. 64).

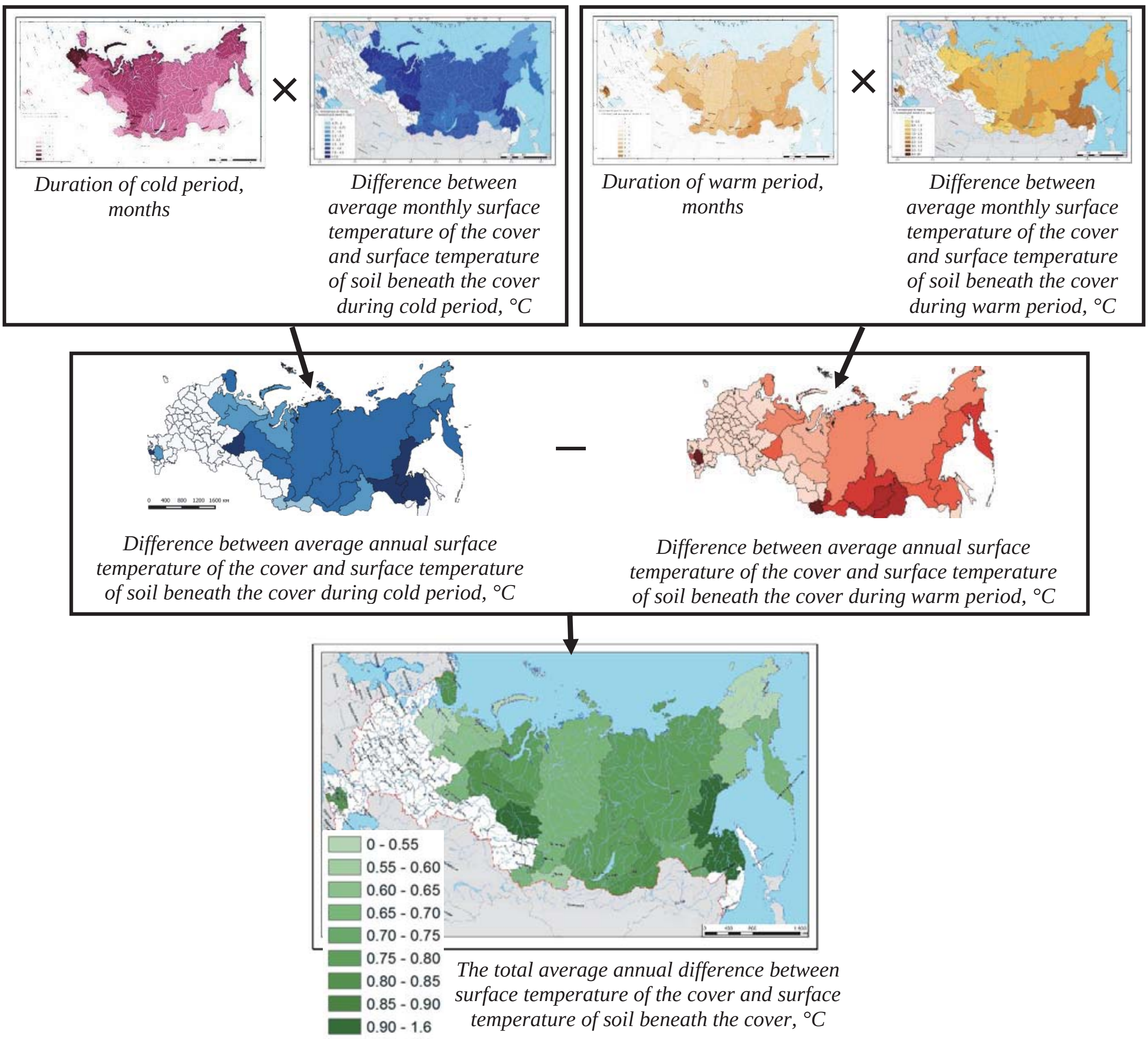


Figure 64. Estimation of the ecosystem contribution to the regulation of permafrost surface heat exchange (°C)

The consumed ES volume is defined as the damage prevented thanks to ecosystem regulation of cryogenic processes. To calculate it, the degree of the permafrost's vulnerability to degradation needs to be determined.

For this purpose, N. V. Tumel and L. I. Zotova (2014) use an environmental hazard coefficient calculated using a regressive equation and scores assigned by experts to certain permafrost and biological characteristics, including, among others, the permafrost temperature and ice content.

The Code of Regulations "Foundations on permafrost grounds" (2012) sets the volumetric heat of soil thawing L_v (J/m^3) equal to the amount of heat necessary to melt ice per unit of volume of soil. It is determined with the formula:

$$L_v = L_0 (W_{tot} - W_w) \rho_d, \qquad (7)$$

where L_0 = 335,000 J/kg is the specific heat of ice melting, W_{tot} is the total moisture content of the rocks, W_w is the moisture content attributable to unfrozen water present in permafrost (%), and ρ_d is the density of the soil skeleton (kg/m^3). The amount of heat consumed to heat frozen soil to melting temperature is not considered, inasmuch as it is far less than the phase transition heat – heating 1 kg of ice by 1 °C requires 4186.8 J.

An increase in the temperature of permafrost, even if it does not result in its complete thawing, inevitably leads to a reduction in soil bearing capacity and the development of cryogenic processes. Therefore, maps of the temperature and ice content of permafrost (Kotlyakov, 1997; Stolbovoi & McCallum, 2002) and electricity consumption in the regions (FSSS database "Regions of Russia, Rosstat, 2013b) were used to assess the technogenic impact on permafrost in regions of Russia (Fig. 65).

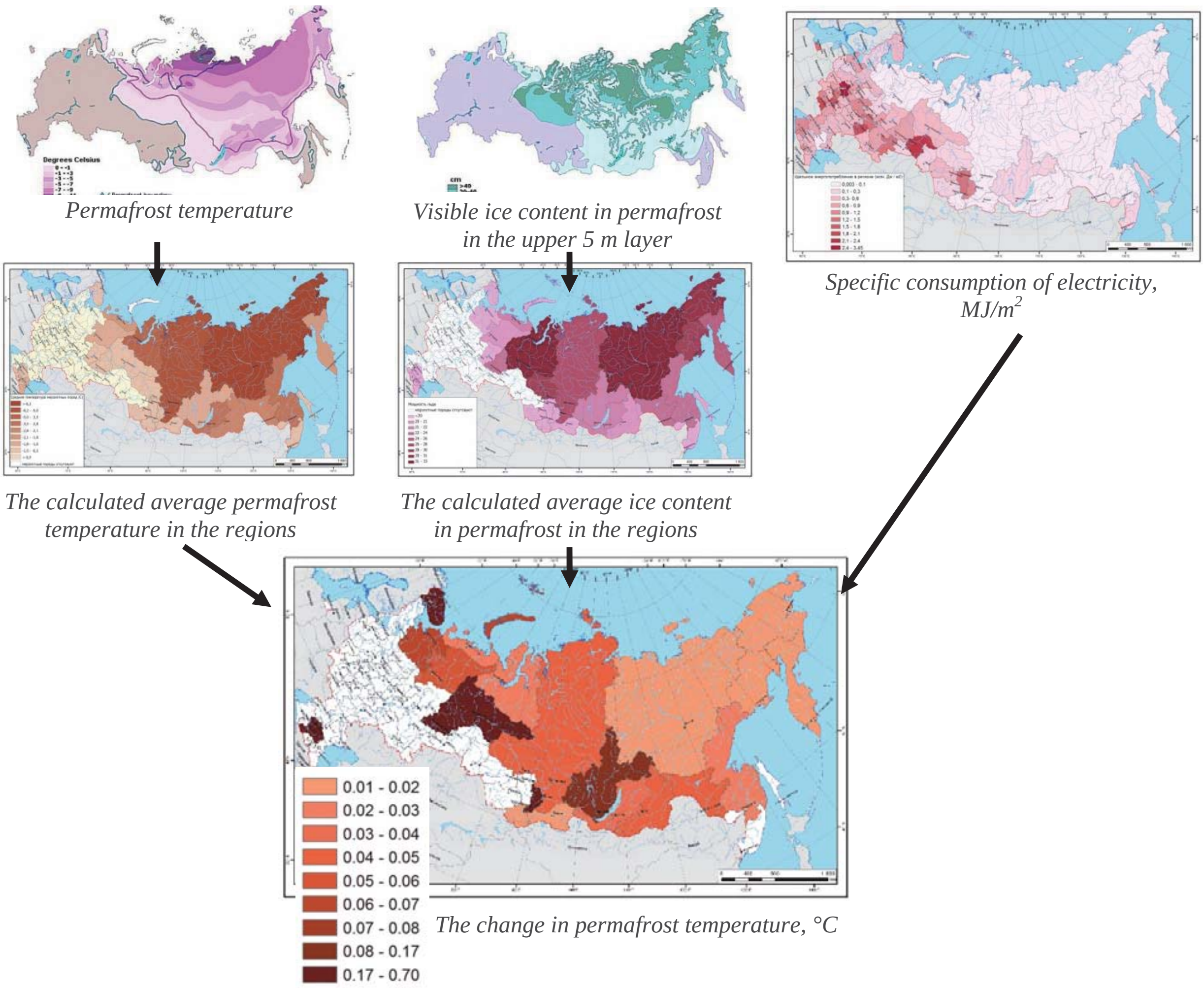


Figure 65. Indicator for assessing the consumed (demanded) volume of the ES of regulating cryogenic processes: change in permafrost temperature (°C), provided that all electricity is consumed to heat it

Preliminary calculations using Equation (7) and a number of assumptions (soil freezing temperature T_{bf} = –0.1 °C, soil skeleton density ρ_d = 1700 kg/m^3, unfrozen water content W_w = 0, the total moisture content W_{tot} corresponds to the mean apparent ice content for the region, the permafrost temperature corresponds to the mean for the region) and the hypothesis that all electricity consumed in a region is used to thaw frozen rock showed that the all locally used technogenic energy is insufficient to fully melt the permafrost or even to increase its temperature by more than 1 °C. However, in the context of global climate change leading to serious disturbance of cryogenic processes, the impact of economic activities on the permafrost at the local level can be significant.

Comparison of the supplied and consumed ES volumes

Figure 66 presents a diagram of the ratio of the consumed and the supplied ES volumes. In the majority of Russian regions (60) there is no permafrost – this is reflected in the circle with zero coordinates. All other values on the diagram lie within the area of oversupply. Regions in which the ES supply and demand are more or less close include the Republic of Khakasia (ecosystem regulation at 0.8 °C, increase in permafrost temperature because of electricity consumption 0.7 °C), Arkhangelsk Oblast (0.5 °C and 0.1 °C) and Chukotka Autonomous Okrug (0.4 °C and > 0.0 °C, respectively). It is noticeable from the last two examples how important the area and the spatial heterogeneity of conditions of the region are in this calculation. In reality, the impact on permafrost rock is more local, and considering the impact of humans, who inhabit 1% of the region's land area, throughout the area produces a distorted result. Any future refinement of the assessment system must take this aspect into account.

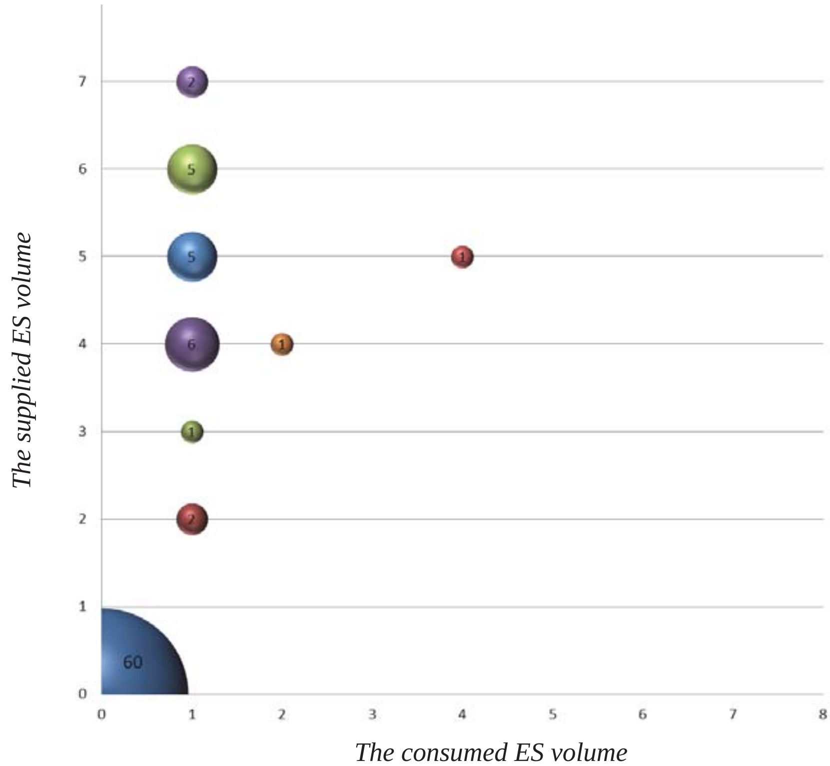


Figure 66. Groups of regions by ratio of supplied and consumed ES volumes:
0 — 0 °C; 1 — 0–0.4 °C; 2 — 0.4–0.5 °C; 3 — 0.5–0.6 °C;
4 — 0.6–0.7 °C; 5 — 0.7–0.8 °C; 6 — 0.8–0.9 °C; 7 — > 0.9 °C.
The bubbles show the numbers of regions

Data required to assess and monitor the ES

We used only one of the alternatives for assessing the ES of regulating cryogenic processes. Among the multitude of factors influencing the permafrost temperature, only two were selected – those that are most related to ecosystems, but they do not take into account, for example, the composition of the rocks that determine the course of temperature fluctuations in the melting layer. This is comparatively easy to do using a map with the types of sediments according to the database "Land Resources of Russia" (Stolbovoi & McCallum, 2002). The same can be said for the effect of slope exposure and inclination. Indicators of the state of vegetation and soil cover, in particular the degree of their disruption due to the impact of vehicles, line structures, overgrazing of cattle, oil spills, reservoirs, etc. are also important.

The approach "from the opposite" – excluding the effect of ecosystems on heat exchange between permafrost and the atmosphere – can and must be validated on the basis of surface temperature according to MODIS satellite data and soil temperature at a depth of 2 cm determined at certain weather stations. This will make it possible to directly assess the heat-insulating effect of vegetation.

The figure for heat flux used in the calculations is based on data on electricity, not heat energy, consumption. Further, it is obvious that it is incorrect to calculate for the entire area of a region. A recalculation for the area directly impacted by human activity is required. After all, the effect of heat is more local and depends on the area of contact between the heat emitter and the rocks. As for leakage, individual heat loss coefficients must be used for heating and electrical networks.

Regulation of biological processes important for the economy and for security

Ecosystem regulation of species with economic importance

This category of ecosystem services includes ecosystem regulation of the following groups of species:
– agricultural pests;
– forest pests and diseases;
– pollinators;
– species harming game and fish resources.

This group of ES is primarily local in scale, since the impact of natural ecosystems on economically vital assets is distributed over the comparatively short travel distance of these animal species (except species that migrate great distances, for example, locusts).

Regulation of agricultural pests

Statement of the task of ES assessment

The ES of controlling populations of agricultural pests is important in agricultural regions were plant husbandry is developed.

The ES volume supplied by ecosystems can be assessed through reduction in damage from agricultural pests thanks to natural ecosystem processes. If the data necessary for quantification are unavailable, an estimation of a score may be done on the basis of the local area of the natural ecosystems.

The consumed ES volume depends on the intensity of agriculture and may be assessed on the basis of the size of croplands in the regions.

Regulation of forest pests and diseases

Statement of the task of ES assessment

The ES of controlling forest pests and diseases is important primarily in regions where forests are greatly reduced and disturbed by humans and are most susceptible to diseases and the impact of pests (Fig. 67). The ES volume supplied by ecosystems is the reduction in damage from forest pests and diseases thanks to natural ecosystem processes. The methodology for assessing this indicator must, however, take into account not only damage that pests do to forests, but their natural role in ecosystems, including as one of the natural succession factors. One possible way to develop this methodology is to identify the relationship between the pest population (damage from pests) and the degree of anthropogenic disturbance of forest ecosystems. As shown in Fig. 67, forests suffer most from pests in regions of the southern belt of the country, where forests are obviously heavily changed by man and are fragmented.

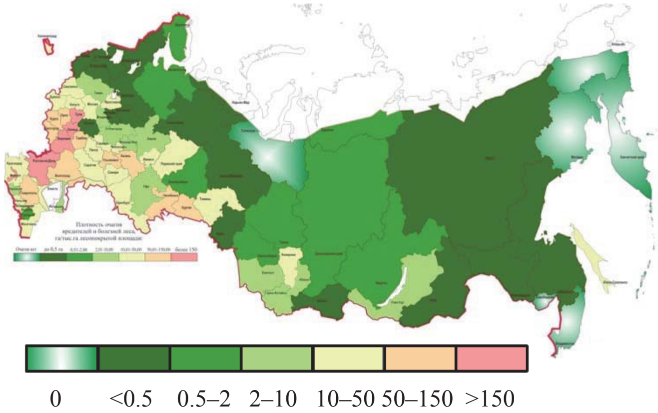


Figure 67. Density of pest and disease foci in the forest in May 2012 according to the Russian Center for Forest Protection (www.rcfh.ru/userfiles/files/plotnost%202012%20may.jpg)

Pollination

The ES of controlling the population of pollinators is essentially the service of pollinating farm crops***.*** Pollination of plants in nature is a vital ecological process that underlies the normal functioning of ecosystems, but is not an ecosystem service (Fig. 2). The ES from which humans directly benefit is the pollination of economically important plants by insects inhabiting natural ecosystems. This service is important in regions where entomophilous farm crops are raise.

The indicator for the estimation of a score of the **supplied ES volume** is the same as the one used to assess the ES of preventing soil erosion on agricultural lands – the area of natural ecosystems in buffer zones 1 km wide around croplands (Fig. 68).

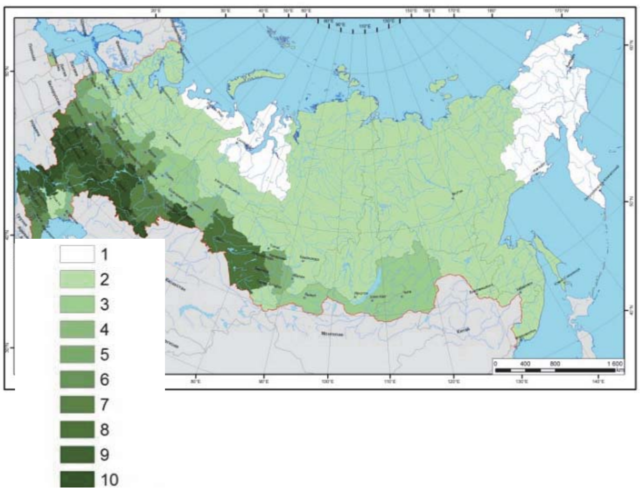
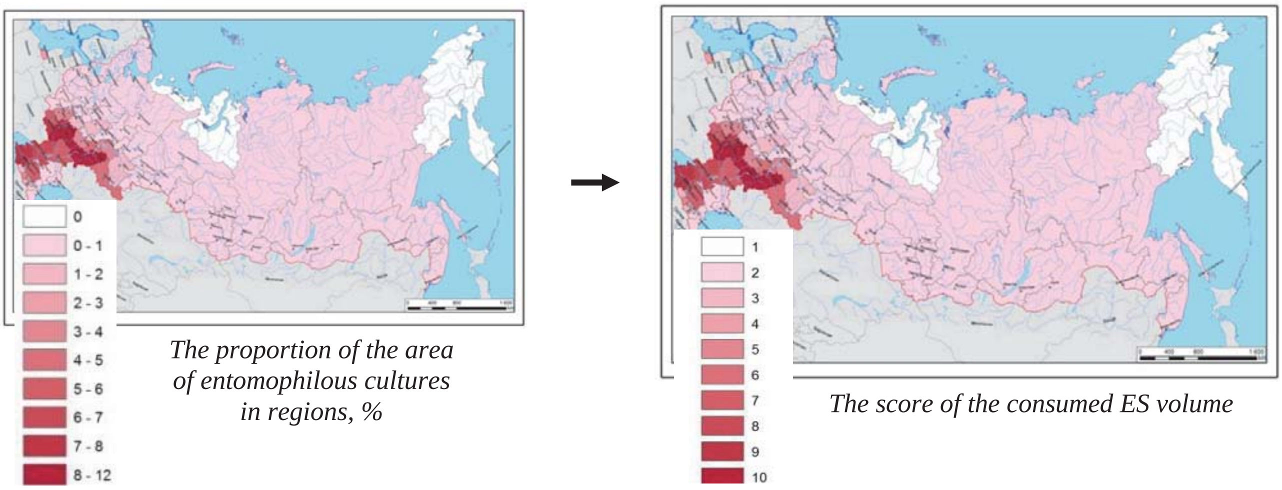


Figure 68. Estimation of the score of the supplied volume of the ES of pollinating farm crops

The indicator for the **consumed ES volume** is the area of entomophilous crops (the sum of the areas planted with fruit and berry crops, sunflower and rape) according to the FSSS database "Agriculture, Hunting and Game Management, Forest Management in Russia" (Fig. 69). Data on the area of entomophilous crops was taken from the FSSS database "Regions of Russia" (Rosstat, 2013b). Their area as a percentage of the area of the region was calculated, and this indicator was used to obtain the score of the consumed ES volume.

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

The difference between the scores of the supplied and consumed volumes *($V_{supplied}$ – $V_{consumed}$)* in Fig. 70 shows, throughout almost the entire country the natural factors that support the service and the socioeconomic factors of its consumption are either balanced (white, score difference of 0), or natural factors prevail (green, positive score difference), i.e., almost the entire country is supplied with this ES. The prevalence of socioeconomic factors, i.e., the relatively large area occupied by entomophilous crops and the small area of surrounding natural ecosystems, is found in only two regions (Kaliningrad Region and the Republic of Adygea).



The proportion of the area of entomophilous cultures in regions, %

The score of the consumed ES volume

Figure 69. Estimation of the score of the consumed volume of the ES of pollinating farm crops

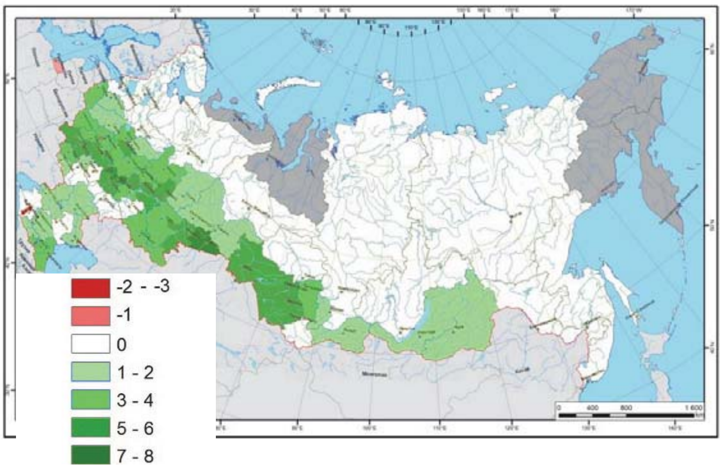


Figure 70. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of pollination

Data required to assess and monitor the ES

To assess the supplied volume:

– the density of insect pollinators in natural ecosystems in different zones;

– the flight distance of insect pollinators;

– the area of different types of natural ecosystems adjoining plantings of entomophilous farm crops.

To assess consumed volume:

– the area of entomophilous crops that can be pollinated by insects from natural communities.

Ecosystem regulation of species with medical importance

Statement of the task of ES assessment

The benefit of this service is the stabilization of natural disease foci. If natural ecosystems are completely destroyed, natural foci of diseases disappear, and the problem that the service helps solve goes away. In this sense this ecosystem service is unique, since total destruction of natural ecosystems solves a special problem. But the total destruction of ecosystems is unacceptable, since all other vital ecosystem services are also destroyed. The assessment of the **supplied ES volume** must include indicators of the stabilization of natural disease foci through the functioning of natural ecosystems, communities, species, and populations. An assessment of the **consumed ES volume** must take into account damage to public health and the regions' economies prevented by stabilization of natural foci.

Another possible approach is to consider natural disease foci as a disservice that does not benefit people, but harms them.

Informational ecosystem services

Genetic resources of wild species and populations

The value of genetic resources, like all biodiversity, for human welfare includes two fundamental components: 1) the key importance of biodiversity for the normal and sustainable functioning of biosystems and, therefore, for the performance of ecosystem services; 2) the direct benefit that man may receive from the use of natural genetic resources. The first component is unquestionably more important, inasmuch as it is the foundation of the sustainability of populations, ecosystems and the biosphere as a whole. It is, however, illogical to consider it as an ecosystem service, inasmuch as biodiversity is the structural foundation for the performance of ecosystem functions and services (Fig. 2). Treating biodiversity itself or support of biodiversity as an ecosystem service leads to ambiguity and confusion. It is appropriate to treat only the direct benefit that man might receive from natural genetic resources and other information as an ecosystem service.

The ES volume supplied by ecosystems was estimated in points by a combination of indicators of species richness and the anthropogenic disturbance of ecosystems (Fig. 71). The indicator for species richness was based on the number of species of vascular plants from the National Atlas of Russia (2004–2008), which seems to be the proper approach to assessing overall species diversity given insufficient data. Plant communities are the basis of all biodiversity, and their diversity largely governs the overall species diversity in ecosystems.

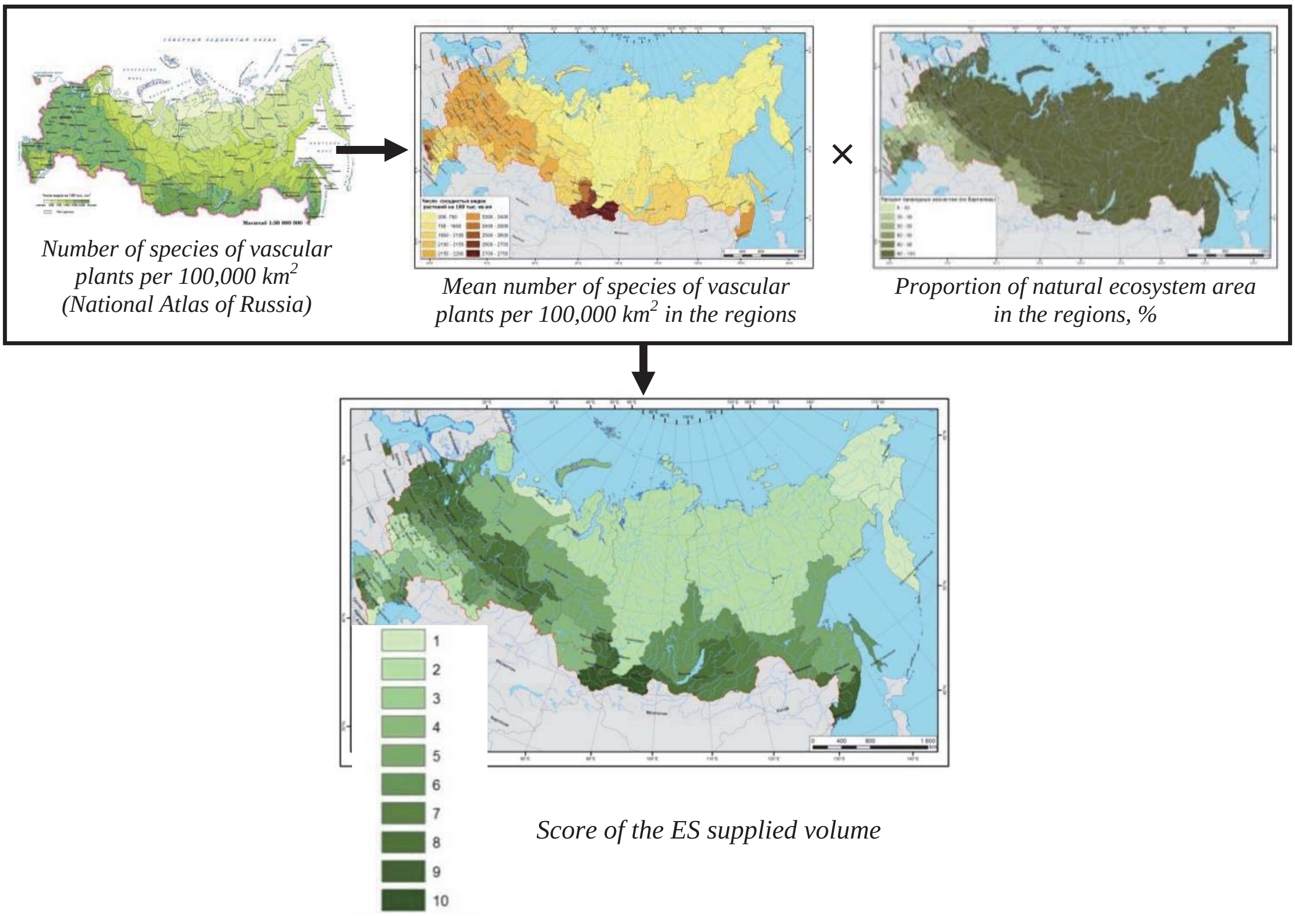
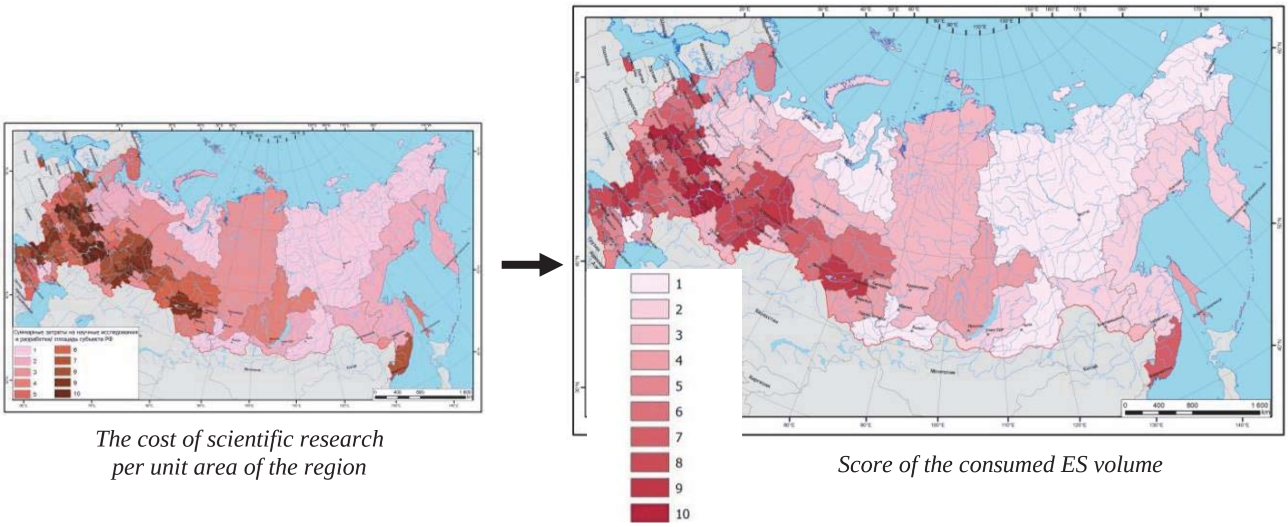


Figure 71. Assessment of the score of the supplied volume of the ES of genetic resource storage in natural ecosystems

The potential volume of the ES of genetic resource storage in ecosystems is inversely related to the degree of anthropogenic transformation of the regions. In many cases, ecosystems are most disturbed by man in regions in which initial species diversity is highest. This emphasizes the key importance of preserving the remaining natural ecosystems in developed regions as repositories of information potentially useful to man. The proportion of natural ecosystem area in the regions was used as the second indicator to assess the supplied ES volume (Fig. 71).

The consumed ES volume depends on the number of natural genetic combinations used by man. The use of natural genetic resources to produce pharmaceutical, cosmetic and other kinds of biotech products has recently grown rapidly. The turnover of products obtained using genetic resources is comparable to or exceeds trade in bioresources. There is, however, no information on the commercial use of genetic resources obtained in Russian ecosystems. It is therefore impossible to determine their usage at the present time. Factors affecting the consumed volume of this ES might include the amount of information available about ecosystems and the intensity of current scientific research. Indicators of the intensity of scientific research in the Russian regions currently available are internal current costs for research according to the FSSS database "Regions of Russia" (Rosstat, 2013b) (Fig. 72). This indicator must obviously by clarified, since data in the "Regions of Russia" database pertain to all studies, from which costs for biological studies (or even more accurately – studies of natural genetic resources) must be separated.



The cost of scientific research per unit area of the region

Score of the consumed ES volume

Figure 72. Assessment of the score of the consumed volume of the ES of genetic resource storage in natural ecosystems

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

The difference in the scores of the supplied and consumed volumes ($V_{supplied}$ – $V_{consumed}$) shows that in a number of regions the intensity of research is relatively high, while the potential amount of natural genetic resources is relatively low. These regions are mostly in the central and southern parts of European Russia (negative values and red in Fig. 73). Positive values (green in Fig. 73) indicate regions where the amount of natural genetic resources is relatively high, and the intensity of research is relatively low. They include primarily the regions of southern Siberia. The value "0" (white) indicates regions where these factors are approximately equal.

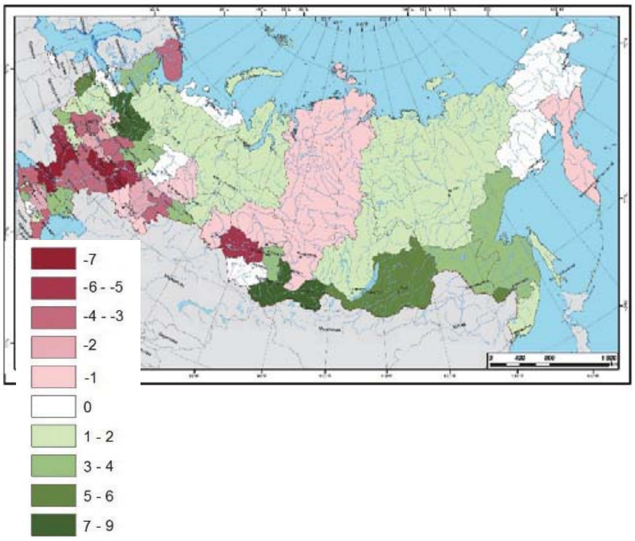
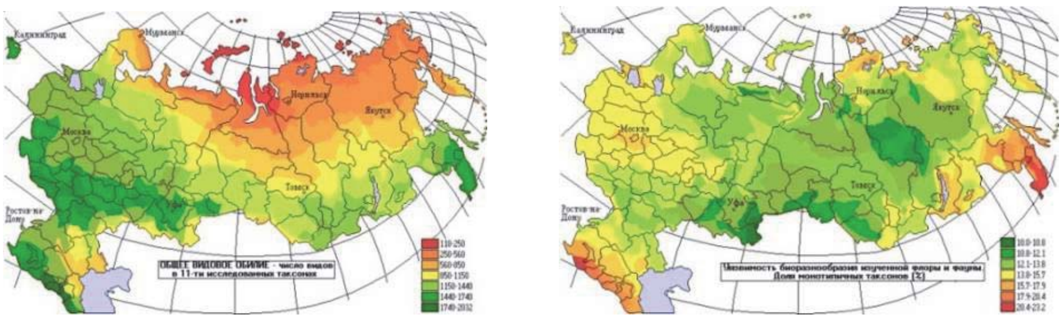


Figure 73. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of genetic resource storage in natural ecosystems

Data required to assess and monitor the ES

The assessment of the supplied ES volume may be supplemented by indicators of the species diversity of other taxonomic groups and indicators of the uniqueness of species diversity, for example, the percentages of monotypic taxons in regional flora and fauna according to data from the Information Resources of the National Strategy and Action Plan for Biodiversity Conservation in Russia (www.sci.aha.ru/biodiv/npd/index.htm) (Fig. 74). The inclusion of indicators of intraspecies diversity is the most important requirement for improving the assessment of this service.

Assessing the consumed ES volume requires data on the intensity of surveys of natural systems and the inclusion of natural genetic resources in economic turnover.



a *b*

Figure 74. Indicators for the assessment of the ES of genetic resource storage in natural ecosystems: a) total species richness in 11 selected taxa of vascular plants, fungi, lichens, insects, fish, amphibians, reptiles, birds and mammals; b) the proportion of monotypic taxa

Information on the structure and functioning of natural systems that can be used by humans

Natural systems (populations, species, ecological communities, ecosystems) contain information on their structure and functioning that man can use. For example, data on the flows of matter and energy in trophic chains may be useful in developing autonomous human life-support systems; information on the role of species diversity may be used to develop sustainable multispecies farm crops, etc.

The ES volume supplied by ecosystems was estimated in points by an indicator of the diversity of natural ecosystems in regions. The map of terrestrial ecosystems (Bartalev et al., 2004) was used to calculate the number of types of natural ecosystems per unit of area of a region. On this basis a score of the supplied ES volume was calculated (Fig. 75).

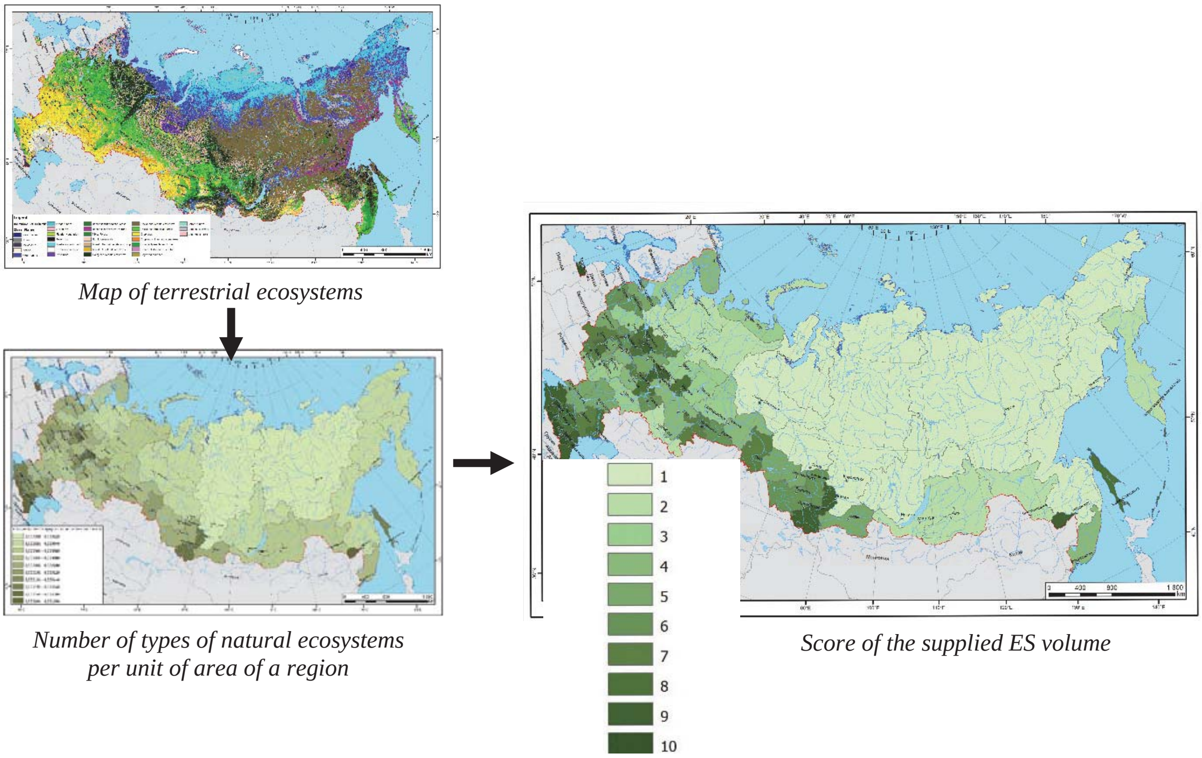


Figure 75. Estimation of the score of the supplied volume of the ES of storage of information on the structure and functioning of natural systems

The consumed ES was assessed in the same way as the ES of genetic resource storage (Fig. 71).

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

The difference in the scores of the supplied and consumed volumes *($V_{supplied}$ – $V_{consumed}$)* identifies regions where the intensity of research is relatively high, while the amount of information on natural systems is relatively low (negative values and red in Fig. 76). Positive values (green in Fig. 76) indicate regions where the amount of information is relatively high, while the intensity of research is relatively low. They primarily include regions in southern Siberia. The value "0" (white) indicates regions where these factors are approximately equal.

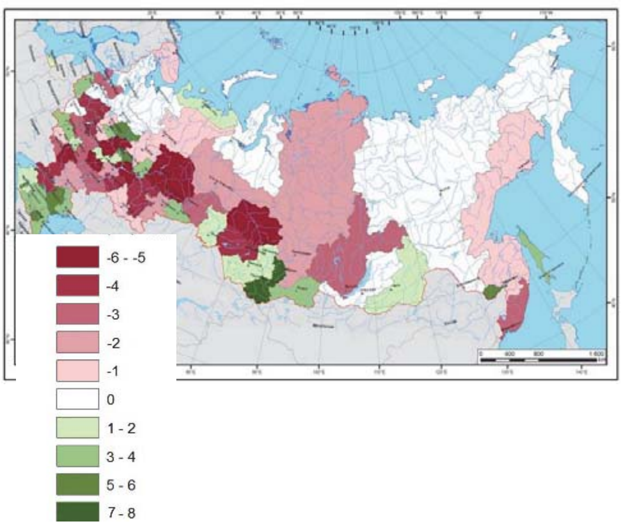


Figure 76. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of storage of information on the structure and functioning of natural systems

Data required to assess and monitor the ES

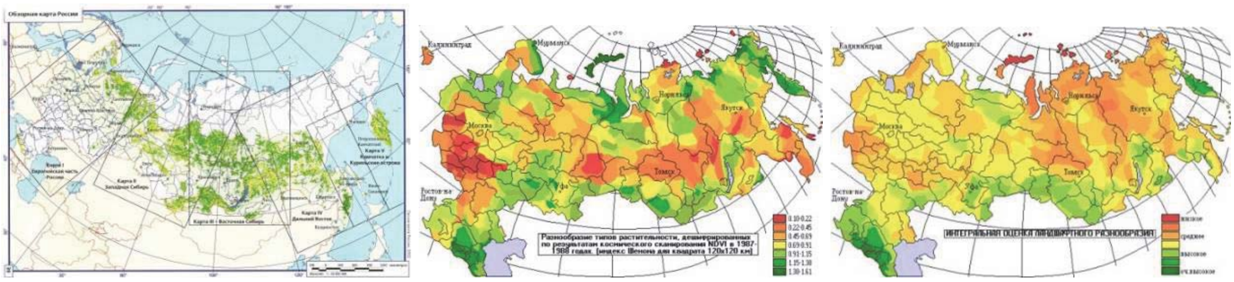
The assessment of the supplied ES volume may be supplemented with the following data:

– data from the Atlas of Intact Forest Areas of Russia (Aksenov et al., 2003) and recent studies of their dynamics (WWF, 2015) to assess the ES of forests (Fig. 77a);

– indicators of species diversity;

– indicators of the diversity of ecosystems, vegetation and landscapes from Information Resources of the National Strategy and Action Plan for Biodiversity Conservation in Russia (Fig. 77b, c).

The consumed ES volume can be clarified on the basis of data on the intensity and distribution of studies of natural populations, species, and ecosystems.



a *b* *c*

Figure 77. Indicators for the assessment of the ES of storage of information on the structure and functioning of natural systems:
a) intact forests (Aksenov et al., 2003);
b) diversity of vegetation;
c) diversity of landscapes

Aesthetic and educational importance of natural systems

The ES volume supplied by ecosystems was estimated in points by a combination of three indicators (Fig. 78):

– the degree of the anthropogenic transformation of regions (natural ecosystems as a percentage of the area of a region);

– the number of species of vascular plants per unit of area of a region as an indicator of species diversity in the region;

– the number of types of ecosystems per unit of area of a region.

This is essentially an assessment of the diversity of natural ecosystems, which is a key component in their aesthetic and educational importance. Other components could not be assessed on the basis of data available in the first phase of the project.

The consumed ES volume was assessed on the basis of a combination of indicators of population density and transport accessibility (the density of car roads and railroads) from the FSSS database "Regions of Russia" (Rosstat, 2013b) (Fig. 79).

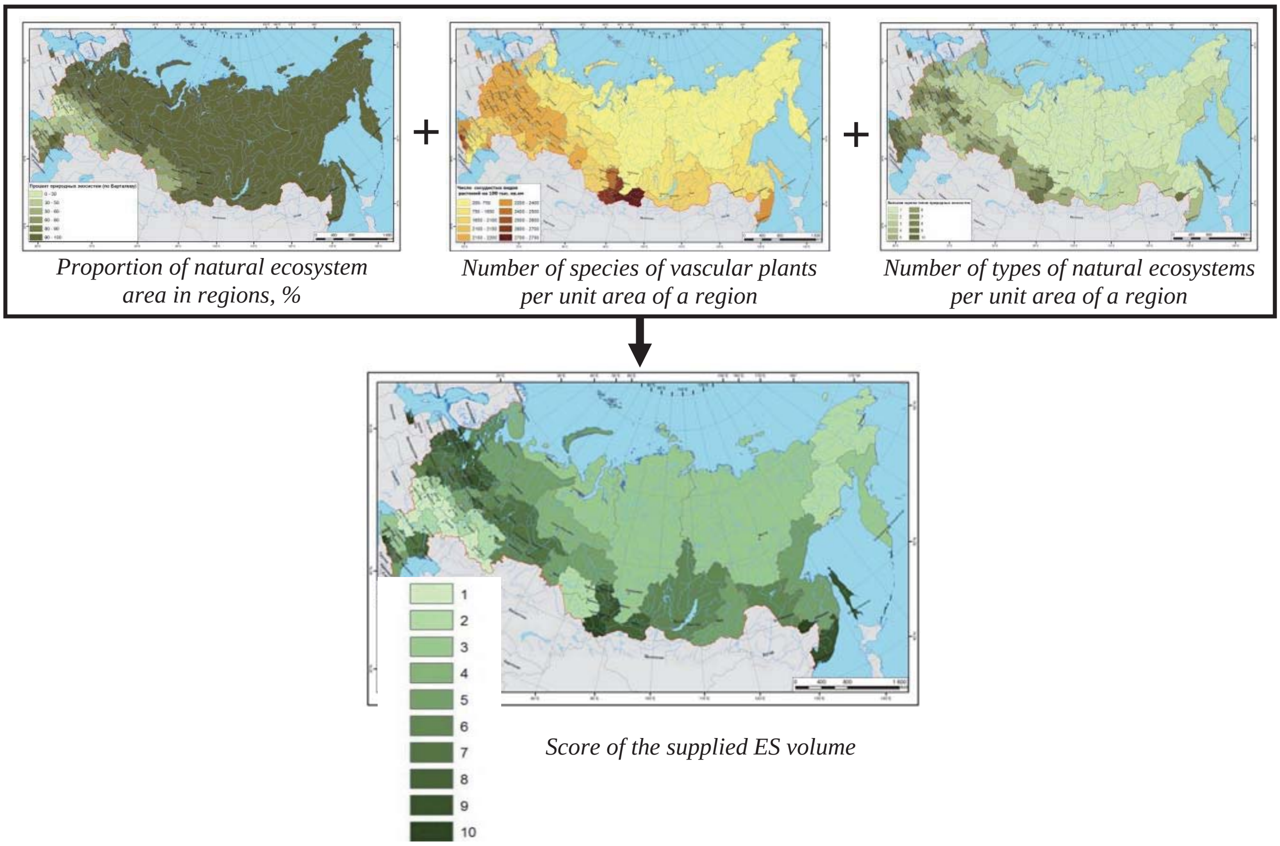


Figure 78. Assessment of the score of the supplied volume of the ES of aesthetic and educational importance of ecosystems

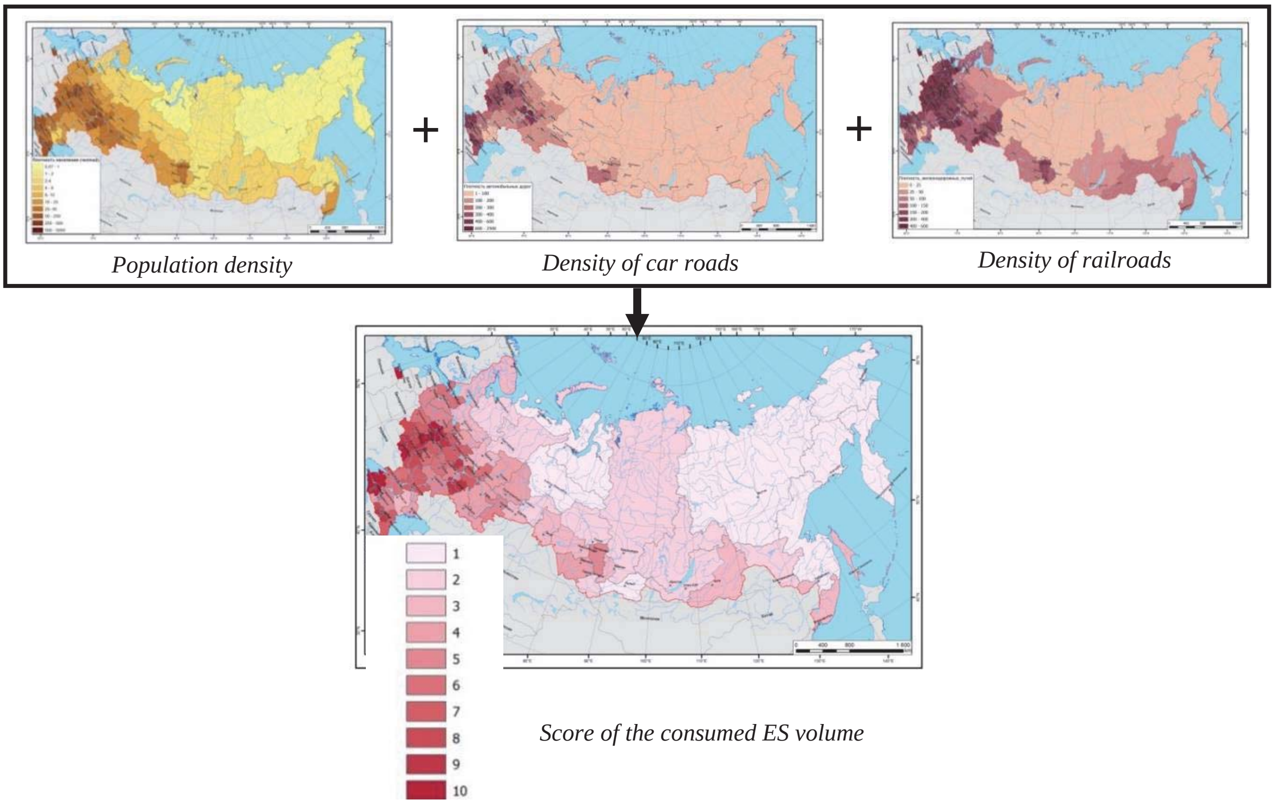


Figure 79. Assessment of the score of the consumed volume of the ES of aesthetic and educational importance of ecosystems

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

Negative differences in the scores of the supplied and consumed ES volumes *($V_{supplied}$ – $V_{consumed}$)* (red spectrum in Fig. 80) show that in these regions the rate at which the ecosystems are visited by the public is relatively high, while their biodiversity is relatively low. Positive values (green in Fig. 79) indicate regions where the diversity of the ecosystems is relatively high, while the rate at which they are visited is relatively low. The value "0" (white) shows the regions where these factors are approximately equal.

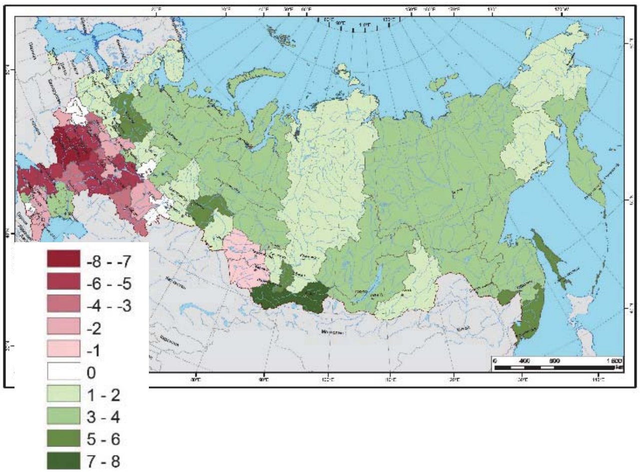


Figure 80. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of aesthetic and educational importance of natural ecosystems

Data required to assess and monitor the ES

Correct assessment of the supplied ES volume requires taking into consideration the diversity of landscapes and the relevance of not only natural, but also cultural landscapes.

Data on the frequency of people's visits to natural ecosystems in different regions, people's aesthetic preferences, and the frequency of educational excursions into nature may be used to assess the consumed volume.

Ethical, spiritual and religious importance of natural systems

Statement of the task of ES assessment

The supplied ES volume is determined primarily not by the properties of natural systems, but by people's attitudes toward them and the history and culture of the region. Information on the national traditions of the regions (e.g., as in Fig. 81) may be helpful in assessing the ethical, spiritual and religious importance of natural systems. The presence of natural monuments of cultural importance (sacred trees, stones, springs, etc.) may be an informative indicator on the local level. On the national level – unique natural objects with importance for national culture (e.g., Lake Baikal). On the global level the formal assessment of this service may be based on UNESCO world heritage sites in Russia: the virgin forests of Komi, Lake Baikal, the Kamchatka volcanoes, Central Sikhote-Alin, Altai's Golden Mountains, the Ubsunur Hollow, the Western Caucasus, Wrangel Island, the Putorana Plateau, the Lena Pillars[5].

[5] http://whc.unesco.org/pg.cfm?cid=31

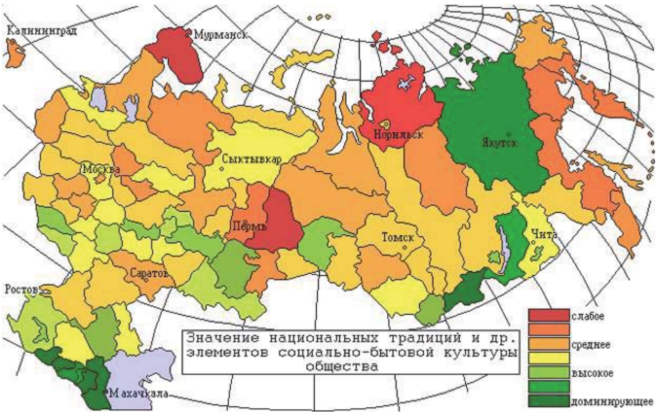


Figure 81. Importance of national traditions in the regions of Russia (Information Resources of the National Strategy and Action Plan for Biodiversity Conservation in Russia)

The consumed ES volume is determined not only by the frequency with which people visit natural ecosystems, but also the frequency with which images of nature are used in the cultural and religious milieu of the regions and the country.

Recreational ecosystem services

Recreational ES are classified as integrated services, since different combinations of all three basic ES categories – productive, environment-forming, and informational – are important for different human recreation options.

Productive ES which are the most important for recreation include the following ES:

– timber for construction and heating of recreational housing;

– non-wood forest resources (mushrooms, berries, nuts, other fruits, medicinal plant resources and products of their metabolism, and plant materials for the production of decorative items);

– game and fish resources (recreational hunting and fishing on internal water bodies).

In general, in recreational terms bioresources are regional and local in importance. Their quality depends on medicinal and decorative plants, mushrooms, berries, and opportunities for hunting and fishing. The areas richest in medicinal plants are the West Caucasus, Altai, and Primorsky Krai. Recreational hunting is popular primarily in forests and mountainous areas. Fishing on rivers and lakes is ubiquitous. The lower Volga is especially popular.

A second important category of ES that support recreation is constituted by *environment-forming* services with respect to creating a healthy environment for the population's recreation. This group might include the following ES:

– environment-forming ES that create the value of resorts: therapeutic waters, baths, mud, climate therapy etc. They are concentrated in major centers of national significance (Caucasian mineral waters, Anapa, etc.) and in medium-sized centers of regional importance (e.g., Belokurikha etc.);

– ES of environment purification: waste decomposition, air, soil and natural water purification;

– ES that create conditions for sports and fitness: trekking, canoeing, mountain climbing, etc. The services in this category are concentrated primarily in the mountains and in areas rich in rivers and lakes. The number of users, which fell drastically after the collapse of the USSR, and the reorientation of tourists to foreign destinations have been increasing in the last years.

Informational ES which are important for recreation include the following ES:

– educational-informational ES – primarily in areas with undisturbed nature and national and nature parks. Resources in this category are theoretically almost ubiquitous, but their quality and potential are unevenly distributed across the regions;

– cultural ES – images and meanings of the cultural landscapes; importance of nature for cultural traditions, local traditions of sustainable exploitation of wild species and ecosystems.

Formation of natural conditions for daily and weekend recreation and summer cottage recreation

This ES is most significant in the recreational category, as it is used by millions of people. It is especially important for regions with a high urban population. In Russia, according to expert estimates, about 15 million people regularly visit the country's gardens and summer cottages. The largest number of visitors is from Moscow and St. Petersburg.

The supplied volume of the service of creating natural conditions for daily recreation close to home, weekend recreation, and summer cottage recreation (including recreational fishing and mushroom and berry forays) is determined by the level of comfort afforded by the natural conditions and the degree of anthropogenic disturbance of the natural environment. Both these factors were assessed on the basis of a map of environmental health assessment of Russia from National Atlas of Russia (2004–2008). The map takes into account 5 gradations of the comfort of natural conditions (from the extreme conditions of the Far North to the comfortable conditions of the temperate zone of European Russia) and 3 gradations of technogenic pressure (moderate, i.e., below the average for Russia; average, i.e., close to the national average; and high, i.e., above the average for Russia) (Fig. 82). When the map was digitized, each polygon received from 1 to 3 points for technogenic pressure and from 1 to 5 points for the comfort of natural conditions. The average of the scores for the polygons was calculated for each region, and it was used to estimate the score of the supplied ES volume (Fig. 82).

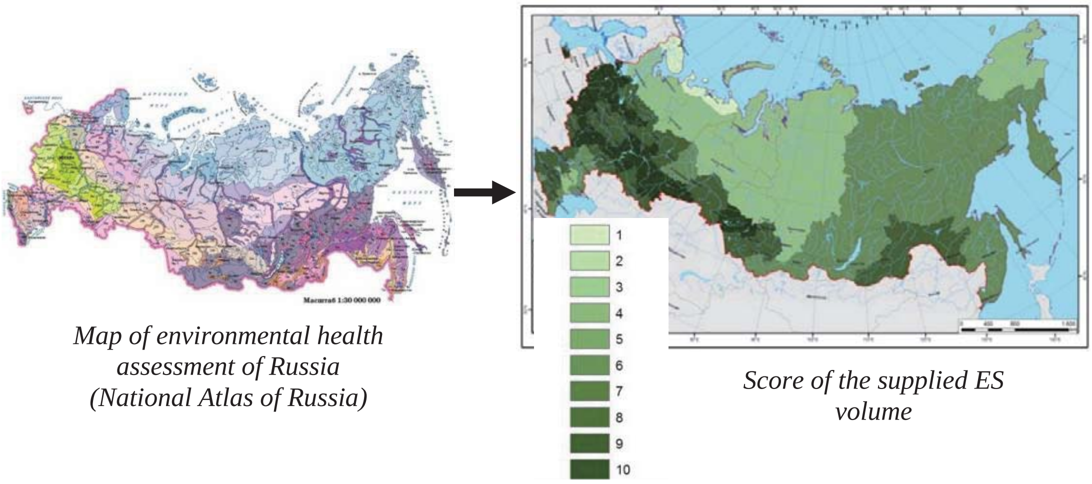


Figure 82. Assessment of the score of the supplied volume of the ES of creating natural conditions for daily and weekend recreation

The consumed ES volume (Fig. 83) is determined primarily by population density. It was assessed in the same way as for the ES of the aesthetic and educational importance of natural ecosystems, i.e., on the basis of a combination of indicators of an area's population density and access to transportation (Fig. 79).

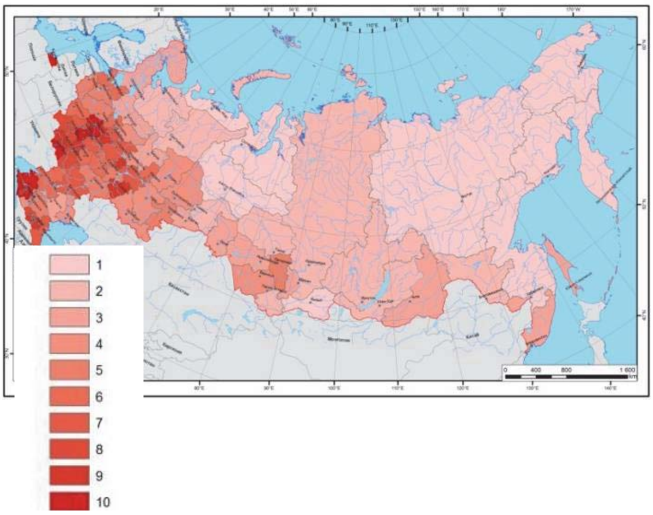


Figure 83. Score of the consumed volume of the ES of creating natural conditions for daily and weekend recreation

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

The difference between the supplied and the consumed ES scores *($V_{supplied}$ – $V_{consumed}$)* shows that natural factors predominate everywhere in the Asian part of Russia, which is understandable, given the low population density (green in Fig. 84). In the European part and in the Urals, the picture is rather mottled: regions where natural factors for supporting the service predominate are interspersed with regions where socioeconomic factors for its use predominate (red in Fig. 84), both in the center and in the south. Factors for the consumption of the service are most predominant in Moscow Oblast.

Data required to assess and monitor the ES

Data required to assess this ES category may be obtained in the near future only as a result of special studies. The most complete and accessible materials exist in some of the administrations of republics, oblasts and municipal districts of major cities, but they pertain to the number and location only of garden societies and summer cottage cooperatives or cottage settlements.

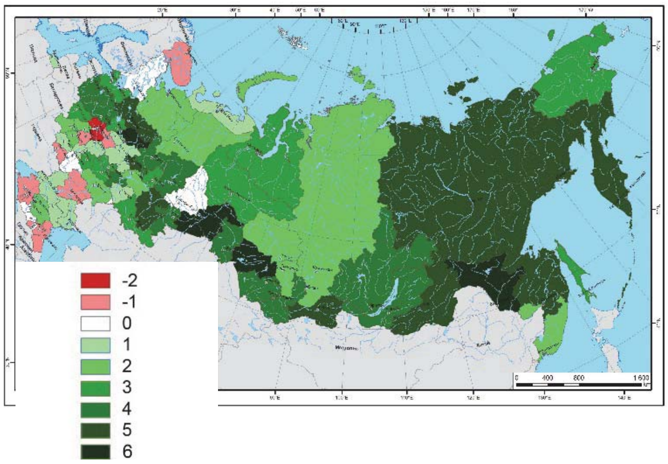
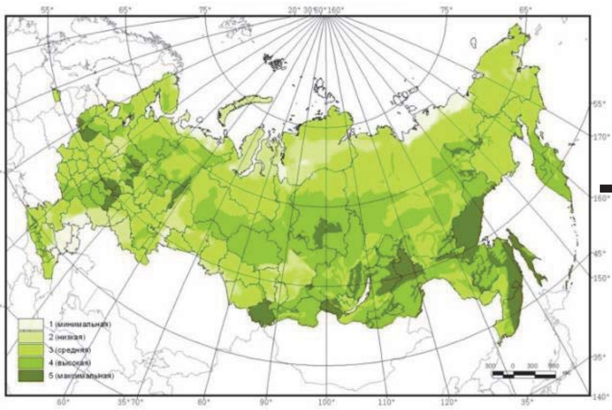


Figure 84. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of creating natural conditions for daily and weekend recreation

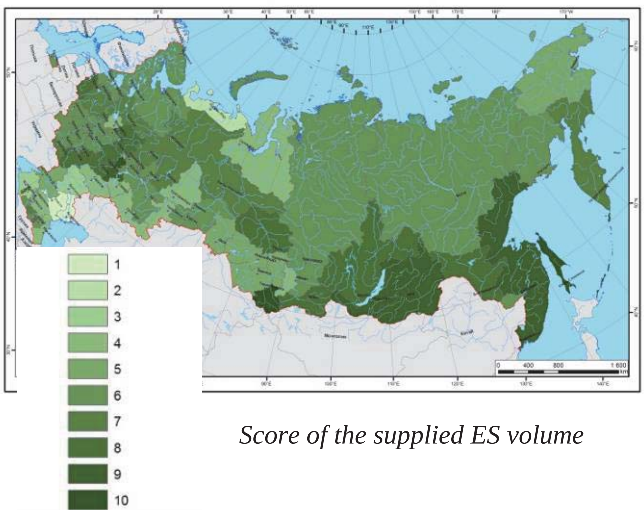
Formation of natural conditions for tourism in nature

An example of the assessment of the ES of the formation of natural conditions for nature tourism might be the study of L. P. Basanets and A. V. Drozdov (2006) in which the territory of Russia was assessed in points using eleven quantitative indicators, referring to three groups of factors – natural, socioeconomic and infrastructural. The assessment of the ES presented in this section is based on this study.

The ES volume supplied by ecosystems is determined by the regions' natural conditions. It was assessed by indicators for the level of comfort of the natural conditions, the environmental situation, and an indicator for landscape diversity (Fig. 85). The last indicator is based on the percentage of forest land, the density of the river network, the roughness of the terrain, and the number of vertical landscape belts in mountainous regions.



Assessment of the natural factors of tourism in nature (Basanets & Drozdov, 2006)



Score of the supplied ES volume

Figure 85. Estimation of the score of the supplied volume of the ES of forming natural conditions for tourism in nature

Areas that combine high landscape diversity and a favorable environmental situation received the highest scores of the supplied ES volume. These include the Altai Republic, the Buryat Republic, Chita Oblast, the krais of Khabarovsk and Primorsky, and the Evenki District. The Republic of Kalmykia, the southern part of Volgograd Oblast, some parts of the Nenets Autonomous Okrug, and the Yano-Indigir lowland in the Sakha Republic received the minimum assessment. They have little landscape diversity and extreme and uncomfortable living conditions.

The consumed ES volume is determined by the number of tourists who visit natural objects of the region, which in turn depends on the region's socioeconomic characteristics and the degree to which tourist infrastructure is developed (Fig. 86).

The socioeconomic factors include indicators of the investment appeal of the regions, population health and potential tourist demand. The last indicator reflects the regions' locations relative to major cities that are main sources of tourists. This is an integral characteristic, which includes the regions' urban populations and a coefficient of demand – the ratio of the population of the country's largest cities to the distance from those cities to the regions' administrative centers.

Moscow Oblast ranks first with respect to the sum total of socioeconomic indicators. The high level of investment appeal is related to the tremendous innovative, industrial, and financial potential of the Moscow region. With respect to the level of public health, this region is not in the top ten, but its health rating is still above the average for the country. Its position with respect to the greatest source of tourists – Moscow – is exceptionally convenient.

The indicator for potential tourism demand makes it possible to identify several more regions that are better located. These are the oblasts of Tver, Ryazan, Tula, Kaluga, and Vladimir.

The group with the minimum socioeconomic assessments includes Siberia and the Far Eastern regions. Their position worsens relative to sources of demand as one moves to the north and east, as the distance from the most densely populated European areas increases. The severity of the climate largely explains the low population of these regions and, as a result, their low tourism demand. Several regions in this group have an investment appeal assessment close to average (Sakha Republic – 16th, Amur Region – 47th), but the majority of regions have low investment appeal.

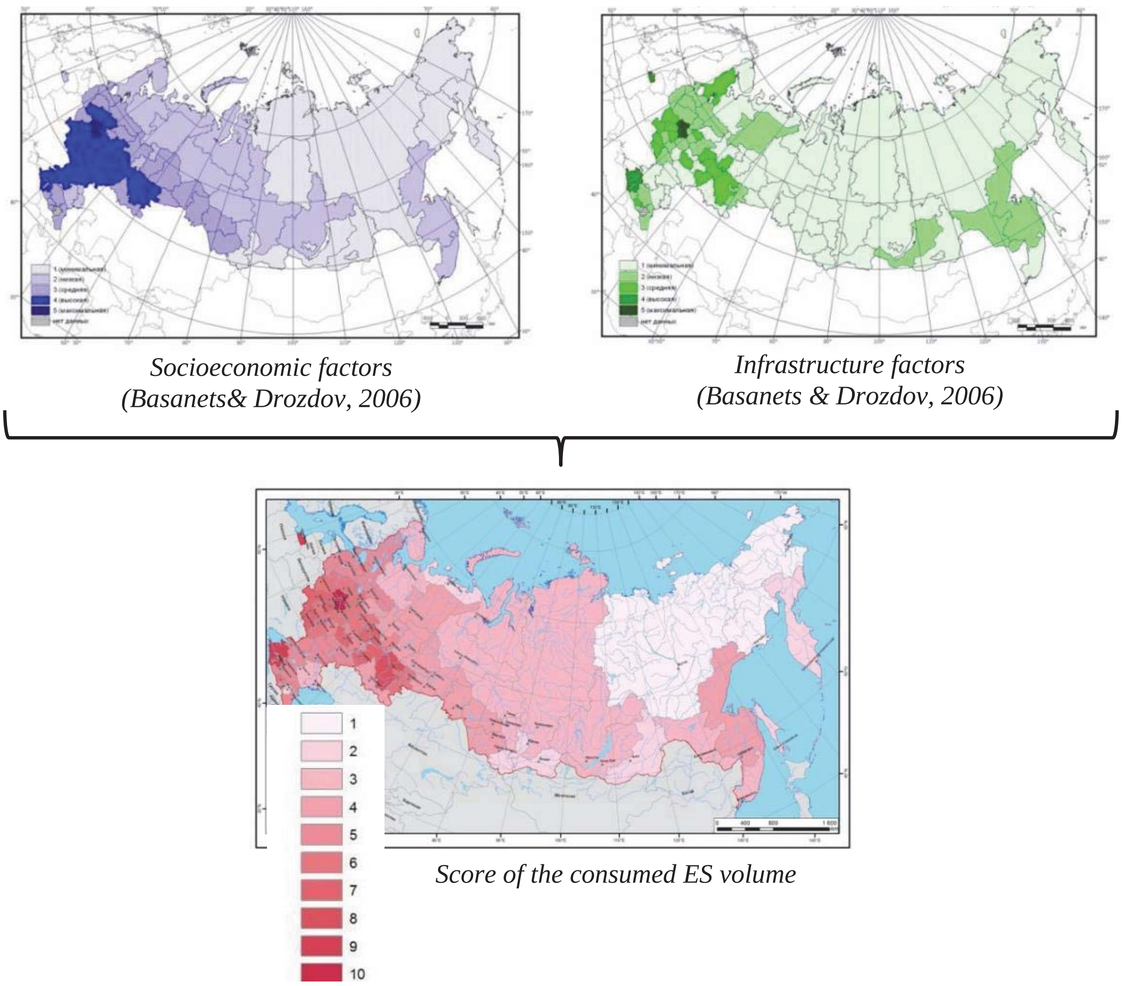


Figure 86. Estimation of the score of the consumed volume of the ES of forming natural conditions for tourism in the nature

The infrastructure factors comprise indicators of the capabilities of accomodation and servicing of tourists. In addition to traditional infrastructure characteristics such as the density of accommodations (specific to tourism in nature) and the density of car roads and railroads, these factors include the following indicators: availability of travel professionals, the density of museums (local museums, regional heritage, natural history) and the parameters of the tourist infrastructure of national parks and other protected areas.

Moscow Oblast is the undisputed leader in terms of ecotourism infrastructure. It leads in transportation accessibility, the availability of travel professionals and the density of museums. It ranks second in density of accommodations. However, with respect to the tourist infrastructure of protected areas, Moscow Oblast ranks only in the fourth decile. The minimum total indicator for tourism infrastructure is in the Republic of Kalmykia, Koryak Okrug and a number of other regions.

The estimation of the score of the consumed ES volume combined the two above-mentioned groups of factors (Fig. 86).

Comparison of the natural and socioeconomic factors determining the supplied and consumed ES volumes

The difference between the supplied and the consumed ES scores *($V_{supplied}$ – $V_{consumed}$)* shows that across the greater part of the country (the north and the Asian part) natural factors that create conditions for tourism in nature are relatively predominant, and this ES is clearly underused (green in Fig. 87). The relative predominance of socioeconomic factors that determine the use of the ES is found in regions of the central and southern parts of European Russia (red in Fig. 87).

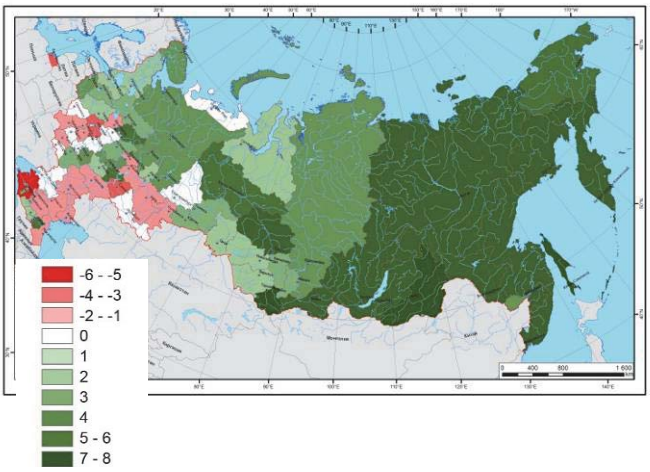


Figure 87. Comparison of the natural and socioeconomic factors determining the supplied and consumed volumes of the ES of forming natural conditions for tourism in nature

When developing tourism in protected areas, it is necessary to understand that their priority is to conserve natural ecosystems and only then provide opportunities for tourism. Tourism inevitably violates natural complexes, that is, in the case of protected areas, the use of recreational ES is in conflict with the task of maintaining informational ES of undisturbed natural ecosystems. Consequently, when tourism comes to strict natural reserves (zapovedniks), it is desirable only in their surroundings.

Formation of natural conditions for resort recreation

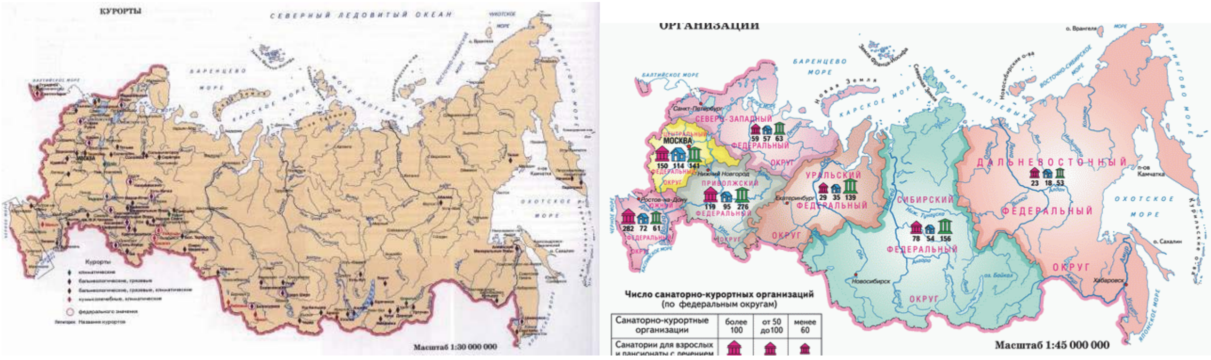
Statement of the task of ES assessment

The ES volume supplied by ecosystems depends on numerous factors:

– how pleasant the climate is;
– the absence of pollutants;
– the presence of natural wellness factors (mineral waters, muds, etc.);
– the presence of water bodies for swimming;
– the presence of mountain slopes for skiing, etc.

The consumed ES volume may be assessed on the basis of the number of vacationers/patients at specialized facilities in the regions from the data of the National Atlas of Russia (2004–2008) (Fig. 88) and from lists of resorts (Chasov, 1983).

Resort centers of national and regional importance have been systematized and described. There are also numerous local, often unlicensed, therapeutic sites (primarily springs and baths). No one is monitoring their status. Information on the number of patients receiving treatment at major resorts is more or less available. However, other indicators, such as the volume of consumed mineral waters, are difficult to estimate.



a *b*

Figure 88. Resorts (a) and sanatorium organizations (b) (National Atlas of Russia)

Data required to assess and monitor the ES

The minimum information for assessing and monitoring this ES category must include the number and cost of trips sold and the number of vacationers/patients. This information is contained in materials published by certain regional statistics agencies.

While studies of natural recreational resources (and sometimes services) on different scales are being conducted in Russia with some frequency (Basanets, 2006; Dorofeev, 2003; Volkova et al., 2015; Tulskaya & Shabalina, 2012), globally these studies are far more extensive and complete (Clough, 2013; Maes et al., 2011; Nahuelhual et al., 2013; Haines-Young & Potschin, 2009).

Comparison of the regions: ratio of natural and socioeconomic factors determining the supplied and consumed volumes of services

This section presents a comparison of Russia's regions with respect to the natural and socioeconomic factors that determine the supplied and consumed ES volumes. As stated above, ES scores aid in assessing the relative intensity of the impact of these factors in the regions. Services that were assessed quantitatively were ranked and assigned a score. The following tables show the scores of the supplied (Table 10) and consumed (Table 11) ES volumes in the regions and the differences in these scores, $V_{supplied} - V_{consumed}$ (Table 12). Regions are grouped by federal districts and ecosystem services in the four categories (productive, environment-forming, informational and recreational).

Productive ES

As shown in Table 10, natural factors that determine the supplied volume of productive ES predominate in certain regions in all federal districts, but fairly sporadically: timber production in the Northwest, Central and Volga districts (the forested regions of the European part of the country); non-wood products in the Northwest, Volga, Urals, Siberia and Far Eastern districts; products of natural pastures in the Volga, North Caucasus and Urals districts (steppe, forest-steppe and piedmont regions); game production in the Northwest, Central and Urals districts (dark green in Table 10).

Factors determining the consumption of timber and non-wood products are relatively intense in the Northwest, Central, Volga and Urals Districts (forest regions); factors for the consumption of natural pastures in the South and North Caucasus districts (steppe and piedmont regions), factors for the consumption of game resources in districts in the European part (except South district) and the Urals (dark red in Table 11).

This ratio of factors determines the relative predominance of factors of the ES consumption in districts in the European part of the country (pink and red in Table 12) and the relative predominance of natural factors that support services in the districts of the Asian part of the country and the Urals (green in Table 12).

Environment-forming ES

Climate-regulating ES (carbon cycle regulation) are provided in certain regions of the Northwest, Central and Volga districts, but the most powerful natural factors for their provision are found in the regions of West Siberia, which are in the Urals and Siberia districts (green and dark green in Table 10). The consumption of these services, which is treated as accounting for "carbon" ES in managed forests, is found in all districts except the South and the North Caucasus, where there are few managed forests (red and dark red in Table 11). The result is an imbalance in factors of the supply and consumption of "carbon services". Factors of the consumption of these ES significantly predominate in the forest regions of the Northwest, Central, Volga, and Siberia districts (red in Table 12) due to carbon accounting in managed forests, while basic natural factors for provision of these ES are found in non-forest districts where there are peaty and black earth soils (green in Table 12).

Natural factors supporting hydrosphere regulation ES are concentrated primarily in the Northwest, Siberia and Far East districts and in the mountainous regions of the North Caucasus district (green and dark green in Table 10). Factors determining the consumption of water resources are concentrated primarily in the regions of the Central, South and North Caucasus districts (red and dark red in Table 11). As a result, natural factors supporting water-regulating services predominate in the Northwest, Siberia and Far East districts (green in Table 12), while factors of their use predominate in the South and North Caucasus districts (red in Table 12).

Soil-protecting ES are supported to varying degrees in regions of all districts (Table 10), but one must remember that the assessment of the ES of preventing soil erosion fundamentally depends on whether we are considering all soils or only agricultural soils (assessments for agricultural soils are presented in Tables 10–12). Factors of the consumption of soil-protection services obviously predominate in the agricultural regions of the Central, Volga, South and North Caucasus districts (Table 11).

Table 10. Scores of the supplied ES volumes by region

	Productive (Provisioning)				Environment-forming (Regulating)										Informational (Cultural)			Recreational	
	Wood production	Non-wood production	Production of natural fodder	Game production	Carbon storage	Regulation of CO_2 flows	Air purification by suburban forests	Regulation of water runoff volume	Regulation of runoff variability	Water purification by terr. ecosyst.	Water purification in aq. ecosyst.	Soil protection from erosion	Self-purification of soils	Pollination	Natural genetic resources	Information on structure and funct.	Aesthetic and educational value	Daily and weekend recreation	Tourism in nature
North West Federal District																			
Arkhangelsk Oblast	3	10	2	1	3	7	2	6	3	6	8	2	7	2	4	2	5	4	6
Vologda Oblast	9	9	1	3	3	8	2	7	2	9	8	2	8	2	8	2	8	8	7
Leningrad Oblast	6	7	1	3	3	3	10	7	2	8	9	2	8	2	8	5	9	10	6
Kaliningrad Oblast	2	3	1	10	2	4	8	6	5	5	8	3	5	3	8	10	10	10	6
Murmansk Oblast	1	10	2	1	7	5	2	8	2	10	10	2	10	2	2	4	5	2	6
Nenets Autonomous Okrug	1	1	3	1	6	3	1	8	2	8	7	1	3	1	1	3	4	2	2
Novgorod Oblast	8	5	1	6	2	7	4	7	2	8	8	3	8	3	8	6	8	10	7
Pskov Oblast	4	7	1	7	3	5	3	6	3	6	8	5	7	5	8	6	8	10	8
Republic of Karelia	4	10	1	2	3	6	2	7	2	9	9	2	10	2	6	3	6	4	6
Komi Republic	5	10	2	1	4	9	3	9	2	10	8	2	6	2	4	2	5	4	7
Central Federal District																			
Belgorod Oblast	1	2	1	6	9	8	4	2	1	1	3	10	3	10	1	4	1	8	7
Bryansk Oblast	4	6	1	5	2	9	7	3	10	2	4	8	6	8	7	7	6	10	6
Vladimir Oblast	4	6	1	6	2	7	9	4	6	4	4	6	4	6	7	8	7	8	6
Voronezh Oblast	1	2	1	2	7	4	4	2	8	1	2	10	1	10	2	3	1	10	8
Ivanovo Oblast	4	6	1	4	2	7	7	5	3	4	5	7	8	7	7	9	8	8	6
Kaluga Oblast	4	3	1	8	2	8	8	4	6	4	5	6	8	6	7	7	8	10	6
Kostroma Oblast	10	8	1	3	2	10	3	6	2	8	6	3	8	3	8	7	9	10	8
Kursk Oblast	1	2	1	3	7	10	6	2	1	1	3	10	3	10	2	7	2	10	6
Lipetsk Oblast	1	2	1	3	5	9	5	3	6	1	4	10	5	10	2	5	1	10	6
Moscow Oblast	2	6	1	7	4	1	7	4	5	4	5	6	7	6	7	6	7	8	6
Oryol Oblast	1	2	1	2	4	9	4	3	8	1	4	10	3	10	2	8	3	10	6
Ryazan Oblast	2	3	1	3	6	7	4	3	7	2	4	9	3	9	5	4	3	8	6
Smolensk Oblast	6	6	1	9	2	6	3	5	4	5	4	6	8	6	7	5	7	10	6
Tambov Oblast	1	3	1	2	7	7	3	3	7	1	2	10	3	10	2	3	1	10	8
Tver Oblast	6	6	1	6	2	6	4	7	2	7	7	4	8	4	8	3	7	10	7
Tula Oblast	1	3	1	7	4	8	8	3	8	1	4	10	3	10	5	5	4	8	6
Yaroslavl Oblast	7	6	1	9	1	6	7	6	2	6	7	5	8	5	8	8	8	10	4
Volga Federal District																			
Kirov Oblast	7	7	1	3	2	10	4	6	3	6	6	5	8	5	7	3	6	8	7
Nizhny Novgorod Oblast	6	7	1	3	2	9	9	4	5	3	4	7	5	7	6	5	5	8	8
Orenburg Oblast	1	2	9	2	5	3	2	2	7	1	1	10	1	10	2	2	1	8	4
Penza Oblast	2	3	1	2	5	7	6	2	1	1	2	10	5	10	2	4	1	10	8
Perm Krai	8	8	1	2	2	10	4	7	2	9	7	3	9	3	8	3	7	8	7
Republic of Bashkortostan	5	4	2	3	4	8	5	5	2	4	3	7	4	7	6	4	3	10	6
Mari El Republic	4	10	1	4	3	9	7	4	5	4	4	6	5	6	7	9	8	10	6
Republic of Mordovia	3	4	1	2	4	10	4	3	7	2	3	9	6	9	4	7	4	10	8
Republic of Tatarstan	2	3	1	2	4	10	7	3	6	2	4	10	3	10	4	4	3	10	6
Samara Oblast	1	2	6	4	6	3	6	3	7	1	1	10	1	10	3	6	3	10	4
Saratov Oblast	1	2	5	3	5	3	2	2	1	1	1	10	2	10	3	3	1	8	4
Udmurt Republic	4	6	1	6	2	7	10	5	3	4	5	7	7	7	7	8	7	10	6
Ulyanovsk Oblast	4	3	1	4	6	6	6	2	10	2	2	9	4	9	3	8	4	10	9
Chuvash Republic	2	5	1	4	3	8	8	3	6	2	4	8	3	8	5	9	5	10	10
South Federal District																			
Astrakhan Oblast	1	1	2	1	1	5	2	1	1	1	1	4	7	4	7	8	8	6	1
Volgograd Oblast	1	2	4	1	3	2	2	2	1	1	1	8	2	8	4	5	3	6	3
Krasnodar Krai	1	2	2	2	4	10	6	3	10	1	6	9	2	9	4	9	4	8	3
Republic of Adygea	2	1	3	4	5	7	10	4	9	2	9	7	5	7	6	10	7	8	8
Republic of Kalmykia	1	1	5	1	1	5	1	1	1	1	1	2	5	2	5	7	7	4	1
Rostov Oblast	1	2	2	1	4	2	4	1	1	1	6	10	1	10	2	5	1	8	5
Northern Caucasus FD																			
Republic of Ingushetia	1	1	8	8	4	1	3	3	10	1	5	8	5	8	5	10	6	8	8
Kabardino-Balkar Republic	1	1	4	3	4	2	8	6	4	3	9	7	5	7	7	10	8	8	7
Karachay-Cherkess Republic	2	1	3	4	4	1	3	9	2	7	10	5	7	5	9	10	10	6	6
Republic of Dagestan	1	2	4	1	3	10	7	1	1	1	4	6	7	6	1	9	5	6	4
Republic of North Ossetia-Alania	1	1	6	3	4	4	10	6	4	3	9	7	7	7	7	10	8	8	6
Stavropol Krai	1	2	6	1	4	7	6	1	1	1	2	8	4	8	3	8	4	8	4
Chechen Republic	2	1	7	2	3	6	8	1	1	1	2	6	6	6	6	10	7	8	6
Ural Federal District																			
Kurgan Oblast	2	3	10	10	5	9	3	1	1	1	2	10	1	10	6	6	6	10	6
Sverdlovsk Oblast	6	7	2	4	4	7	9	5	2	7	5	3	7	3	8	3	7	6	4
Tyumen Oblast	6	8	3	2	10	6	2	3	4	3	2	4	2	4	8	4	7	8	6
Khanty-Mansi Autonom. Okrug	3	9	2	1	10	4	2	6	2	8	7	2	4	2	5	1	5	4	7
Chelyabinsk Oblast	2	3	9	10	5	4	7	4	1	3	3	7	2	7	5	7	6	10	4
Yamalo-Nenets Autonom. Okrug	1	4	2	1	6	4	2	6	2	7	8	1	4	1	2	1	4	4	4
Siberia Federal District																			
Altai Krai	2	2	9	3	5	4	3	4	2	2	3	8	4	8	4	6	3	8	5
Zabaykalsky Krai	3	5	3	5	3	5	2	4	2	3	7	3	9	3	7	2	5	8	9
Irkutsk Oblast	4	8	2	2	2	6	4	6	1	7	7	2	8	2	6	1	6	6	8
Kemerovo Oblast	4	2	5	1	3	2	7	10	1	10	9	5	8	5	8	6	8	8	5
Krasnoyarsk Krai	2	5	2	1	3	4	2	8	2	8	7	2	8	2	2	1	4	4	6
Novosibirsk Oblast	2	5	9	3	5	8	3	2	5	2	2	8	2	8	4	5	3	10	5
Omsk Oblast	5	10	8	1	6	7	2	2	6	2	1	8	1	8	5	7	5	8	5
Altai Republic	2	3	3	5	3	4	3	10	1	10	10	2	9	2	10	9	10	6	10
Republic of Buryatia	2	4	2	3	3	4	2	7	2	7	9	3	9	3	8	2	6	6	9
Tyva Republic	1	7	2	3	3	5	2	7	2	7	9	3	9	3	10	5	8	6	8
Republic of Khakassia	2	1	3	3	3	2	4	10	1	9	10	4	6	4	9	9	9	8	4
Tomsk Oblast	6	0	2	1	10	5	2	4	4	5	4	2	3	2	5	1	5	4	8
Far East Federal District																			
Amur Oblast	3	1	2	4	4	5	2	7	1	5	10	2	7	2	6	2	6	8	8
Jewish Autonomous Oblast	2	1	2	5	6	2	4	7	2	5	10	2	4	2	8	9	10	6	6
Kamchatka Krai	1	3	2	1	5	2	2	8	2	10	10	1	7	1	1	2	4	6	7
Magadan Oblast	1	2	2	1	6	2	2	9	1	9	8	1	7	1	2	1	3	6	6
Primorsky Krai	3	4	2	6	3	2	4	8	3	8	10	2	7	2	9	4	9	6	9
Republic of Sakha (Yakutia)	1	9	2	1	4	3	2	6	2	5	5	2	7	2	2	1	4	6	6
Sakhalin Oblast	2	4	2	1	6	2	4	10	1	10	10	2	9	2	6	8	9	6	10
Khabarovsk Krai	2	5	2	1	4	2	2	9	2	9	10	2	8	2	5	1	5	6	9
Chukotka Autonomous Okrug	1	1	2	1	4	2	1	9	1	6	8	1	8	1	1	1	3	4	5

The assessment of the balance of the factors shows that factors of ES consumption are most predominant in the South Federal District, partially in agricultural districts of the Siberia Federal District and, with respect to soil self-purification ES, in regions of the Central, Volga and Urals districts (red and dark red in Table 12).

Informational ES

Natural factors determining the supplied volume of informational ES are related to biodiversity indicators. They are relatively strong in regions of all districts, but the most in the mountainous regions of the North Caucasus and Siberia districts (green and dark green in Table 10). Factors of the consumption of informational ES are most intense in regions developed by man with a high population density and well-developed road system (the Central, Volga and South districts (red and dark red in Table 11). As a result, factors of the consumption of informational ES predominate in the Central, Volga and South districts (red in Table 12), while natural factors that support these services predominate in the Northwest, North Caucasus and Siberia districts (green in Table 12).

Recreational services

The distribution of natural and socioeconomic factors for the provision and consumption of recreational ES shows that they are fairly well balanced. Natural factors predominate in regions with good climate, which have been most heavily developed by man, and it is there that factors of the consumption of those services are strongest. In the majority of regions, therefore, natural and socioeconomic factors are in balance (white and light shades in Table 12), and only in the Siberia and Far East districts is there a slight dominance of natural factors providing recreational services.

Overall, Table 12 presents an entirely predictable picture: natural factors providing ecosystem services are relatively predominant in the Northwest, Siberia and Far East districts (green colors), while socioeconomic factors of ES consumption predominate in the Central, Volga, South and North Caucasus districts (red colors).

Table 11. Scores of the consumed ES volumes by region

	Productive (Provisioning)				Environment-forming (Regulating)											Informational (Cultural)			Recreational	
Region	Wood production	Non-wood production	Production of natural fodder	Game production	Carbon storage	Regulation of CO_2 flows	Air purification by suburban forests	Regulation of water runoff volume	Regulation of runoff variability	Water purification by terr. ecosyst.	Water purification in aq. ecosyst.	Agric. soil protect. from water eros.	Agric. soil protect. from wind eros.	Self-purification of soils	Pollination	Natural genetic resources	Information on structure and funct.	Aesthetic and educational value	Daily and weekend recreation	Tourism in nature
North West Federal District																				
Arkhangelsk Oblast	7	9	2	1	8	5	1	1	1	1	4	1	1	3	2	2	2	2	2	3
Vologda Oblast	10	8	1	3	9	7	5	2	2	4	5	2	1	4	2	1	1	3	3	5
Leningrad Oblast	10	7	1	4	8	9	4	10	5	9	9	1	2	6	2	8	8	7	7	5
Kaliningrad Oblast	3	5	1	10	3	7	3	3	9	8	10	5	6	7	4	8	8	9	9	9
Murmansk Oblast	2	8	2	1	5	4	3	4	1	4	7	1	1	3	2	5	5	3	3	3
Nenets Autonomous Okrug	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Novgorod Oblast	10	9	1	8	9	10	2	1	2	4	5	3	3	3	2	6	6	6	6	5
Pskov Oblast	5	10	1	7	5	9	1	2	1	3	4	4	4	4	2	2	2	6	6	5
Republic of Karelia	7	10	1	1	6	7	1	1	1	2	5	1	1	3	2	3	3	4	4	5
Komi Republic	5	4	2	1	10	6	3	1	1	3	3	1	1	3	2	3	3	2	2	4
Central Federal District																				
Belgorod Oblast	2	1	1	9	2	6	8	3	9	3	8	9	8	8	9	7	7	9	9	7
Bryansk Oblast	9	9	1	6	5	10	2	2	4	3	6	6	6	6	2	4	4	8	8	7
Vladimir Oblast	10	9	1	9	7	10	2	2	6	10	9	6	5	8	2	9	9	9	9	6
Voronezh Oblast	3	3	1	5	1	3	3	3	6	3	7	8	8	8	10	9	9	8	8	6
Ivanovo Oblast	6	10	1	5	7	10	2	3	4	8	9	5	5	6	2	6	6	7	7	6
Kaluga Oblast	6	2	1	7	6	9	1	2	5	7	9	5	5	6	2	10	10	8	8	7
Kostroma Oblast	10	6	1	2	10	10	2	8	1	4	4	3	3	4	2	1	1	4	4	4
Kursk Oblast	2	1	1	4	1	5	2	3	5	3	4	10	8	7	7	8	8	9	9	7
Lipetsk Oblast	3	2	1	2	1	3	10	3	7	6	9	8	8	8	9	1	1	9	9	6
Moscow Oblast	4	9	1	10	7	10	7	10	10	10	10	5	5	10	2	10	10	10	10	10
Oryol Oblast	2	2	1	4	1	3	1	2	4	3	7	10	9	7	5	1	1	8	8	6
Ryazan Oblast	5	6	1	5	3	4	5	2	4	9	7	7	7	8	3	7	7	7	7	6
Smolensk Oblast	6	7	1	10	5	10	2	2	2	9	5	5	5	6	2	5	5	7	7	6
Tambov Oblast	3	4	1	1	2	4	3	1	4	2	5	7	8	7	10	6	6	7	7	5
Tver Oblast	9	7	1	10	8	10	2	6	2	9	5	4	4	6	2	7	7	6	6	6
Tula Oblast	2	1	1	10	2	6	10	4	7	10	10	10	8	10	5	8	8	9	9	7
Yaroslavl Oblast	9	4	1	10	6	8	4	3	5	9	9	5	4	6	2	9	9	7	7	6
Volga Federal District																				
Kirov Oblast	10	5	1	3	8	9	2	1	1	4	5	4	4	5	2	4	4	4	4	4
Nizhny Novgorod Oblast	10	7	1	4	6	9	3	5	7	4	10	5	5	7	3	10	10	7	7	6
Orenburg Oblast	2	2	8	1	1	3	9	6	3	2	4	10	9	9	6	3	3	5	5	4
Penza Oblast	4	2	1	4	3	6	1	2	3	2	7	8	7	7	5	9	9	7	7	7
Perm Krai	8	4	1	2	9	10	4	5	4	7	8	3	2	6	2	8	8	4	4	4
Republic of Bashkortostan	4	2	3	2	5	7	5	2	5	7	7	9	6	8	3	8	8	5	5	8
Mari El Republic	10	10	1	3	7	8	3	2	3	2	7	5	4	4	2	3	3	5	5	7
Republic of Mordovia	5	5	1	1	4	8	3	1	3	3	5	7	6	6	2	6	6	7	7	5
Republic of Tatarstan	2	3	1	3	3	7	7	4	9	5	10	7	7	10	5	10	10	8	8	7
Samara Oblast	2	1	5	6	2	5	8	5	8	5	10	9	7	9	10	10	10	9	9	7
Saratov Oblast	2	1	5	3	1	3	2	2	3	2	4	8	10	8	10	6	6	6	6	5
Udmurt Republic	9	5	1	8	7	10	6	3	5	3	8	5	5	5	2	5	5	7	7	5
Ulyanovsk Oblast	5	6	1	3	4	8	2	2	4	4	8	6	6	7	6	10	10	6	6	5
Chuvash Republic	3	6	1	2	4	10	3	2	7	4	4	8	6	7	2	8	8	9	9	7
South Federal District																				
Astrakhan Oblast	1	1	7	1	1	3	4	6	2	1	5	6	10	6	2	4	4	5	5	3
Volgograd Oblast	2	1	4	4	1	1	3	2	3	1	5	7	10	8	7	7	7	7	7	5
Krasnodar Krai	2	2	2	5	3	6	5	9	8	3	10	7	7	10	9	8	8	9	9	9
Republic of Adygea	2	1	4	6	5	7	2	6	5	3	9	5	5	5	10	5	5	9	9	6
Republic of Kalmykia	2	1	10	1	1	1	1	2	1	1	3	7	10	5	2	1	1	3	3	3
Rostov Oblast	2	1	4	4	1	3	3	7	5	2	7	8	9	10	8	9	9	7	7	5
Northern Caucasus FD																				
Republic of Ingushetia	1	1	9	10	3	5	1	8	5	2	5	9	6	8	4	5	5	8	8	4
Kabardino-Balkar Republic	1	1	10	4	2	4	1	8	5	5	7	9	6	7	5	7	7	8	8	6
Karachay-Cherkess Republic	2	1	10	9	4	6	3	3	2	4	9	9	6	5	3	6	6	6	6	5
Republic of Dagestan	2	1	10	1	1	4	1	9	5	1	6	9	10	8	2	5	5	7	7	5
Republic of North Ossetia-Alania	1	1	9	1	3	5	1	7	7	8	10	10	6	7	3	7	7	9	9	5
Stavropol Krai	2	1	9	1	1	3	2	10	5	1	7	8	10	9	7	5	5	6	6	5
Chechen Republic	2	1	9	1	3	4	2	7	4	2	4	10	7	8	2	4	4	9	9	2
Ural Federal District																				
Kurgan Oblast	6	4	5	10	3	6	1	1	1	2	4	7	6	7	2	3	3	4	4	4
Sverdlovsk Oblast	8	6	2	3	9	9	9	2	5	10	9	2	2	7	2	9	9	6	6	4
Tyumen Oblast	4	8	2	3	6	6	1	1	10	2	4	1	1	5	2	7	7	2	2	4
Khanty-Mansi Autonom. Okrug	3	5	2	1	8	5	7	1	3	1	2	1	1	4	2	3	3	1	1	3
Chelyabinsk Oblast	3	3	6	4	4	8	10	3	6	10	10	6	6	9	2	9	9	6	6	6
Yamalo-Nenets Autonom. Okrug	2	1	2	1	4	4	3	1	1	1	1	1	1	1	1	1	1	1	1	3
Siberia Federal District																				
Altai Krai	3	2	8	2	4	5	2	1	1	3	1	7	10	8	2	4	4	4	4	4
Zabaykalsky Krai	3	2	2	3	8	8	1	1	1	1	1	3	2	4	2	1	1	3	3	2
Irkutsk Oblast	8	2	2	1	9	7	2	1	1	3	4	1	1	5	2	4	4	2	2	3
Kemerovo Oblast	3	2	3	1	7	9	10	7	5	10	10	7	4	8	2	4	4	6	6	3
Krasnoyarsk Krai	3	1	2	1	5	3	2	1	1	2	2	1	1	2	2	3	3	2	2	3
Novosibirsk Oblast	3	3	5	1	4	5	2	2	2	2	4	5	8	8	2	9	9	4	4	4
Omsk Oblast	4	3	5	1	5	6	3	1	2	4	5	5	9	8	2	6	6	4	4	4
Altai Republic	2	2	3	2	7	4	1	1	1	2	1	6	2	2	2	1	1	2	2	2
Republic of Buryatia	2	2	2	2	6	6	1	1	1	1	1	2	1	3	2	2	2	2	2	3
Tyva Republic	2	2	2	1	3	1	1	1	1	1	1	5	8	2	2	1	1	1	1	2
Republic of Khakassia	2	1	3	1	7	3	3	1	1	10	3	5	9	5	2	1	1	4	4	2
Tomsk Oblast	4	4	2	1	9	7	2	1	1	1	1	1	1	3	2	6	6	2	2	3
Far East Federal District																				
Amur Oblast	3	2	2	3	8	4	1	1	1	1	2	1	1	4	2	2	2	2	2	3
Jewish Autonomous Oblast	3	1	2	2	7	6	1	1	1	1	3	2	2	2	2	3	3	4	4	3
Kamchatka Krai	2	3	2	1	2	4	1	1	1	1	1	1	1	1	1	2	2	1	1	2
Magadan Oblast	2	2	2	1	5	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1
Primorsky Krai	3	5	2	5	10	6	2	2	2	3	6	1	1	4	2	7	7	4	4	3
Republic of Sakha (Yakutia)	2	2	2	1	4	3	1	1	1	1	1	1	1	3	2	1	1	1	1	1
Sakhalin Oblast	2	8	2	1	9	8	2	1	5	5	3	1	1	3	2	4	4	3	3	2
Khabarovsk Krai	3	3	2	1	6	3	1	1	1	2	1	1	1	3	2	2	2	1	1	4
Chukotka Autonomous Okrug	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 12. Difference in scores of the supplied and consumed ES volumes by region

	Productive (Provisioning)				Environment-forming (Regulating)											Informational (Cultural)			Recreational	
	Wood production	Non-wood production	Production of natural fodder	Game production	Carbon storage	Regulation of CO_2 flows	Air purification by suburban forests	Regulation of water runoff volume	Regulation of runoff variability	Water purification by terr. ecosyst.	Water purification in aq. ecosyst.	Agric. soil protect. from water eros.	Agric. soil protect. from wind eros.	Self-purification of soils	Pollination	Natural genetic resources	Information on structure and funct.	Aesthetic and educational value	Daily and weekend recreation	Tourism in nature
North West Federal District																				
Arkhangelsk Oblast	-4	1	0	0	-5	2	1	5	2	5	4	1	1	4	0	2	0	3	2	3
Vologda Oblast	-1	1	0	0	-6	1	-3	5	0	5	3	0	1	4	0	7	1	5	5	2
Leningrad Oblast	-4	0	0	-1	-5	-6	6	-3	-3	-1	0	1	0	2	0	0	-3	2	3	1
Kaliningrad Oblast	-1	-2	0	0	-1	-3	5	3	-4	-3	-2	-2	-3	-2	-1	0	2	1	1	-3
Murmansk Oblast	-1	2	0	0	2	1	-1	4	1	6	3	1	1	7	0	-3	-1	2	-1	3
Nenets Autonomous Okrug	0	0	1	0	5	2	0	7	1	7	6	0	0	2	0	0	2	3	1	0
Novgorod Oblast	-2	-4	0	-2	-7	-3	2	6	0	4	3	0	0	5	1	2	0	2	4	2
Pskov Oblast	-1	-3	0	0	-2	-4	2	4	2	3	4	1	1	3	3	6	4	2	4	3
Republic of Karelia	-3	0	0	1	-3	-1	1	6	1	7	4	1	1	7	0	3	0	2	0	1
Komi Republic	0	6	0	0	-6	3	0	8	1	7	5	1	1	3	0	1	-1	3	2	3
Central Federal District																				
Belgorod Oblast	-1	1	0	-3	7	2	-4	-1	-8	-2	-5	1	2	-5	1	-6	-3	-8	-1	0
Bryansk Oblast	-5	-3	0	-1	-3	-1	5	1	6	-1	-2	2	2	0	6	3	3	-2	2	-1
Vladimir Oblast	-6	-3	0	-3	-5	-3	7	2	0	-6	-5	0	1	-4	4	-2	-1	-2	-1	0
Voronezh Oblast	-2	-1	0	-3	6	1	1	-1	2	-2	-5	2	2	-7	0	-7	-6	-7	2	2
Ivanovo Oblast	-2	-4	0	-1	-5	-3	5	2	-1	-4	-4	2	2	2	5	1	3	1	1	0
Kaluga Oblast	-2	1	0	1	-4	-1	7	2	1	-3	-4	1	1	2	4	-3	-3	0	2	-1
Kostroma Oblast	0	2	0	1	-8	0	1	-2	1	4	2	0	0	4	1	7	6	5	6	4
Kursk Oblast	-1	1	0	-1	6	5	4	-1	-4	-2	-1	0	2	-4	3	-6	-1	-7	1	-1
Lipetsk Oblast	-2	0	0	1	4	6	-5	0	-1	-5	-5	2	2	-3	1	1	4	-8	1	0
Moscow Oblast	-2	-3	0	-3	-3	-9	0	-6	-5	-6	-5	1	1	-3	4	-3	-4	-3	-2	-4
Oryol Oblast	-1	0	0	-2	3	6	3	1	4	-2	-3	0	1	-4	5	1	7	-5	2	0
Ryazan Oblast	-3	-3	0	-2	3	3	-1	1	3	-7	-3	2	2	-5	6	-2	-3	-4	1	0
Smolensk Oblast	0	-1	0	-1	-3	-4	1	3	2	-4	-1	1	1	2	4	2	0	0	3	0
Tambov Oblast	-2	-1	0	1	5	3	0	2	3	-1	-3	3	2	-4	0	-4	-3	-6	3	3
Tver Oblast	-3	-1	0	-4	-6	-4	2	1	0	-2	2	0	0	2	2	1	-4	1	4	1
Tula Oblast	-1	2	0	-3	2	2	-2	-1	1	-9	-6	0	2	-7	5	-3	-3	-5	-1	-1
Yaroslavl Oblast	-2	2	0	-1	-5	-2	3	3	-3	-3	-2	0	1	2	3	-1	-1	1	3	-2
Volga Federal District																				
Kirov Oblast	-3	2	0	0	-6	1	2	5	2	2	1	1	1	3	3	3	-1	2	4	3
Nizhny Novgorod Oblast	-4	0	0	-1	-4	0	6	-1	-2	-1	-6	2	2	-2	4	-4	-5	-2	1	2
Orenburg Oblast	-1	0	1	1	4	0	-7	-4	4	-1	-3	0	1	-8	4	-1	-1	-4	3	0
Penza Oblast	-2	1	0	-2	2	1	5	0	-2	-1	-5	2	3	-2	5	-7	-5	-6	3	1
Perm Krai	0	4	0	0	-7	0	0	2	-2	2	-1	0	1	3	1	0	-5	3	4	3
Republic of Bashkortostan	1	2	-1	1	-1	1	0	3	-3	-3	-4	-2	1	-4	4	-2	-4	-2	5	-2
Mari El Republic	-6	0	0	1	-4	1	4	2	2	2	-3	1	2	1	4	4	6	3	5	-1
Republic of Mordovia	-2	-1	0	1	0	2	1	2	4	-1	-2	2	3	0	7	-2	1	-3	3	3
Republic of Tatarstan	0	0	0	-1	1	3	0	-1	-3	-3	-6	3	3	-7	5	-6	-6	-5	2	-1
Samara Oblast	-1	1	1	-2	4	-2	-2	-2	-1	-4	-9	1	3	-8	0	-7	-4	-6	1	-3
Saratov Oblast	-1	1	0	0	4	0	0	0	-2	-1	-3	2	0	-6	0	-3	-3	-5	2	-1
Udmurt Republic	-5	1	0	-2	-5	-3	4	2	-2	1	-3	2	2	2	5	2	3	0	3	1
Ulyanovsk Oblast	-1	-3	0	1	2	-2	4	0	6	-2	-6	3	3	-3	3	-7	-2	-2	4	4
Chuvash Republic	-1	-1	0	2	-1	-2	5	1	-1	-2	0	0	2	-4	6	-3	1	-4	1	3
South Federal District																				
Astrakhan Oblast	0	0	-5	0	0	2	-2	-5	-1	0	-4	-2	-6	1	2	3	4	3	1	-2
Volgograd Oblast	-1	1	0	-3	2	1	-1	0	-2	0	-4	1	-2	-6	1	-3	-2	-4	-1	-2
Krasnodar Krai	-1	0	0	-3	1	4	1	-6	2	-2	-4	2	2	-8	0	-4	1	-5	-1	-6
Republic of Adygea	0	0	-1	-2	0	0	8	-2	4	-1	0	2	2	0	-3	1	5	-2	-1	2
Republic of Kalmykia	-1	0	-5	0	0	4	0	-1	0	0	-2	-5	-8	0	0	4	6	4	1	-2
Rostov Oblast	-1	1	-2	-3	3	-1	1	-6	-4	-1	-1	2	1	-9	2	-7	-4	-6	1	0
Northern Caucasus FD																				
Republic of Ingushetia	0	0	-1	-2	1	-4	2	-5	5	-1	0	-1	2	-3	4	0	5	-2	0	4
Kabardino-Balkar Republic	0	0	-6	-1	2	-2	7	-2	-1	-2	2	-2	1	-2	2	0	3	0	0	1
Karachay-Cherkess Republic	0	0	-7	-5	0	-5	0	6	0	3	1	-4	-1	2	2	3	4	4	0	1
Republic of Dagestan	-1	1	-6	0	2	6	6	-8	-4	0	-2	-3	-4	-1	4	-4	4	-2	-1	-1
Republic of North Ossetia-Alania	0	0	-3	2	1	-1	9	-1	-3	-5	-1	-3	1	0	4	0	3	-1	-1	1
Stavropol Krai	-1	1	-3	0	3	4	4	-9	-4	0	-5	0	-2	-5	1	-2	3	-2	2	-1
Chechen Republic	0	0	-2	1	0	2	6	-6	-3	-1	-2	-4	-1	-2	4	2	6	-2	-1	4
Ural Federal District																				
Kurgan Oblast	-4	-1	5	0	2	3	2	0	0	-1	-2	3	4	-6	8	3	3	2	6	2
Sverdlovsk Oblast	-2	1	0	1	-5	-2	0	3	-3	-3	-4	1	1	0	1	-1	-6	1	0	0
Tyumen Oblast	2	0	1	-1	4	0	1	2	-6	1	-2	3	3	-3	2	1	-3	5	6	2
Khanty-Mansi Autonom. Okrug	0	4	0	0	2	-1	-5	5	-1	7	5	1	1	0	0	2	-2	4	3	4
Chelyabinsk Oblast	-1	0	3	6	1	-4	-3	1	-5	-7	-7	1	1	-7	5	-4	-2	0	4	-2
Yamalo-Nenets Autonom. Okrug	-1	3	0	0	2	0	-1	5	1	6	7	0	0	3	0	1	0	3	3	1
Siberia Federal District																				
Altai Krai	-1	0	1	1	1	-1	1	3	1	-1	2	1	-2	-4	6	0	2	-1	4	1
Zabaykalsky Krai	0	3	1	2	-5	-3	1	3	1	2	6	0	1	5	1	6	1	2	5	7
Irkutsk Oblast	-4	6	0	1	-7	-1	2	5	0	4	3	1	1	3	0	2	-3	4	4	5
Kemerovo Oblast	1	0	2	0	-4	-7	-3	3	-4	0	-1	-2	1	0	3	4	2	2	2	2
Krasnoyarsk Krai	-1	4	0	0	-2	1	0	7	1	6	5	1	1	6	0	-1	-2	2	2	3
Novosibirsk Oblast	-1	2	4	2	1	3	1	0	3	0	-2	3	0	-6	6	-5	-4	-1	6	1
Omsk Oblast	1	7	3	0	1	1	-1	1	4	-2	-4	3	-1	-7	6	-1	1	1	4	1
Altai Republic	0	1	0	3	-4	0	2	9	0	8	9	-4	0	7	0	9	8	8	4	8
Republic of Buryatia	0	2	0	1	-3	-2	1	6	1	6	8	1	2	6	1	6	0	4	4	6
Tyva Republic	-1	5	0	2	0	4	1	6	1	6	8	-2	-5	7	1	9	4	7	5	6
Republic of Khakassia	0	0	0	2	-4	-1	1	9	0	-1	7	-1	-5	1	2	8	8	5	4	2
Tomsk Oblast	2	-4	0	0	1	-2	0	3	3	4	3	1	1	0	0	-1	-5	3	2	5
Far East Federal District																				
Amur Oblast	0	-1	0	1	-4	1	1	6	0	4	8	1	1	3	0	4	0	4	6	5
Jewish Autonomous Oblast	-1	0	0	3	-1	-4	3	6	1	4	7	0	0	2	0	5	6	6	2	3
Kamchatka Krai	-1	0	0	0	3	-2	1	7	1	9	9	0	0	6	0	-1	0	3	5	5
Magadan Oblast	-1	0	0	0	1	1	1	8	0	8	7	0	0	5	0	0	-1	2	5	5
Primorsky Krai	0	-1	0	1	-7	-4	2	6	1	5	4	1	1	3	0	2	-3	5	2	6
Republic of Sakha (Yakutia)	-1	7	0	0	0	0	1	5	1	4	4	1	1	4	0	1	0	3	5	5
Sakhalin Oblast	0	-4	0	0	-3	-6	2	9	-4	5	7	1	1	6	0	2	4	6	3	8
Khabarovsk Krai	-1	2	0	0	-2	-1	1	8	1	8	8	1	1	5	0	3	-1	4	5	5
Chukotka Autonomous Okrug	0	0	0	0	3	1	0	8	0	5	7	0	0	7	0	0	0	2	3	4

SCALE OF ECOSYSTEM SERVICES

Russia's size determines the critical importance of considering the spatial scale of ecosystem services and the zoning of the country's territory for the further development of the system of accounting for, monitoring and assessing ecosystem services.

Ecosystem services can be divided into several groups according to whether their impact depends on distance and on direction. On the basis of this approach one might determine the services with respect to which a "donor – recipient" relationship might develop. In particular, it is obvious that there are no inter-regional "donor – recipient" relationships for local and point services. For services that depend on the direction of natural flows or flows of consumers, these relationships are determined by the location of the region (upstream or downstream on a river, prevailing winds, basic directions of the movements of people). Examples of different ES groups based on the classification of R. Costanza (2008) and corresponding "donor – recipient" relationships are presented in Table 13.

Table 13. Classification of ecosystem services by spatial characteristics

	ES category	*ES examples*	*"Donor – recipient" relationship*
1	Global non-proximal (does not depend on proximity)	• Biogeophysical mechanisms for the global climate regulation (regulation of energy flows between the surface and atmosphere) • Storage of carbon • Regulation of the flows of greenhouse gases • The value of biodiversity, its cultural and ethical relevance	**Donors** – natural regions **Recipients** – all regions
2	Regional and multiregional proximal (depends on proximity)	• Regulation of cloud formation and the amount of precipitation • Regulation of the albedo	**Donors** – natural regions **Recipients** – surrounding regions
3	Local proximal (depends on proximity) and in situ (point of use)	• Protection from storms, floods and other extreme phenomena • Waste neutralization • Pollination and biological pest control • Soil formation and protection against soil erosion • Timber and non-wood products of the forest consumed on site • Other biological products consumed on site	No donor – recipient relationships
4	Directional flow related: flow from point of production to point of use	• Regulation of runoff stability • Regulation of runoff quantity • Water cleaning • Prevention of water erosion and of the accumulation of sediment in water bodies • Prevention of wind erosion and dust storms	**Donors** – natural upstream or upwind regions **Recipients** – downstream or downwind regions
5	User movement related: flow of people to unique natural features	• Genetic resources • Recreational services • Cultural and aesthetic relevance of biodiversity • Natural pastures • Productive services (timber and other biological products)	**Donors** – natural regions accessible to consumers **Recipients** – regions from which service consumers come

Different ES “operate” on different scales. Mechanisms for the integration of their value into the economy and the decision-making process must therefore align with the scale of the impact of a service. Table 14 describes the importance of ES at different spatial scales.

Table 14. Examples of ES at different spatial scales and their importance in Russia

ES	*Point and local scale*	*Regional scale*	*Multiregional and national scale*	*International and global scale*
Productive				
Wood production	**High** Production of firewood and building materials for personal use. Timber is an important resource for a significant number of individuals and legal entities, especially in the countryside	**High** The availability and cost of timber are factors impacting the cost-effectiveness of large wood-processing enterprises. In a number of regions income from the forestry and wood-processing industries constitutes an important part of the budget	**Medium** The forest sector constitutes a significant portion of the national economy but lags far behind the fuel and energy sector. The forest complex accounts for about 1% of Russia’s GDP	**High** As of 2012 Russia was the world leader in export of lumber and ranked second in the export of sawn wood
Non-wood production	**Medium** Collecting mushrooms, berries and medicinal plants is an important resource for personal consumption and private sale for certain categories of people	**Low** This resource does not play a key role in the regions’ economies	**Low** This resource does not play a key role in the national economy	Undetermined It is hard to estimate Russia’s contribution to global production of non-wood products because of insufficient data
Production of foddet at natural pastures and hayfields	**High** Provides fodder resources for local communities, including the indigenous reindeer herding population of the North	**Medium** Significantly affects the regional level of development of livestock husbandry and reindeer herding	**Medium** Affects the national level of agriculture development	Undetermined It is hard to estimate Russia’s contribution to the global production of natural pastures and hayfields because of insufficient data
Production of freshwater ecosystems	**High** River and lake fish are an important resource for the local population in certain regions	**High** Plays a significant role in the economy of certain regions	**Medium** Fishing represents a significant portion of the national economy but lags far behind other sectors of the economy. Fishing accounts for less than 1% of Russia’s GDP	**Low** The export of freshwater fish from Russia does not constitute a significant percentage of global turnover
Game production	**Medium** An important resource for personal consumption and private sale for certain categories of the population	**Low** At present this resource does not play a key role in the regions’ economies	**Low** This resource does not play a key role in the country’s economy	Undetermined It is hard to estimate Russia’s contribution to the global game production because of insufficient data
Production of honey in natural areas	**High** Important in certain locales	**Low** At present this resource does not play a key role in the regions’ economies	**Low** This resource does not play a key role in the country’s economy	Undetermined It is hard to estimate Russia’s contribution to the global production of natural honey because of insufficient data

ES	*Point and local scale*	*Regional scale*	*Multiregional and national scale*	*International and global scale*
Environment-forming				
Regulation of the carbon cycle and flows of greenhouse gases	**Extremely low** Under the Kyoto Protocol, Russia has in progress the Bikin project, which is aimed at preventing the emission of carbon in cedar-deciduous forests. At present there are no local projects	**Low, in the long term – moderate** Nongovernmental organizations are sometimes able to introduce a "carbon" component to regional forest policy	**Low, in the long term – high** Government policy recognizes the need for adequate accounting of the role of Russia's forests in preserving the global climate	**High** Russia's terrestrial ecosystems are major carbon sinks and stocks and have an important impact on the Earth's climate system
Biogeophysical regulation of the climate	**Medium** The microclimate and local climate substantially depend on vegetation	**High** The ES is important for regulating the level of precipitation and wind force in continental regions	**High** The country's large area determines the significant impact of the physical parameters of ecosystems on the continental climate	**High** The country's large area determines the significant impact of the physical parameters of ecosystems on the global climate
Regulation of water runoff; water purification by terrestrial ecosystems	**High** Protection of springs, streams, wells. Provision of water to the local population and economy	**High** Regulation of the runoff and behavior of small rivers and lakes, prevention of flooding. The ES are critical to a number of regions, supplying them with water and preventing flooding	**Medium, in the long term – low** The importance of water supply ES will increase with current changes in climate and vegetation	**Medium** The runoff from Russian rivers, especially into the Arctic Ocean, impacts oceanic circulation, the Earth's climate system, and migration routes of marine bioresources
Assurance of water quality by freshwater ecosystems	**High** Determines water quality in small ponds and lakes	**High** Determines water quality in water bodies of regional importance	**Medium** Impact on water quality in large rivers and lakes	**Medium** Impact on water quality in coastal seawaters and cross-border rivers
Soil formation and protection	**High** Determines the fertility and stability of the soils	**High** Important for agricultural and mountainous regions and for permafrost zones	**High** Determines the intensity of soil erosion and, consequently, the sustainability of national agriculture	**Low** Prevention of cross-border dust storms and and sedimentation of cross-border water bodies
Recreational				
Establishment of natural conditions for recreation	**High** Recreation in nature close to home is a vital kind of recreation for the majority of the population	**Medium** A large number of people visit recreation sites of regional importance (primarily water bodies, mushroom forests)	**Low, in the long term – medium** The importance of resorts and unique nature sites of national importance will increase as the tourism infrastructure develops	**Low, in the long term – medium** The importance of resorts and unique nature sites of international importance will increase as the tourism infrastructure develops

ES of local scale must be compensated and supported by local residents and local enterprises first and foremost. For example, a neighboring region will not pay to preserve soil in a given region (except when water and wind erosion are degrading the environment in the neighboring regions) or to protect springs and small rivers (if this has little effect on total runoff downstream). The maintenance of local ES requires public environmental education and the development of local mechanisms of payment for ES.

ES with an impact on several regions (e.g., forests at headwaters regulate runoff downstream in other regions) require the development of multiregional mechanisms for compensation or ES markets. For example, large cities downstream might pay to protect natural ecosystems upstream to increase water quality (an example is preserving the natural ecosystems in the catchment area that supplies water to New York).

Carbon storage and absorption are vital *global* climate-regulating functions. In terrestrial ecosystems the greatest threats to these functions are anthropogenic disturbances of natural ecosystems related to felling, peat production, wetland drainage, mineral extraction and fires. The local population in regions that perform a major portion of “carbon” ES usually cannot afford to compensate to minimize these impacts on ecosystems and have a stake in intensifying raw material production, since they are employed in that field. For production companies, minimizing the harm to ecosystems is merely an additional complication and encumbrance. That is, the local population and businesses basically have no interest in maintaining the global ES of carbon cycle regulation. The exception is indigenous peoples with a traditional economy who have an interest in preserving natural ecosystems, and they are interested in other ecosystem functions but not carbon. In this respect the only example of a successful joint forest management project under the Kyoto mechanism, which is being implemented in the forests of the Bikin river basin (Khabarovsk Krai) is indicative. The gist of the project was that the “Tiger” Udegei community would receive leasing rights to significant areas with a waiver of industrial felling and activation of traditional uses of natural resources (gathering Korean pine nuts, berries, mushrooms, ferns, medicinal plants, etc.). The rent was paid from the sale of units of greenhouse gas emissions reduction. The project’s administrative problems, including its official organization within UNFCCC structures and implementation of emissions quotas, were solved with the help of the World Wildlife Fund (WWF). After the Russian Federation rejected commitments under the second round of the Kyoto Protocol, all joint projects in the country were stopped, but by that time a national park had been established in the Bikin forests, which ensured the continuation of conservation activities in that area.

The entire global community is a consumer and beneficiary of carbon ES. It is creating mechanisms for their preservation (examples are forest management under the Kyoto Protocol, the Convention on Biological Diversity, etc.). The REDD+ program is a specialized mechanism intended to preserve the functions of terrestrial ecosystems in regulating the carbon cycle. This program, however, covers only tropical forests in developing countries. The conclusion in December 2015 of the Paris Agreement, which will replace the Kyoto Protocol as of 2020, encouraged domestic interest in preserving and strengthening the carbon-regulating functions of the boreal forests. The prospects for purposeful national activity to regulate the carbon cycle of terrestrial ecosystems, however, remain somewhat unclear, and there is a tremendous diversity of opinions on this issue. One possible prospect is related to the development of a national market for carbon ecosystem services.

EXAMPLES OF ECONOMIC EVALUATION OF ECOSYSTEM SERVICES IN RUSSIA

Active research on the economic valuation of ES and biodiversity in Russia began in the 1990 within the framework of the preparatory phase of the Global Environmental Facility project "Biodiversity Conservation of the Russian Federation". Pioneer results for the economics of biodiversity conservation were obtained in three directions: scientific research, case studies, educational modules and training. Attention was also paid to the impact of economic policy on nature at macro and sectoral levels. The results of these studies were included in books that were almost the first in Russia on economic aspects of wildlife conservation: "The Economics of Biodiversity Conservation" (Ministry of Natural Resources and Environment of the Russian Federation, 1995) and "Analysis of socioeconomic factors affecting the state of biological diversity" (PAIMS,1995).

Economic studies were continued during the implementation of the GEF project "Conservation of Biodiversity of the Russian Federation" (1997–2002). It pursued the following main economic objectives:

– identification of the economic value of biodiversity and its components, including the ES value;

– analysis of lessons learned from applying economic mechanisms of biodiversity conservation in Russia and in other countries;

– dissemination of the best modern approaches in the field of ecological economics for the purposes of nature conservation and restoration and sustainable use of bioresources;

– creation and introduction of new economic mechanisms for sustainable nature management.

Initial small projects were devoted to the synthesis of world experience, new methods for the economic valuation of wildlife and bioresources, the introduction of modern approaches to natural capital assessment, and the preparation of training programs for seminars on biodiversity economics. The results of these studies were summarized in the compilation "Economic Assessment of Biodiversity" (Bobylev & Tishkov, 1999).

More than 40 organizations from almost 20 regions of Russia took part in the competition announced by the GEF project on the dissemination of positive experience of application of economic biodiversity assessments to justify current activities for biodiversity conservation and rational use of bioresources. For dissemination and demonstration, New methods proposed by the regional organizations of Kaliningrad, Volgograd, Krasnoyarsk, Moscow and other regions were selected for further dissemination and demonstration.

The GEF project paid much attention to estimation of the real economic value, the cost of ES and biodiversity, which is important for the cost-benefit analysis of various programs and projects, and trends of the economy as a whole. The available methods of economic assessment of wildlife, natural objects and ES were analysed. The concept of total economic value was recognized as the most promising approach for biodiversity assessment. This concept takes into account both the cost of wildlife use, as well as the cost of biodiversity "non-use" and conservation. The total economic value for ES and biodiversity of many Russian regions and PAs was estimated on the basis of this approach. The economic results of the GEF project were summarized and published in a compilation "The Economics of Biodiversity Conservation" (Tishkov, 2002). This guide has not lost its relevance and is widely used in Russia today.

After the GEF project was completed, economic studies on ES and biodiversity were carried out within projects of UNDP, Wetland International, World Wide Fund for Nature, and NGO "Cadastre" (Yaroslavl), for example, projects on salmon valuation in Kamchatka (Bobylev et al., 2008) and on the economic assessment of protected areas and wetlands and ES payment schemes in the Lower Volga

(Bobylev et al., 2012). Currently, among Russian organizations, the NGO "Cadastre" (Yaroslavl) conducts an economic ES evaluation, including projects on the Curonian Spit and in Kamchatka, the protected areas of Yaroslavl Oblast, and Tomsk Oblast. The studies on the economic evaluation of intraspecies diversity of Pacific salmons (Shirkova & Shirkov, 2006) and reviews of modern methods of ES economic evaluation in Russia (Medvedeva, 2010) are also useful.

In general, in ES assessment projects implemented in Russia, the concept of total economic value was the most widely used as well as the cost approach (primarily for rare animal species), rental approach, and alternative cost-benefit analysis (for individual ecosystems).

The Biodiversity Conservation Center (BCC, Moscow) worked since 2009 to draw attention in Russia and other NIS countries to the international process "The Economics of Ecosystems and Biodiversity – TEEB". BCC jointly with the institutes of the Russian Academy of Sciences organized two conferences: "TEEB Project – Economics of Ecosystems and Biodiversity: Prospects for the Participation of Russia and other NIS Countries" (2010) and "Integration of Ecosystem Services in the Economy of the NIS Countries" (2011). The materials of these international meetings, largely reflecting modern approaches to ES research and evaluation and the possibility of their introduction into practice, are published in two collections (Biodiversity Conservation Center, 2010, 2011).

THE IMPORTANCE OF ECOSYSTEM SERVICES TO SUSTAINABLE DEVELOPMENT

The importance of ecosystem services for the economy and public welfare of Russia

Russia’s ecosystems perform functions and services critical to ensuring environmental security, sustainable economic development, preservation of health, and an increase in the population’s standard of living in Russia. The climate-regulation services of Russian ecosystems have global relevance.

Productive ES support the operation of important sectors of the Russian economy – forestry, fishing, hunting and traditional forms of agriculture. For many regions of the country, in the northern European part, in Siberia and the Far East, these sectors constitute a significant proportion of the regional economies. That is, these regions depend greatly on productive ES. Ecosystem services that provide the product of natural pastures, fishery and hunting are key to supporting the traditional lifestyle of indigenous people. *Environment-forming* ecosystem services are vital. They support the stable environmental conditions on which opportunities for the regions’ economic development and the population’s health and quality of life depend. Climate- and water-regulating ES create the foundation for farming. ES that lower the probability and intensity of natural disasters minimize threats to human life and health and damage to the economy as a whole. *Informational* ES provide opportunities for the development of biotech and environmentally friendly production facilities in the future. The value of informational ES is comparable to the value of productive services. Annual world turnover in medicines and cosmetics derived from natural genetic resources is about 100 billion dollars per year (Lohan & Johnston, 2003), which equals or exceeds the size of the markets for timber and seafood (TEEB, 2010).

Recreational ES provide an opportunity for people to have adequate recreation. Annual turnover in tourism in nature is measured in tens of billions of dollars.

Foreign and domestic ES assessments (Bobylev et al., 2001; Pavlov, Bukvareva, 2010; Pavlov et al., 2009) show that the value and importance to man of environment-forming ES are radically underestimated. Even the portion of them that can be quantified by today’s methods far exceeds the value of biological products that humans take from nature. For example, an estimate of the total economic value of the Dubno wetlands “Crane Land” (“Zhuravlivaya rodina”) in Moscow Oblast showed that the value of the direct consumption of bioresources, including hunting, fishing, the collection of forest products (mushrooms, berries, nuts) and the aesthetic and scientific use is $3.2–5.0 million per year. The indirect value, counting only a portion of regulating ES (carbon sequestration, water-cleaning functions of wetlands, and the healthful effect of recreation) was estimated at $7.0–9.4 million per year, i.e., almost twice the direct value (Bobylev et al., 2001).

The scale of the value of environment-forming ES is partly illustrated by well-known examples of damage from their degradation. For example, in China in the early 1990s annual damage from deforestation totaled 12% of GDP. A major part of it (92%) was a result of the degradation of forest environment-forming ES, while only 8% of the damage was attributed to a reduction in wood stock (Yu-shi et al., 1997). An example in Russia might be the forest and peat fires of 2010, which largely resulted from the loss of the water-regulating services of peat ecosystems in the European part of the country. Total losses from the loss of harvest, forests, the property of individuals and organizations, etc., came to about 1% of Russia’s GDP, but if the additional mortality of the population is included the losses are about 2% of GDP (Bobylev et al., 2012). And this is damage from the degradation of one kind of ES in one part of the country over one year. The loss of only a portion of environment-forming services therefore causes damage amounting to several percent of GDP, i.e., it can completely curtail the country's economic growth. It is obvious that the full value of environment-forming services is many times greater. By creating favorable environmental conditions, they are in fact the natural foundation of the country's socioeconomic stability.

Global importance of Russian ecosystems

Russia has the world's largest areas of natural ecosystems (Fig. 83), which are key to maintaining global biodiversity and maintaining biosphere regulation. Unique complexes of intact natural ecosystems of Northern Eurasia include practically the entire diversity of boreal and arctic species and ecological communities. Russia is the location of a major center for the stabilization of biosphere processes. This primarily pertains to climate-regulation ES.

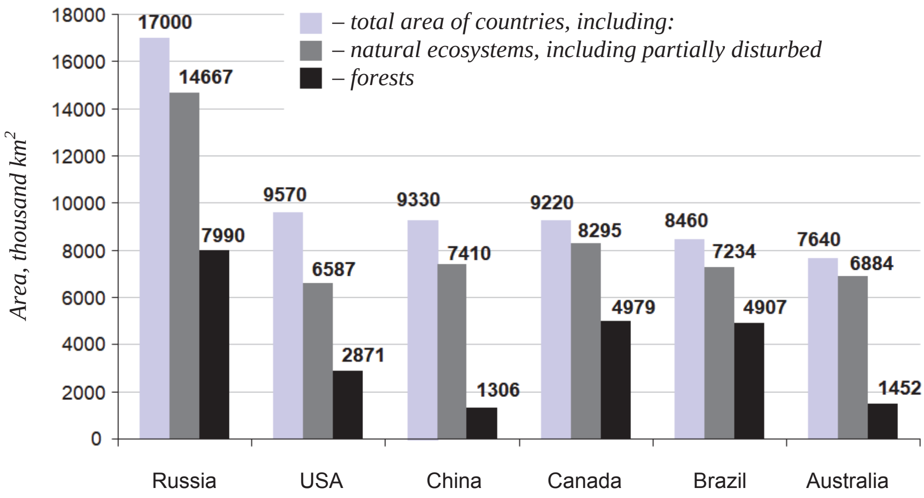


Figure 83. Total area of terrestrial natural ecosystems in the largest countries (data from: Tishkov, 2002)

The carbon storage in the vegetation and soils of all of Russia's ecosystems comes to 336 Gt (40 Gt in vegetation and 296 Gt in soils), which equals 16% of global reserves in these pools (while Russia accounts for 11% of the area of global dry land). A large portion of carbon stock is in soils, constituting 19.7% of global reserves, while carbon in vegetation constitutes 7.2% of global stock. Carbon stock in soil worldwide exceeds stock in vegetation by a factor of 3–5, but in Russia by a factor of 7.5. Carbon stock in Russia's soils is one-fifth of the world's carbon reserves in soils, although the area of Russia is one-eighth of the area of dry land (Zavarzin & Kudeyarov, 2006).

Russia ranks first in the world in forest area and is behind only Brazil in carbon stock in the forest phytomass (there is far more biomass per 1 hectare in tropical forests than in boreal forests). However, the carbon stock in Russian forests' soil is far greater than in the tropics. The total carbon stock in Russian forests is therefore the world's largest. The soils and phytomass of the forest reserves, including forests, non-forested lands and wetlands hold about 290 GtC (253–257 GtC and 33–36 GtC respectively); the agricultural soils hold 45 GtC (Zamolodchikov et al., 2005; Sohngen et al., 2005).

The carbon stock in Russia's wetlands is from 109 to 210 Gt (Vompersky et al., 1999; Parish et al., 2008; NEESPI, 2004), i.e., from 20 to 50% of its world reserves in peat. About half of it (about 70 Gt) is concentrated in West Siberia (Smith et al., 2004).

Finally, the world's largest terrestrial carbon storage is in Russia's permafrost, which occupies about 11 million km^2, i.e., 65% of the country's area. According to different estimates, Russia has from 1/2 to 2/3 of the world's permafrost area (NEESPI, 2004).

Russia's ecosystems therefore play the role of very large, long-term carbon repositories.

Russia's ecosystems provide the ES of carbon sequestration, annually absorbing from 199 to 761 MtC (Dolman et al., 2012). Russia's forests exhibit a net inflow of carbon estimated at from 136 to 250 MtC per year, depending on the time period in question, the forest categories being estimated and the selection of data sources (Zamolodchikov et al., 2011, 2013a, 2013b).

The northern location of Russia's ecosystems determines the extraordinary importance of their carbon accumulation function. It is in a cold, damp climate that conditions are created for carbon sequestration. The optimal temperature for destruction is higher than for production. Production under cold conditions may therefore exceed destruction, and the surplus biomass will be buried in long-term repositories. Another important factor contributing to the suppression of destruction and to the sequestration of carbon is excess moisture. It is in northern regions where these conditions are created. As stated above, the main terrestrial carbon reserves are concentrated in soils, and this largely pertains to northern ecosystems.

Therefore, Russian ecosystems are not only the most powerful carbon repository, but also most powerful inflow into long-term terrestrial repositories.

The global importance of the biogeophysical climate-regulating ES of Russian ecosystems is determined by the country's large area. A change in this ES group over large areas affects not only the regional, but also the global climate. The importance of changes in surface albedo is greatest in regions with a long duration of snow cover, including Russia. Positive feedback between an increase in the area of woody and shrubby vegetation, which significantly reduces the albedo, and an increase in regional temperatures, especially in spring, forms under these conditions. The effect of this relationship on the climate is intensified even more if the region adjoins an ocean. In this case there is another positive relationship – between the increase in regional land temperatures and the shrinkage of ice on adjoining waters, which in turn reduces the ocean's albedo. It is these conditions that are typical of Russia's Arctic, which makes the impact of this region on climate extremely powerful.

The functions of Russia's ecosystems in regulating the water cycle also have not only a continental but also a global significance due to the huge extent of river runoff to the Arctic Ocean, which largely determines that ocean's state and thus affects global climate.

DEVELOPMENT OF A SYSTEM FOR ASSESSING AND MONITORING ECOSYSTEM SERVICES AND MECHANISMS FOR CONSIDERING THEIR VALUE IN DECISION-MAKING

The assessments of Russia's ES carried out in the present Prototype Report show that the scale of ES impact is commensurate with human needs, and a number of life-supporting services are being consumed fully or even excessively.

Current practice of managing ecosystem services in Russia

The system for monitoring and assessing ES in Russia is lacking, as are mechanisms for integrating the overall ES value into decision-making processes.

The exploitation of basic bioresources (forests, fish, game animals), i.e., the productive ES, have, however, always been an object of strict government regulation. In post-Soviet times, mechanisms for this regulation have greatly weakened, and the illegal unreported and unregulated (IUU) harvesting of all kinds of resources has grown substantially. In addition, until now these ES are considered only as a result of the functioning of commercial species, rather than ecosystems as a whole.

Environment-forming ES are almost disregarded and are not regulated by the state, except for the water-protecting and soil-protecting properties of the forest. The RF Forest Code now identifies protected forests, in which specially protected areas with limited forest use may be designated (shore- and soil-protecting areas of forest along the shores of water bodies, the slopes of ravines and gulches, forest edges on the borders of unforested areas, habitats of rare and endangered animals and plants, and others). Russia's ratification of the Kyoto Protocol created hopes for the large-scale joint implementation of carbon absorption projects based on forest management. Two projects were implemented ("Prevention of Emissions in Bikin River Basin Forests" and "Forestation of Altai Villages"). Russia's refusal to participate in the second round of the Kyoto Protocol created an obvious barrier on the path toward the further development of similar project activities. However, in accordance with the UNFCCC, Russia presents a report on the inventory of greenhouse gases, which assesses the carbon balance and its content in living phytomass, deadwood, litter and a 30-centimeter soil layer in managed forests (National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2011, 2013b). The system of state administrations does not take into account other environment-forming services.

Nor is there an understanding of informational ES in state and legal regulation. An example of the adverse impact of this omission on the national nature protection policy is afforded by the current changes in the system of strictly protected areas – zapovedniks – in Russia. The preservation and study of information that is stored in undisturbed natural ecosystems was traditionally a priority of Russia's zapovedniks. At present, lack of understanding of the value of information embedded in undisturbed natural systems, which in many cases are preserved only in zapovedniks (which account for less than 2% of the geographic area of the country) led to the strategy of prioritizing the development of tourism in them. The development of tourism inevitably leads to various disturbances of natural systems and thereby to a loss of information about their structure and functions. Natural complexes of zapovedniks must be guarded against any disturbing anthropogenic impacts. Tourism can be successfully developed at other forms of PAs, primarily in national parks.

Both objective and subjective factors can be identified among impediments to the development of a system for economic ES assessment in Russia. Objective factors include the low sensitivity of a traditional market economy to environmental problems, which is manifest both in theory and in practice. Here one might note the hidden nature (latency) of a large number of environmental problems; the traditional market simply does not see them. Modern economics cannot precisely define the benefits, harms and prices of ecosystem functions or "digitize" and represent environmental problems to the authorities, business and society. Unresolved environmental and economic problems might include: the lack of prices for the overwhelming majority of ecosystem services; underestimation of environmental harms; the diffusion (scattering) of goods; the inadequate reflection of the time factor (the market's shortsightedness); and public goods. Among subjective factors for Russia one must note the failure of decision-makers to make environmental problems a priority; departmental silos; insufficient funding for ecosystem preservation, etc.

The status of the environmental monitoring system in Russia can be rated as unsatisfactory. Governmental authorities pay the greatest attention to environmental pollution indicators. The bioresource accounting system is being reformed and does not provide complete data about the status of bioresources. The low reliability of these data is an acute problem. Estimates of unreported extraction of bioresources (IUU harvesting) approach the scale of all legal harvesting.

Moreover, access to information about the status of wildlife is being commercialized. Access to databases is necessary to assess ecosystem services, but this information is now costly. Moreover, it is not always clear exactly which databases have these data right now and to whom they belong.

The national forest accounting system in Russia is focused on the accounting of timber resources in forests, which are broken down by categories of use (protected, exploited, reserved, etc.) on the basis of the dominant varieties, age groups, etc. The entire forested area of Russia was covered by the national forest resources accounting system by the early 1960s. Since then government accounting has taken place every 5 years, and public reference guides with the results have been published. The tradition endured until 2003, when the last reference guide was issued (VNIILM, 2003). The first computerized database for forest resources was created in 1998. In 1998, competent authorities switched to annual updates of the forest resources database. Forest registry information is now provided for a fee, which makes it hard to access.

Principles for comprehensive assessment and management of ecosystem services

At present the objective of natural resources management in Russia in the overwhelming majority of cases is to maximize the product that can be extracted sustainably (timber, seafood, game production) or the profit (recreational services). Now, however, there is a need to transition to a new concept of nature management in which environment-forming ES and the biodiversity that supports them must have priority.

The ES efficiency is inextricably linked to biodiversity indicators. It is therefore necessary to take a possible change in biodiversity into account when particular ES are consumed. The consumption of different services requires different management goals with respect to ecosystems and populations. The report "Millennium Ecosystem Assessment" (2005) notes that the improvement in one service often leads to the deterioration of another. Analysis of the mutual influence of effects from the consumption of some ES on the quality and stability of others is one of the key steps in developing natural resource management plans. Table 15 shows the management goals in the consumption of productive, environment-forming, and informational ES and the changes in biodiversity that correspond to these goals.

Table 15. Management goals in the consumption of different ES and attendant changes in biodiversity

ES	*Management goals*	*Changes in biodiversity*	*Changes in the total biomass of communities*
Productive	Maximum sustainable extracted biomass	Decline in diversity	Decline in constant biomass
Environment -forming	Efficient and sustainable ecosystem functioning	Preservation of the natural level of biodiversity	Preservation of the natural level of biomass
Informational	Preservation and acquisition of information from natural systems		

When natural biosystems are exploited, there is a contradiction between the goals of obtaining the maximum sustainable harvest and maintaining environment-forming functions. The strategies for managing biosystems to achieve these goals differ.

Management goals in the consumption of environment-forming and informational ES coincide with maintaining the natural levels of biodiversity and biomass. Environment-forming ES are most efficiently and sustainably performed by undisturbed natural climax communities. Any disturbance leads to a weakening of the natural regulation of the environment. In the majority of cases (except the aesthetic component of cultural landscapes, which is primarily important for recreational services), information functions are also maximized in undisturbed natural ecosystems.

When the productive ES are consumed, the management goal conflicts with the maintenance of natural levels of biodiversity, since it requires the disturbance of ecosystems. The management goal is to maximize the sustainable harvest. The high productivity of communities is possible only if their structure is simplified and diversity is reduced. For the purpose of maximum harvest, the early and middle stages of succession or their artificial equivalents are optimum.

Commercial exploitation of natural systems is appropriate only if the value of their environment-forming ES is comparable with the value of the biological product obtained. In the majority of cases, however, the value of the environment-forming ES exceeds many times over all the benefits that might accrue from extracting biological product from natural ecosystems. In these cases, the implementation of the strategy of "maximum sustainable harvest" substantially lowers the total "benefit" of biodiversity. The intensity and forms of exploitation of natural systems to obtain biological products must be strictly limited by the requirement to preserve the structure and environment-forming functions of ecosystems, species and populations.

The second conflict in management goals, which arises during the management of natural ecosystems, is the simultaneous consumption of recreational and informational ES in protected areas. PAs are primarily intended to preserve natural systems unaltered by man. Protected natural systems are repositories of information about the structure and functioning of wildlife (biodiversity) which is to be understood and used by future generations. The importance of this information cannot be fully appreciated today. The second important function of PAs is the development of environmental and educational tourism. The recreational use of PAs inevitably disturbs the functioning of natural systems, i.e., it conflicts with the first objective. When these conflicts in the goals of managing PAs arise, the priority should be to preserve undisturbed natural ecosystems, i.e., the use of the ecosystem service of information retention. Recreational use of PAs is allowable only in such areas and only to the extent that protected natural systems are not disturbed.

Preliminary requirements for the national system of monitoring, assessing and managing ecosystem services

The system of monitoring, assessing and managing ES should take into account the state of natural ecosystems and biodiversity, as they are the structural and functional basis of ES. These issues will be considered in Volume 2 of the Prototype Report, and the full requirements for the system of monitoring, assessing and managing ES will be set after that. In the present Volume 1 of the Prototype Report, only the general preliminary requirements were formulated:

– considering the current state and possible changes of biodiversity at different hierarchical levels (intra-population, intraspecific, species and ecosystem diversity) as a basis of ecosystem functions and services, because biodiversity is a critical factor in the efficiency and stability of ecosystem functioning;

– valuation of biodiversity, considering ecosystem functions of all hierarchical levels and their implications for the stability of natural systems and ES performance;

– accounting for the total value of all major groups of ES, and above all environment-forming (regulating) ES; priority of environment-forming (regulating) ES in possible conflicts between aims of use of different ES;

– estimation of ES in three indicators: supplied, demanded and consumed ES;

– considering spatial scales of ecosystem functions and services;

– comparing spatial distribution of ES and indicators of socio-economic development of regions in the choice of the assessment methods and management goals;

– use of best available techniques and technologies of ES assessment.

MAIN FINDINGS

● Terrestrial ecosystem services are critical for the well-being of the population and economy of Russia. The volume of the most important ES provided by ecosystems is comparable to the amount of basic needs of the population and economy of the Russian regions for regulation of the environment, natural bioproduction, and conditions for recreation.

● A number of the most important life-supporting ES are fully used, or they are already not sufficient to meet the needs of people and the economy. This is true for ecosystem regulation of runoff, ensuring water quality by terrestrial ecosystems, water purification in aquatic ecosystems, and absorption of air pollutants by suburban forests.

● The uneven distribution of supplied, demanded and consumed ES makes some regions ES donors and others ES recipients. These relationships must be considered in national and multiregional planning and development of ES markets.

● Currently ES are missing in the field of state regulation. ES are not adequately assessed and are not taken into account when making decisions.

Provisioning ES (the main biological resources) are in part subject to government regulation, but in the post-Soviet time, it was significantly weakened and the share of illegal unreported and unregulated (IUU) harvesting of all types of bioresources has grown substantially.

Environment-forming (regulating) ES are practically not taken into account and are not regulated by the government, except for some forest ES (partly water and soil protection and “carbon” services). The failure to account for regulating ES in decision making leads to damage that may exceed the supposed profit several times.

Informational ES are completely absent in governmental and legal regulations.

Recreational ES are understood in a very limited sense – merely as the possibility of obtaining profit from recreation in nature. Particularly, this has a negative impact on the strategy of development of Russia’s strictly protected areas (zapovedniks). The traditional priority task of preservation and study of nature was replaced by the task of tourism development, which inevitably leads to violations of natural systems and a loss of information about their structure and functions.

● ES monitoring is absent in Russia. Monitoring of natural ecosystems (except for forests) and the components of biodiversity which form the structural and functional basis of ES is incomplete and does not correspond to the modern level of technology. Bioresource accounting systems are permanently being reformed and do not provide comprehensive information. The degree of official data reliability is low, especially on IUU harvesting and forest fires. Many of the data are not available in the public domain.

● It is necessary to immediately start forming a national system of ES monitoring and assessment, as well as mechanisms of integrating ES values in decision making. If this is not done, the environmental safety and sustainable development of Russia will be threatened, and global advantages of an ecological donor country will be lost.

REFERENCES

All-Russian Research Institute of Civil Defense. (1996). Methodology for forecasting contamination of open water sources by accident-prone chemical substances in extremely dangerous situations. Moscow. (In Russian. Методика прогнозной оценки загрязнения открытых водоисточников аварийно химически опасными веществами в чрезвычайно опасных ситуациях. – М.: ВНИИ ГОЧС, 1996. – 37 с.).

Aksenov, D. Ye., Dobrynin, D. V., Dubinin, M. Yu., Egorov, A. V., Isaev, A. S., Karpachevsky, M. L., Lestadius, L.G., Potapov, P. V., Purekhovsky, A. Zh., Turubanova, S. A., Yaroshenko, A. Yu. (2003). Atlas of intact forest areas of Russia. Moscow: MSoEU; Washington: World Resources Inst. (In Russian. Атлас малонарушенных лесных территорий России / Д. Е. Аксенов, Д. В. Добрынин, М. Ю. Дубинин, А. В. Егоров, А. С. Исаев, М. Л. Карпачевский, Л. Г. Лестадиус, П. В. Потапов, А. Ж. Пуреховский, С. А. Турубанова, А. Ю. Ярошенко – М.: Изд-во МСоЭС; Вашингтон: Изд-во World Resources Inst., 2003. – 184 с. (http://old.forest.ru/rus/publications/intact/index.htm).

Artamonov, V.I. (1986). Plants and cleanliness of the natural environment. Moscow: Nauka. (In Russian. Артамонов В.И. Растения и чистота природной среды. – М.: Наука, 1986. – 175 с.).

Balakay, N. I. (2011). Methodology of reducing surface runoff and pollutants mass from environmental measures. Izv. Lower-Volga agrouniversity. complex: science and higher prof. education, 1 (21), 89–97. (In Russian. Балакай Н.И. Методология снижения поверхностного стока и массы загрязняющих веществ от применения природоохранных мероприятий // Изв. Нижневолж. агроуниверситет. комплекса: наука и высш. проф. образование. – 2011. № 1 (21). – С. 89–97).

Baro, F., Chaparro, L., Gomez-Baggethun, E., Langemeyer, J., Nowak, D.J., Terradas, J. (2014). Contribution of ecosystem services to air quality and climate change mitigation policies the case of urban forests in Barcelona, Spain. AMBIO, 43, 466–479.

Bartalev, S. A., Belvard, A. S., Ershov, D. V., Isaev, A. S. (2004). Map of terrestrial ecosystems of Northern Eurasia. Moscow: Space Res. Institute, RAS. (In Russian. Барталев С.А., Белвард А.С, Ершов Д.В., Исаев А.С. Карта наземных экосистем Северной Евразии. – М.: Ин-т косм. исслед. РАН, 2004). http://terranorte.iki.rssi.ru.

Basanets, L. P. (2006). Ecological and tourist zoning of Russia (PhD dissertation). Moscow. (In Russian. Басанец Л.П. Эколого-туристское районирование России: Автореф. дис. ... канд. геогр. наук. – М., 2006. – 28 с.).

Basanets, L.P., Drozdov, A.V. (2006). Nature management for tourism, ecological imperative and prospects of Russia. In Nature management and sustainable development. World Ecosystems and Problems of Russia (pp. 322–340). Moscow: KMK. (In Russian. Басанец Л.П., Дроздов А.В. Туристское природопользование, экологический императив и перспективы России // Природопользование и устойчивое развитие. Мировые экосистемы и проблемы России. – М.: Т-во науч. изд. КМК, 2006. – С. 322–340.).

Bastian, O., Grunewald, K., Khoroshev, A.V. (2015). The significance of geosystem and landscape concepts for the assessment of ecosystem services – exemplified in a case study in Russia. Landscape Ecology, 30 (7), 1145–1164.

Biodiversity Conservation Center. (2010). The Economics of Ecosystems and Biodiversity: The Potential and Prospects of Northern Eurasia. "TEEB Project: Prospects for the Participation of Russia and Other NIS Countries" (Moscow, February 24, 2010) Moscow. (In Russian. Экономика экосистем и биоразнообразия: потенциал и перспективы стран Северной Евразии: Мат-лы совещ. «Проект TEEB – экономика экосистем и биоразнообразия: перспективы участия России и других стран ННГ» (Москва, 24.02.2010) – М.: Изд-во Центра охраны дикой природы, 2010. – 136 с.).

Biodiversity Conservation Center. (2011). The problems of integrating ecosystem services into the economies of the NIS (Moscow, March 28–29, 2011). Moscow. (In Russian. Проблемы интеграции экосистемных услуг в экономику стран ННГ: Мат-лы междунар. конф. (Москва, 28–29 марта 2011 г.). – М.: Изд-во Центра охраны дикой природы, 2011).

Bobylev, S. N., Kasyanov, P. V., Soloveva, S. V., Stetsenko, A. V. (2008). Integrated economic assessment of salmon in Kamchatka. Moscow: Human Rights. (In Russian. Бобылев С.Н., Касьянов П.В., Соловьева С.В., Стеценко А.В. Комплексная экономическая оценка лососевых Камчатки. – М.: Права человека, 2008. – 64 с.).

Bobylev, S. N., Perelet, R. A., Solovyeva, S. V. (2012). Assessment and implementation of a payment system for ecosystem services in nature protected areas. Volgograd: UNDP, GEF. (In Russian. Бобылев С.Н., Перелет Р.А., Соловьева С.В. Оценка и внедрение системы платежей за экосистемные услуги на особо охраняемых природных территориях. – Волгоград: ПРООН, ГЭФ, 2012. – 219 с.).

Bobylev, S. N., Sidorenko, V. N., Luzhetskaya, N. V. (2001). Economic basis for wetlands conservation. Moscow: Wetlands International. (In Russian. Бобылев С.Н., Сидоренко В.Н., Лужецкая Н.В. Экономические основы сохранения водно-болотных угодий. – М.: Wetlands International, 2001. – 56 с.).

Bobylev, S. N., Tishkov, A. A. (1999). Economic Assessment of Biodiversity. Moscow: CPRP, Project GEF "Conservation of Biodiversity". (In Russian. Экономическая оценка биоразнообразия / Ред. С.Н. Бобылев, А.А. Тишков. – М.: ЦПРП, Проект ГЭФ «Сохранение биоразнообразия», 1999. – 112 с.).

Bogoslovsky, B. B., Samokhin, A. A., Ivanov, K. E., Sokolov, D. P. (1984). General hydrology (hydrology of land). Leningrad: Gidrometeoizdat. (In Russian. Богословский Б.Б., Самохин А.А., Иванов К.Е., Соколов Д.П. Общая гидрология (гидрология суши). – Л.: Гидрометеоиздат, 1984. – 42 с.).

Bukvareva, E.N., Grunewald, K., Bobylev, S.N., Zamolochikov, D.G., Zimenko, A.V., Bastian, O. (2015). The current state of knowledge of ecosystems and ecosystem services in Russia. A status report. AMBIO, 44 (6), 491–507.

Chasov, E. I. (Ed.). (1983). Resorts: Encyclopedic Dictionary. Moscow: Sov. encycl. (In Russian. Курорты: Энциклопедический словарь / Гл. ред. Е.И. Чазов. – М.: Сов. энцикл., 1983. – 590 с.).

Chernyshenko, O. V. (2001). Absorptive ability and gasresistance of woody plants in conditions of a city (Doctoral dissertation). Moscow: Moscow State Forest University. (In Russian. Чернышенко О.В. Поглотительная способность и газоустойчивость древесных растений в условиях города: Дис. ... д-ра биол. наук. – М.: Моск. гос. ун-т леса, 2001).

Clough, P. (2013). The value of ecosystem services for recreation. In J. R. Dymond (Ed.), Ecosystem services in New Zealand – conditions and trends (pp. 330–342). Lincoln, New Zealand: Manaaki Whenua Press.

Code of Regulations "Foundations on permafrost grounds". (2012). Moscow: Approved by Ministry of Regional Development of Russia. No. 622 of 29.12.2011. (In Russian. Свод правил «Основания и фундаменты на вечномерзлых грунтах». СП 25.13330.2012. Утв. приказом Минрегион России № 622 от 29.12.2011. – М., 2012. – 118 с.).

Costanza, R. (2008). Ecosystem services: multiple classification systems are needed. Biological Conservation, 141, 350–352.

Dolman, A. J., Shvidenko, A., Schepaschenko, D., Ciais, P., Tchebakova, N., Chen, T., van der Molen, M. K., Belelli Marchesini, L., Maximov, T. C., Maksyutov, S., Schulze, E.-D. (2012). An estimate of the terrestrial carbon budget of Russia using inventory-based, eddy covariance and inversion methods. Biogeosciences, 9, 5323–5340.

Dorofeev, A. A. (2003). Landscape-recreational analysis of territory for ecological tourism (on an example of the Tver region (PhD dissertation). Smolensk. (In Russian. Дорофеев А.А. Ландшафтно-рекреационный анализ территории для целей экологического туризма (на примере Тверской области): Автореф. дис. ... канд. геогр. наук. – Смоленск, 2003. – 28 с.).

Efremov, S. P., Efremova, T. T., Melentyeva, N. V. (1998). Carbon storage in peatland ecosystems. In V. A. Alexeyev and R. A. Birdsey (Eds.), Carbon storage in forests and peatlands of Russia. Radnor: USDA Forest Service.

Egoshina, T. L. (2005). Non-wood plant resources of Russia. Moscow: NIA-Nature. (In Russian. Егошина Т.Л. Недревесные растительные ресурсы России. – М.: НИА-Природа, 2005. – 80 с.).

Ershov, E. D. (1971). Approximate quantitative evaluation of the influence of various natural factors on rocks temperature regime. In Permafrost Research, Isuue 11 (pp. 52–56). Moscow: Moscow State University. (In Russian. Ершов Э.Д. Приближенная количественная оценка влияния различных факторов природной обстановки на температурный режим пород // Мерзлот. исслед. – М.: Изд-во МГУ, 1971. № 11. – С. 52–56).

Grunewald, K., Bastian, O., Drozdov, A. (Eds.). (2014a). TEEB-Prozesse und Ökosystem-Assessment in Deutschland, Russland und weiteren Staaten des nördlichen Eurasiens. BfN-Skripten 372. Bonn. (German and Russian).

Grunewald, K., Bastian, O., Drozdov, A., Grabowsky, V. (Eds.). (2014b). Erfassung und Bewertung von Ökosystemdienstleistungen (ÖSD) – Erfahrungen, insbesondere aus Deutschland und Russland. BfN-Skripten 373. Bonn (German and Russian).

Gryaznov, S. E., Kuzminyh, Yu. V., Bogachev, Yu. K. (2011). Assessment and measurement of illegal logging in the forest sector of the Russian Federation. News of Higher education institutions. Forest Journal, 5, 124–130. (In Russian. Грязнов С.Е., Кузминых Ю.В., Богачев Ю.К. Оценка и измерение нелегальных лесозаготовок в лесном секторе Российской Федерации // Изв. высш. учеб. заведений. Лес. журн. – 2011. № 5. – С. 124–130).

Guidance on calculation of fees for unorganized discharge of pollutants into water bodies. Approved by the State Committee for Environment Protection of the Russian Federation. December 29. 1998. (In Russian. Методические указания по расчету платы за неорганизованный сброс загрязняющих веществ в водные объекты. Утв. Гос. ком. РФ по охране окр. Среды. 29 дек. 1998).

Haines-Young, R. and M. Potschin, M. (2009): Upland Ecosystem Services. Report to Natural England. Coordination Contract. (www.nottingham.ac.uk/CEM/pdf/Upland%20Ecosystem%20Services_FinalReport_080409.pdf).

Haines-Young, R. and Potschin, M. (2013). Common international classification of ecosystem services (CICES): Consultation on Version 4, August–December 2012. EEA Framework Contract No EEA/IEA/09/003.

Harris, I., Jones, P. D., Osborn, T. J., Lister, D. H. (2014). Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 dataset. Intern. J. Climatology, 34 (3), 623–642.

Ilyichev, V. A., Vladimirov, V. V., Sadovsky, A. V. (2003). Prospects for settlements development in the North in modern conditions. Moscow: RAASN. (In Russian. Ильичев В.А., Владимиров В.В., Садовский А.В. и др. Перспективы развития поселений Севера в современных условиях. – М.: РААСН, 2003. – 152 с.).

Information Resources of the National Strategy and Action Plan for Biodiversity Conservation in Russia. http://www.sci.aha.ru/biodiv/npd/index.htm (In Russian. Информационные ресурсы Национальной стратегии и плана действий по сохранению биоразнообразия России).

Inisheva, L. I., Kobak, K. I., Turchinovich, I. E. (2013). The development of the swamping process and the rate of carbon accumulation in swamp ecosystems in Russia. Geography and nature resources, 3, 60–68. (In Russian. Инишева Л.И., Кобак К.И., Турчинович И.Е. Развитие процесса заболачивания и скорость аккумуляции углерода в болотных экосистемах России // География и природ. ресурсы. – 2013. № 3. – С. 60–68).

Jolankai, G. (1983). Modelling of non-point source pollution. In Application of ecological modelling in environmental management (pp. 283–379). Amsterdam: Elsevier.

Jolankai, G. (1992). Hydrological, chemical and biological processes of contaminant transformation and transport in river and lake system: State-of-the-art report. Paris: UNESCO.

Joosten, H. (2009). The global peatland CO_2 picture: peatland status and drainage related emissions in all countries of the world. Wetland International.

Kalinin, V. M. (2008). Ecological hydrology. Tyumen: Tyumen State University. (In Russian. Калинин В.М. Экологическая гидрология. – Тюмень: Изд-во Тюмен. гос. ун-та, 2008. – 148 с.).

Kalinin, V. M. (2010). Water and oil (hydrological and environmental problems of the Tyumen region). Tyumen: Tyumen State University. (In Russian. Калинин В.М. Вода и нефть (гидролого-экологические проблемы Тюменского региона). – Тюмень: Изд-во Тюмен. гос. ун-та, 2010. – 222 с.).

Kotlobay, A., Lopina, O., Kharchenkov, Yu., Bryukhanov, A., Schegolev, A., Smirnov, D. (2006). Evaluation of timber of doubtful origin and analysis of the practice of introducing systems for tracing the origin of wood in a number of multi-forest regions of the North-West, Siberia and the Far East of Russia. Moscow: WWF. (In Russian. Котлобай А., Лопина О., Харченков Ю., Брюханов А., Щеголев А., Смирнов Д. Оценка объемов древесины сомнительного происхождения и анализ практики внедрения систем отслеживания происхождения древесины в ряде многолесных регионов Северо-Запада, Сибири и Дальнего Востока России. – М.: ВВФ, 2006. – 56 с.).

Kotlyakov, V. M. (Ed.). (1997). Atlas of snow and ice resources of the world. Moscow: Institute of Geography RAS; NPP Cartography. Vol. I. (In Russian. Атлас снежно-ледовых ресурсов мира / Гл. ред. В.М. Котляков. – М.: Ин-т географии РАН; НПП «Картография», 1997. Т. I.).

Kravtsova, M. V., Aladinskaya, A. R., Pisklova, O. P. (2014). Calculation of pollutant concentrations using computer simulation of emission dispersion. News of Samara Science Center of RAS, 16 (1–6), 1784–1790. (In Russian. Кравцова М.В., Аладинская А.Р., Писклова О.П. Расчет концентраций загрязняющих веществ с применением компьютерного моделирования рассеивания выбросов // Изв. Самар. Науч. центра РАН. – 2014. Т. 16. № 1–6. – С. 1784–1790).

Kudryavtsev, V. A., Garagulya, L. S., Kondratyeva, K. A., Melamed, V. G. (1974). Framework for the permafrost forecast for engineering-geological studies. Moscow: Moscow State Univ. (In Russian. Кудрявцев В.А., Гарагуля Л.С., Кондратьева К.А., Меламед В.Г. Основы мерзлотного прогноза при инженерно-геологических исследованиях. – М.: Изд-во МГУ, 1974. – 432 с.).

Kulagin, Yu. Z. (1974). Woody plants and industrial environment. Moscow: Nauka. (In Russian. Кулагин Ю.З. Древесные растения и промышленная среда. – М.: Наука, 1974. – 125 с.).

Kurganova, I. N., Lopes de Gerenyu, V. O., Six, J., Kuzyakov, Y. (2014). Carbon cost of collective farming collapse in Russia. Global Change Biology, 20, 938–947.

Laptev, N. I. (2009). Wild plants: socioeconomic importance for the Tomsk region. Towards a sustainable development of Russia, 47, 42–43. (In Russian. Лаптев Н.И. Дикоросы: социально-экономическое значение для Томской области // На пути к устойчивому развитию России. – 2009. № 47. – С. 42–43).

Lobanova, Z. M. (2009). Ecology and protection of the biosphere. Barnaul: Altai State Technical University. (In Russian. Лобанова З.М. Экология и защита биосферы. – Барнаул: Изд-во АлтГТУ, 2009. – 130 с.).

Lohan, D., Johnston, S. (2003). The international regime for bioprospecting. Existing policies and emerging issues for Antarctica. UNU/IAS Report.

Lomanova, N. V. (Ed.). (2011). The state of game resources in the Russian Federation in 2008–2010: Information-analytical materials. Game animals of Russia (biology, protection, resource management, rational use). Issue 9. Moscow: Phys. culture. (In Russian. Состояние охотничьих ресурсов в Российской Федерации в 2008–2010 гг.: Информ.-аналит. мат-лы. Ред. Н.В. Ломанова // Охотничьи животные России (биология, охрана, ресурсоведение, рациональное использование). Вып. 9. – М.: Физ. культура, 2011. – 219 с.).

Maes, J., Paracchini, M. L., Zulian, G. A. (2011). European assessment of the provision of ecosystem services. Towards an atlas of ecosystem services. Luxembourg: Publ. Office EU.

Medvedeva, O. E. (2010). Implementation of economic assessments of ecosystem services in Russia. In Economics of ecosystems and biodiversity: the potential and prospects of the countries of Northern Eurasia (pp. 108–113). Moscow: Biodiversity Conservation Center. (In Russian. Медведева О.Е. Использование экономических оценок экосистемных услуг в России // Экономика экосистем и биоразнообразия:

потенциал и перспективы стран Северной Евразии. – М.: Изд-во Центра охраны дикой природы, 2010. – С. 108–113).
Mesjatz, V. K. (Ed.). (1989). Agricultural Encyclopedic Dictionary. Moscow: Sov. encycl. (In Russian. Сельскохозяйственный энциклопедический словарь. / Редкол.: В.К. Месяц (гл. ред.) и др. – М.: Сов. энцикл., 1989. – 656 с.)
Mikhailov, S. A. (2000). Diffuse contamination of aquatic ecosystems. Evaluation methods and mathematical models. Analitical overview. Barnaul: Den. (In Russian Михайлов С.А. Диффузное загрязнение водных экосистем. Методы оценки и математические модели. Аналит. обзор. – Барнаул: День, 2000. – 130 с.).
Millennium Ecosystem Assessment. Washington, DC: Synthesis. Island Press, 2005.
Ministry of Natural Resources and Environment of the Russian Federation. (1995). The economics of biodiversity conservation. Moscow. (In Russian. Экономика сохранения биоразнообразия. – М.: МПР РФ, 1995. – 296 с.).
Ministry of Natural Resources and Environment of the Russian Federation. (2014). Governmental report "On the state and protection of the environment of the Russian Federation in 2013". Moscow. (In Russian. Государственный доклад «О состоянии и об охране окружающей среды Российской Федерации в 2013 году». – М.: МПР РФ, 2014. – 463 с.).
Ministry of Natural Resources and Environment of the Russian Federation. (2015a). Government report "On the state and protection of the environment of the Russian Federation in 2014". Moscow. (In Russian. Государственный доклад «О состоянии и об охране окружающей среды Российской Федерации в 2014 году». – М.: МПР РФ, 2015. – 473 с.).
Ministry of Natural Resources and Environment of the Russian Federation. (2015b). The fifth national report "Conservation of Biodiversity in the Russian Federation". Moscow. (In Russian. Пятый национальный доклад «Сохранение биоразнообразия в Российской Федерации». – М.: МПР РФ, 2015. – 124 с.).
Moiseev, B. N., Filipchuk, A. N. (2009). IPCC methodology for calculating annual carbon deposition and assessing its applicability for Russian forests. Forest Industry, 4, 11–13. (In Russian. Моисеев Б.Н., Филипчук А.Н. Методика МГЭИК для расчета годичного депонирования углерода и оценка ее применимости для лесов России // Лес. хоз-во. – 2009. № 4. – С. 11–13).
Mudrov, Yu. V. (2007). Permafrost phenomena in the cryolithozone of plains and mountains. Basic concepts and definitions. M.: Nauchny Mir. (In Russian. Мудров Ю.В. Мерзлотные явления в криолитозоне равнин и гор. Основные понятия и определения. – М.: Науч. мир, 2007. – 316 с.).
Nahuelhual, L., Carmona, A., Lozada, P., Jaramillo, A., Aguayo, M. (2013). Mapping recreation and ecotourism as a cultural ecosystem service: An application at the local level in Southern Chile. Applied Geography, 40, 71–82.
National Atlas of Russia. Volumes 1–4. (2004–2008). Moscow: Federal Agency for Geodesy and Cartography of Russia. (In Russian. Национальный атлас России. – М.: Роскартография, 2004–2008. Т. 1–4 (http://xn--80aaaa1bhnclcci1cl5c4ep.xn--p1ai/).
National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2011. (2013a). Part 1. Moscow. (In Russian. Национальный доклад Российской Федерации о кадастре антропогенных выбросов из источников и абсорбции поглотителями парниковых газов, не регулируемых Монреальским протоколом, за 1990–2011 гг. – М., 2013а. Ч. 1. – 421 с.).
National report of the Russian Federation on the cadastre of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for 1990–2011. (2013b). Part 2. Annexes. Moscow. (In Russian. Национальный доклад Российской Федерации о кадастре антропогенных выбросов из источников и абсорбции поглотителями парниковых газов, не регулируемых Монреальским протоколом, за 1990–2011 гг. – М., 2013б. Ч. 2. Приложения. – 91 с.).
National Strategy of Biodiversity Conservation in Russia. (2001). Moscow: RAS, Ministry of Natural Resources of Russia, GEF Project "Conservation of Biodiversity". (In Russian. Национальная стратегия сохранения биоразнообразия России. – М.: РАН, МПР России, Проект ГЭФ «Сохранение биоразнообразия», 2001. – 75 с.).
NEESPI. (2004). The Northern Eurasia Earth Science Partnership Initiative. Science plan. 3.1. Terrestrial ecosystem dynamics (www.neespi.org).
Nikanorov, A. M. (2012). Quality of surface waters of the Russian Federation. Yearbook, 2011. Rostov-on-Don: Institute of Hydrochemistry. (In Russian. Качество поверхностных вод Российской Федерации: Ежегодник. Гл. ред. А. М. Никаноров. 2011. – Р. н/Д.: Гидрохим. ин-т, 2012. – 553 с.).
Nowak, D.J., Crane, D.E., Stevens, J.C. (2006). Air pollution removal by urban trees and shrubs in the United States. Urban Forestry & Urban Greening, 4, 115–123.
PAIMS. (1995). Analysis of socioeconomic factors affecting the state of biological diversity: Prep. phase of the GEF project "Conservation of Biodiversity in Russia". Annex. 1. Moscow. (In Russian. Анализ социально-экономических факторов, влияющих на состояние биологического разнообразия: Подготов. фаза проекта ГЭФ «Сохранение биоразнообразия России». Прил. 1. – М.: ПАИМС, 1995. – 288 с.).
Parish, F., Sirin, A., Charman, D., Joosten, H., Minayeva, T., Silvius, M. and Stringer, L. (Eds.). (2008). Assessment on Peatlands, Biodiversity and Climate Change: Main Report. Kuala Lumpur: Global Environment Centre, and Wageningen: Wetlands International.
Pavlov, D. S., Bukvareva, E. N. (2010). Environment-forming functions of wildlife and ecologocentric concept of nature management. In Economics of ecosystems and biodiversity: the potential and prospects of the countries of Northern Eurasia (pp. 7–19). Moscow:

Biodiversity Conservation Center. (In Russian. Павлов Д.С., Букварёва Е.Н. Средообразующие функции живой природы и экологоцентрическая концепция природопользования // Экономика экосистем и биоразнообразия: потенциал и перспективы стран Северной Евразии. – М.: Изд-во Центра охраны дикой природы, 2010. – С. 7–19.).

Pavlov, D. S., Striganova, B. R., Bukvareva, E. N., Dgebuadze, Yu. Yu. (2009). Preservation of biological diversity as a condition for sustainable development. Moscow: Institute of Sustainable Development – Center for Ecology Politics of Russia. (In Russian. Павлов Д.С., Стриганова Б.Р., Букварёва Е.Н., Дгебуадзе Ю.Ю. Сохранение биологического разнообразия как условие устойчивого развития. – М.: Ин-т устойчивого развития – Центр экол. политики России, 2009. – 84 с.).

Prokacheva, V. G., Usachev, V. F. (2004). Polluted lands in the regions of Russia. Hydrographic aspect. St. Petersburg: Nedra. (In Russian. Прокачева В.Г., Усачев В.Ф. Загрязненные земли в регионах России. Гидрографический аспект. СПб.: Недра, 2004. 106 с.).

Prokacheva, V. G., Usachev, V. F. (2006). Contaminated lands by districts, urban settlements and river catchments. North-West Federal District of Russia. St. Petersburg: Nedra. (In Russian. Прокачева В.Г., Усачев В.Ф. Загрязненные земли по районам, городским поселениям и в речных водосборах. Северо-Западный федеральный округ России. – СПб.: Недра, 2006. – 102 с.).

Prokacheva, V. G., Usachev, V. F. (2010). Contaminated lands by districts, urban settlements and river catchments. Siberian Federal District of Russia. St. Petersburg: Lem Publishing house. (In Russian. Прокачева В.Г., Усачев В.Ф. Загрязненные земли по районам, городским поселениям и в речных. Сибирский федеральный округ России. – СПб.: Изд-во Лема, 2010. – 164 с.).

Prokacheva, V. G., Usachev, V. F. (2011). Contaminated lands by districts, urban settlements and river catchments. Far Eastern Federal District of Russia. St. Petersburg: Lem Publishing house. (In Russian. Прокачева В.Г., Усачев В.Ф. Загрязненные земли по районам, городским поселениям и в речных водосборах. Дальневосточный федеральный округ России. – СПб.: Изд-во Лема, 2011. – 110 с.).

Ptichnikov, A., Kuritsyn, A. (2011). Systems for tracing wood in Russia: the experience of timber companies and forest management bodies. Analitical report. Moscow: WWF of Russia. (In Russian. Птичников А., Курицын А. Системы отслеживания происхождения древесины в России: опыт лесопромышленных компаний и органов управления лесами: Аналит. отчёт. – М.: WWF России, 2011. – 116 с.).

Romanovsky, N. N. (1980). The coldness of the Earth. Moscow: Prosveschenie. (In Russian. Романовский Н.Н. Холод Земли. – М.: Просвещение, 1980. – 138 с.).

Romanovsky, V. E., Drozdov, D. S., Oberman, N. G., Malkova, G. V., Kholodov, A. L., Marchenko, S. S., Moskalenko, N. G., Sergeev, D. O., Ukraintseva, N. G., Abramov, A. A., Gilichinsky, D. A. and Vasiliev, A. A. (2010). Thermal state of permafrost in Russia. Permafrost and Periglacial Processes, 21 (2), 136–155.

Rosstat. (2013a). Agriculture, Hunting and Hunting Industry, and Forest Management in Russia.Statistical Bull. Moscow. (In Russian. Сельское хозяйство, охота и охотничье хозяйство, лесоводство в России. 2013: Стат. сб. – М.: Росстат, 2013. – 462 с.) (www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1138718713500).

Rosstat. (2013b). Regions of Russia. Socioeconomic indicators. Statistical Bull. Moscow: (In Russian. Регионы России. Социально-экономические показатели. 2013: Стат. сб. – М.: Росстат, 2013. – 990 с.) (www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1138623506156).

Rozhkov, V. A., Wagner, V. B., Kogut, B. M., Konyushkov, D. E., Nilsson, S., Sheremet, V. B., and Shvidenko, A. Z. (1996). Soil Carbon estimates and soil carbon map for Russia. Working paper. WP-96-60. Laxenburg, Austria: IIASA.

Savichev, O. G. (2014). Methodology for assessing the actual and permissible impact of economic activity on the chemical composition and quality of fresh natural waters. Fundamental Research, 8, 704–708. (In Russian. Савичев О.Г. Методология оценки фактического и допустимого влияния хозяйственной деятельности на химический состав и качество пресных природных вод // Фундамент. исслед. – 2014. № 8. – С. 704–708).

Shirkova, E. E., Shirkov, E. I. (2006). Economic evaluation of biological diversity of exploited wildlife objects (on the example of intraspecific diversity of Pacific salmon). In Conservation of biodiversity of Kamchatka and adjacent seas. Reports of VI Scientific Conf (pp. 151–173). Petropavlovsk-Kamchatsky: Kamchatpress. (In Russian Ширкова Е.Э., Ширков Э.И. Экономическая оценка биологического разнообразия эксплуатируемых объектов живой природы (на примере внутривидового разнообразия тихоокеанских лососей) // Сохранение биоразнообразия Камчатки и прилегающих морей: Докл. VI науч. конф. – Петропавловск-Камчат.: Камчатпресс, 2006. – С. 151–173).

Shoba, S. A. (Ed.). (2011). National Atlas of Soils of the Russian Federation. Moscow: Astrel, AST. (In Russian. Национальный атлас почв Российской Федерации. Гл. ред. С.А. Шоба. – М.: Астрель; АСТ, 2011. – 632 с.).

Shvidenko, A. Z., Shchepashchenko, D. G. (2014). Carbon budget of Russian forests. Sibirian Forest journal, 1, 69–92. (In Russian. Швиденко А.З., Щепащенко Д.Г. Углеродный бюджет лесов России // Сибир. лес. журн. – 2014. № 1. – С. 69–92).

Smelyansky, I. (2012). The role of Russian steppe ecosystems in carbon deposition. Steppe bull, 35, 4–8. (In Russian. Смелянский И. Роль степных экосистем России в депонировании углерода // Степ. бюл. – 2012. № 35. – С. 4–8).

Smelyansky, I. E., Buivolov, Yu. A., Bazhenov, Yu. A., Bakirova, R. T., Borovik, L. P., Borodin, A. P., Bykova, E. P., Vlasov, A. A., Gavrilenko, V. S., Goroshko, O. A., Gribkov, A. V., Kirilyuk, V. E., Korsun, O. V., Kreindlin, M. L., Kuksin, G. V., Lysenko, U. N., Polchaninova, N. Yu., Pulyaev, A. I., Ryzhkov, O. V., Ryabinina, Z. N., Tkachuk, T. E. (2015). Steppe fires and management of fire situation in steppe PAs: ecological and nature protection aspects. Analytical review. Moscow: Biodiversity Conservation Center. (In Russian. Степные пожары и управление пожарной ситуацией в степных ООПТ: экологические и природоохранные аспекты. Аналит. обзор / Смелянский И.Э., Буйволов Ю.А., Баженов Ю.А. и др. – М.: Изд-во Центра охраны дикой природы, 2015. – 144 с.).

Smith, L. C., MacDonald, G. M., Velichko, A. A., Beilman, D. W., Borisova, O. K., Frey, K. E., Kremenetski, K. V., Sheng, Y. (2004). Siberian peatlands a net carbon sink and global methane source since the Early Holocene. Science, 303, 353–356.

Sohngen, B., Andrasko, K., Gytarsky, M., Korovin, G., Laestadius, L., Murray, B., Utkin, A., Zamolodchikov, D. (2005). Stocks and flows. Carbon inventory and mitigation potential of the Russian forest and land base. World Resources Institute.

Stolbovoi, V. (2002). Carbon in Russian soils. Climate Change. 2002, 55, 131–156.

Stolbovoi, V., McCallum, I. (2002). Land Resources of Russia (CD-ROM). Laxenburg, Austria: International Institute for Applied Systems Analysis and the Russian Academy of Science. (http://webarchive.iiasa.ac.at/Research/FOR/russia_cd/guide.htm).

Strategy for the development of the hunting industry of the Russian Federation until 2030. Approved by the Government of the Russian Federation of July 3, 2014 No. 1216-р. Moscow. (In Russian. Стратегия развития охотничьего хозяйства Российской Федерации до 2030 года. Утв. распоряжением Правительства РФ от 3.07.2014 № 1216-р.).

Sturman, V. I. (2003). Ecological mapping. Moscow: Aspect Press. (In Russian. Стурман В.И. Экологическое картографирование. – М.: Аспект Пресс, 2003. – 251 с.).

Tarabrin, V. P., Chernyshova, L. V., Peltykhina, R. I. (1984). Use of green plantations for the environment optimization in pollution zone of ferrous metallurgy enterprises. In Plants and industrial environment (pp. 101–106). Sverdlovsk: Ural State Univ. (In Russian. Тарабрин В.П., Чернышова Л.В., Пельтихина Р.И. Использование зеленых насаждений для оптимизации среды в зоне загрязнения предприятий черной металлургии // Растения и промышленная среда: Сб. науч. тр. – Свердловск: УрГУ, 1984. – С. 101–106).

TEEB. (2010). The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. London and Washington: Earthscan.

The list of fishery management standards: the maximum permissible concentrations (MPCs) and the approximately safe levels of exposure (ASLE) of harmful substances for water bodies that are of fishery importance. Approved by RF State committee on Fisheries No. 96 of April 28, 1999. (In Russian. Перечень рыбохозяйственных нормативов: предельно допустимых концентраций (ПДК) и ориентировочно безопасных уровней воздействия (ОБУВ) вредных веществ для воды водных объектов, имеющих рыбохозяйственное значение. Утв. приказом Гос. ком. РФ по рыболовству от 28.04.1999 № 96).

Tishkov, A. A. (Ed.). (2002). The Economics of biodiversity conservation. Handbook. Moscow: GEF Project "Conservation of Biodiversity", Institute of Environmental Economics. (In Russian. Экономика сохранения биоразнообразия: Справочник / Ред. А.А. Тишков; науч. ред.-сост. С.Н. Бобылев, О.Е. Медведева, С.В. Соловьева. – М.: Проект ГЭФ «Сохранение биоразнообразия»; Ин-т экономики природопользования, 2002. – 604 с.).

Tulskaya, N. I., Shabalina, N. V. (2012). Mathematical-cartographic modeling for the assessment of the tourist and recreational potential of a territory (on the example of the Central Federal District). In // Cartography and geoinformatics in studies of changes in natural environment and society: Materials of the All-Russia scientific-practical conf., dedicated the 80th anniversary of the Department of Cartography and Geoinformatics, Faculty of Geography, Moscow State University. Moscow. www.geogr.msu.ru/cafedra/karta/anniversary/docs/tulskaya.pdf (In Russian. Тульская Н.И., Шабалина Н.В. Математико-картографическое моделирование для оценки туристско-рекреационного потенциала территории (на примере Центрального федерального округа) // Картография и геоинформатика в исследованиях изменений природной среды и общества: Мат-лы Всерос. науч.-практ. конф., посвящ. 80-летию каф. картографии и геоинформатики геогр. фак. МГУ. – М., 2012).

Tumel, N. V., Zotova, L. I. (2014). Geoecology of cryolithozone. Moscow: Faculty of Geography, Moscow State University. (In Russian. Тумель Н.В., Зотова Л.И. Геоэкология криолитозоны. – М.: Географ. фак. МГУ, 2014. – 244 с.).

Vladimirov, A. M., Orlov, V. G. (2009). Protection and monitoring of surface inland waters. St. Petersburg: Publishing House of RSHU, (In Russian. Владимиров А.М., Орлов В.Г. Охрана и мониторинг поверхностных вод суши. – СПб.: Изд-во РГГМУ, 2009. – 220 с.).

VNIIClesresurs. (1996). Forest use in the Russian Federation in 1946–1992. Moscow. (In Russian. Лесопользование в Российской Федерации в 1946–1992 гг. – М.: ВНИИЦлесресурс, 1996. – 313 с.).

VNIILM. (2003). Forest Resources of Russia (on accounting for January 1, 2003). Handbook. Moscow. (In Russian. Лесной фонд России (по учету на 1 января 2003 г.). Справочник. – М.: ВНИИЛМ, 2003. – 640 с.).

Volkova, N. V., Feraru, G. S., Tretyakova, L. A. (2015). Assessment of the ecological-and-touristic potential of a region and the prospects for its use (on the example of the Belgorod Oblast). Economics and Management. Regional economy. Theory and practice, 2 (377), 27–38. (In Russian. Волкова Н.В., Ферару Г.С., Третьякова Л.А. Оценка эколого-туристического потенциала региона и перспективы его использования (на примере Белгородской области) // Экономика и управление. Региональная экономика. Теория и практика. – 2015. №2 (377). – С. 27–38).

Vompersky, S. E., Tsyganova, O. P., Kovalev, A. G., Glukhova, T. V., Valyaeva, N. A. (1999). Wetlands of Russia as a factor of atmospheric carbon sequestration (pp. 124–145). In // Global changes in the natural environment and climate. Moscow. (In Russian. Вомперский С.Э., Цыганова О.П., Ковалев А.Г. и др. Заболоченность территории России как фактор связывания атмосферного углерода // Глобальные изменения природной среды и климата. – М.: 1999. – С. 124–145).

Vorobiev, G. I. (Ed.). (1985). Forest Encyclopedia (article "Pollution of the environment"). Moscow: Sov. encycl. (In Russian. Лесная энциклопедия (статья «Загрязнение окружающей среды»). Гл. ред. Г.И. Воробьев. – М.: Сов. энцикл., 1985. – 563 с.).

Water quality standards for water bodies of fishery importance, including standards for maximum permissible concentrations of harmful substances in the waters of water bodies of fishery importance. Approved by the Federal Agency for Fisheries No. 18 of January 18, 2010. (In Russian. Нормативы качества воды водных объектов рыбохозяйственного значения, в том числе нормативы предельно допустимых концентраций вредных веществ в водах водных объектах рыбохозяйственного значения. Утв. приказом Росрыболовства от 18.01.2010 № 20).

WWF. (2015). Intact forest territories of Russia: the current state and losses over the past 13 years. Poster. Moscow. (In Russian. Малонарушенные лесные территории России: современное состояние и утраты за последние 13 лет / Постер. – М.: Всемир. фонд дикой природы (WWF), 2015).

Yu-shi, M., Datong, N., Guang, X., Hongchang, W., Smil, V. (1997). An assessment of the economic losses resulting from various forms of environmental degradation in China. Occasional Paper of the Project on Environmental Scarcities, State Capacity, and Civil Violence. Cambridge: American Academy of Arts and Sciences and the University of Toronto. https://homerdixon.com/environmental-scarcities-state-capacity-and-civil-violence/china/.

Zamolodchikov, D. G. (2012). Dynamics of the carbon balance of Russian forests and its contribution to the change in carbon dioxide atmospheric concentration. Use and protection of natural resources in Russia, 5, 31–38. (In Russian. Замолодчиков Д.Г. Динамика углеродного баланса лесов России и ее вклад в изменение атмосферной концентрации углекислого газа // Использ. и охрана природ. ресурсов в России. – 2012. № 5. – С. 31–38).

Zamolodchikov, D. G., Grabovsky, V. I., Kraev, G. N. (2011). Dynamics of the carbon budget of Russian forests for the last two decades. Lesovedenie, 6 16–28. (In Russian. Замолодчиков Д.Г., Грабовский В.И., Краев Г.Н. Динамика бюджета углерода лесов России за два последних десятилетия // Лесоведение. – 2011. № 6. – С. 16–28).

Zamolodchikov, D. G., Grabovsky, V. I., Korovin, G. N., Guitarsky, M. L., Blinov, V. G., Dmitriev, V. V., Kurts, V. A. (2013a). The carbon budget of managed forests of the Russian Federation in 1990–2050: retrospective assessment and forecast. Meteorology and hydrology, 10, 73–92. (In Russian. Замолодчиков Д.Г., Грабовский В.И., Коровин Г.Н. и др. Бюджет углерода управляемых лесов Российской Федерации в 1990–2050 гг.: ретроспективная оценка и прогноз // Метеорология и гидрология. – 2013. № 10. – С. 73–92).

Zamolodchikov, D. G., Grabovsky, V. I., Shulyak, P. P., Chestnykh, O. V. (2013b). Influence of fires and logging on the carbon balance of the Russian forests, Lesovedenie, 5, 36–49. (In Russian. Замолодчиков Д.Г., Грабовский В.И., Шуляк П.П., Честных О.В. Влияние пожаров и заготовок древесины на углеродный баланс лесов России // Лесоведение. – 2013. № 5. – С. 36–49).

Zamolodchikov, D. G., Utkin, A. I., Korovin, G. N., Chestnykh, O. V. (2005). Dynamics of carbon pools and flows in the territory of the Russian Forest Fund. Ecology, 5, 323–333. (In Russian. Замолодчиков Д.Г., Уткин А.И., Коровин Г.Н., Честных О.В. Динамика пулов и потоков углерода на территории лесного фонда России // Экология. – 2005. № 5. – С. 323–333).

Zavarzin, G. A., Kudeyarov, V. N. (2006). Soil as the main source of carbon dioxide and a reservoir of organic carbon in the territory of Russia. Herald of RAS, 76 (1), 14–29. (In Russian. Заварзин Г.А., Кудеяров В.Н. Почва как главный источник углекислоты и резервуар органического углерода на территории России // Вестн. РАН. – 2006. – Т. 76. № 1. – С. 14–29).

PROJECT PARTICIPANTS

Russian experts

Sergey Bobylev, Faculty of Economics, M.V. Lomonosov Moscow State University, Doctor of Economics, Professor.

Elena Bukvareva, Biodiversity Conservation Center, Doctor of Biology.

Alexey Danilkin, A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Doctor of Biology.

Yury Dgebuadze, A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Doctor of Biology, Academic.

Alexander Drozdov, Institute of Geography, Russian Academy of Sciences, Ph.D. in Geography.

Oleg Filenko, Faculty of Biology, M.V. Lomonosov Moscow State University, Doctor of Biology, Professor.

Vasily Grabovsky, Center for Forest Ecology and Productivity, Russian Academy of Sciences, Ph.D. in Biology.

Armen Grigoryan, Biodiversity Conservation Center.

Alexander Khoroshev, Faculty of Geography, M.V. Lomonosov Moscow State University, Ph. D. in Geography.

Gleb Kraev, Center for Forest Ecology and Productivity, Russian Academy of Sciences, Ph.D. in Geography.

Alexey Narykov, Biodiversity Conservation Center.

Renat Perelet, Institute for Systems Analysis, Russian Academy of Sciences, Doctor of Economics.

Ilya Smelyansky, Sibecocenter.

Bella Striganova, A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Doctor of Biology, Professor, Corresponding Member of RAS.

Arkady Tishkov, Institute of Geography, Russian Academy of Sciences, Doctor of Geography, Professor.

Dmitry Zamolodchikov, Faculty of Biology, M.V. Lomonosov Moscow State University, Center for Forest Ecology and Productivity, Russian Academy of Sciences, Doctor of Biology, Professor.

Alexey Zimenko, Biodiversity Conservation Center.

German experts

Olaf Bastian, Leibniz Institute of Ecological Urban and Regional Development (IÖR Dresden), Dr. habil.

Karsten Grunewald, Leibniz Institute of Ecological Urban and Regional Development (IÖR Dresden), Dr. habil.

Lennart Kümper-Schlake, German Federal Agency for Nature Conservation (BfN)

Biodiversity Conservation Center

The Charitable Foundation "Biodiversity Conservation Center" (BCC) is a professional Russian non-governmental environmental organization. It was organized in 1992 by a group of representatives of the Movement of Nature Protection Volunteer Squads and was established by the Russian Social Ecological Union.

The Biodiversity Conservation Center deals with nature protection tasks in Russia and neighboring countries, including development and implementation of nature conservation projects in Northern Eurasia, support of nature reserves, national parks and other protected areas, methodological and consultative support to environmental initiatives, development of innovative technologies for wildlife conservation, and the coordination of these actions.

The main BCC programs and projects are aimed at practical solutions of socially significant environmental problems. BCC projects include the following: "Ecosystem services (TEEB Russia)", "Improvement of PA management", "March for Parks", "Fund named after F.R. Shtilmark", "Science and Art for Environmental Education", "Forest Revitalization Fund", "Wildlife Network", "Information Support for Nature Protection Activities", "Protected Areas of Russia: Information and Reference System", "Oka Canyon", "Commander Islands", "Seaside coasts", "Adopt a zakaznik (a kind of PA)", "Sustainable livelihood of the population in protected areas", "State of natural communities: remote analysis", "Save Russian desman!", "Rodents of Northern Eurasia: Conservation Priorities", "Saiga conservation information support", etc.

41, Vavilova Street, Office 2, 117312 Moscow, Russia
Tel./Fax: +7 (499) 124 71 78
E-mail: biodivers@biodiversity.ru
www.biodiversity.ru; www.oopt.info

Leibniz Institute of Ecological Urban and Regional Development

Leibniz Institute of Ecological Urban and Regional Development

The Leibniz Institute of Ecological Urban and Regional Development (IOER) in Dresden is an establishment of the Leibniz Association for research in the spatial sciences focusing on ecological aspects of sustainable development. It was founded on 1 January 1992, is jointly funded by the federal and Saxony governments and is a research establishment with a staff of over 100.

The Institute addresses the scientific basis for the sustainable development of cities and regions in the national and international context. Research concentrates on five main areas:

- 'Landscape Change and Management'
- 'Resource Efficiency of Settlement Structures'
- 'Environmental Risks in Urban and Regional Development'
- 'Monitoring of Settlement and Open Space Development'
- 'Economic Aspects of Ecological Urban and Regional Development'

The Institute makes its findings available to the political authorities and society.

Weberplatz 1, 01217 Dresden
Tel./Fax: +49 (0)351 46 79 210 / +49 (0)351 46 79 212
www.ioer.de

ISBN 978-5-93699-090-8