Chapter 10
Ecosystem Services of Russian Landscapes

Elena Bukvareva, Dmitry Zamolodchikov and Karsten Grunewald

Abstract Russian landscapes provide important ecosystem services (ES) of local, regional and global scale and are crucially important for the economy and people of the country. The Project TEEB-Russia is the first attempt at a nation-wide ES assessment in Russia. The result of the first phase of the project (2013–2015) was the "Prototype National Report on Ecosystem Services of Russia, Volume 1, Terrestrial Ecosystems Services." A methodology for ES assessment was developed with allowance for the current status of the national public statistics. ES volumes supplied by ecosystems and consumed by humans were assessed. The degree of ES use was assessed by the ratio of supplied ES to consumed ES. These methodological approaches allowed to compare the regions of Russia and define regions, which are ES donors and ES consumers. However, further progress in defining the principles of ES management requires moving from the interregional to landscape scale. In particular, the optimization of the tasks of biodiversity conservation and ES use can be effectively solved at the landscape level.

Keywords Ecosystem services · Supplied · Demanded · Consumed services · National assessment · Regional comparison · Management of ES · Biodiversity conservation

E. N. Bukvareva (✉)
Biodiversity Conservation Center, Vavilova Street 41, Office 2, 117312 Moscow, Russia
e-mail: bukvareva@gmail.com

D. Zamolodchikov
Biological Faculty, Lomonosov Moscow State University, Leninskie gory, d. 1, str. 12, 119234 Moscow, Russia
e-mail: dzamolod@mail.ru

Centre for Ecology and Productivity of Forests of Russian Academy of Sciences, Profsouznaya Street, 84/32, 117997 Moscow, Russia

K. Grunewald
Leibniz Institute of Ecological Urban and Regional Development, Weberplatz 1, 01217 Dresden, Germany
e-mail: k.grunewald@ioer.de

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10.1 Introduction

The concept of ecosystem services (ES) is one of the most rapidly developing fields of up-to-date ecological research, aiming at maintaining life-supporting functions of biodiversity and sustainable development of the biosphere. The international TEEB process (The Economics of Ecosystems and Biodiversity; TEEB 2019; Hedden-Dunkhorst et al. 2015) encourages studies on the national and regional levels. National ES assessments are an important tool for maintaining ES and have already been carried out by many countries, including national projects within the TEEB framework (TEEB 2019).

Russian landscapes, diverse and occupying large areas, provide important ecosystem services of local, regional and global scale and are crucially important for the economy and people of the country. The importance and necessity of the ES concept development in Russia were proclaimed by the scientific community and a number of pioneering works on ES assessments were made in Russia and other post-soviet new 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.

To start a national ES valuation and accounting process 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) (Grunewald et al. 2014c). The TEEB-Russia project is 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 was supported by the Ministry of Natural Resources and Environment of the Russian Federation. The result of the first phase of the project "TEEB-Russia 1" (2013–2015) was the first volume of the Prototype National Report on Ecosystem Services of Russia (Bukvareva and Zamolodchikov 2018), hereinafter Prototype Report. This report pursues methodological goals and shows possible approaches to non-monetary estimation of terrestrial ES at the national level on the data available today.

In the present publication, we discuss the methodology of national non-monetary assessment of ES in Russia explaining indicators of supplied, demanded and consumed ES and providing examples of ES valuation by different methods. After that we discuss the main problems encountered during the assessment and future assessment tasks including analysis of interrelations between biodiversity and ES at interregional and landscape scales.

10.2 Materials and Methods

10.2.1 Data Sources and Assessment Units

The primary data sources for assessing ES were open-state databases, published maps and statistical digests including, first and foremost, public databases of the Federal State Statistics Service (FSSS) and other federal agencies, digital cartographic materials from "Land Resources of Russia" (Stolbovoi and McCallum 2002), a map of the terrestrial ecosystems of Northern Eurasia (Bartalev et al. 2003) and National Atlas of Russia (2004–2008).

The assessment area was the territory of Russian Federation. The main national-level sources of socio-economic data, as well as some environmental indicators in Russia, are the public databases of FSSS and other federal agencies, which produce data for the constituents of the Russian Federation. Thus, constituents of the Russian Federation—oblasts, krais, republics, etc., (hereinafter the regions) were used as assessment units. The use of administrative regions as assessment units corresponds well to the state statistics, but this approach does not fit well with ecosystem processes. However, we believe this approach was the most appropriate for the national system of ES assessment in Russia because it corresponds to the national statistical system and allows a comparison of ES between the regions. Similar approach was implemented for some European sub-continental assessments using NUTS (EU statistical areas) as a spatial mapping unit for the ES evaluation (Maes et al. 2011; Schulp et al. 2014; Zulian et al. 2014).

10.2.2 Classification of Ecosystem Services

Classification of terrestrial ES adopted in the Prototype Report combines the approaches of the Millennium Ecosystem Assessment (2005), CICES (Haines-Young and Potschin 2013) and the National Strategy of Biodiversity Conservation in Russia (2001). A comparison of ES classifications in MEA, CICES and in the Prototype Report is presented in Bukvareva et al. (2019). In total, 31 ES were considered (Table 10.1). ES were grouped into four categories: productive (provisioning), i.e., production of biomass that is removed from ecosystems by people; environment-forming (regulating), i.e., the establishment and maintenance of environmental conditions conducive to human life and economic development; informational (cultural), i.e., all kinds of information that is contained in natural ecosystems and can be used by people; recreational, i.e., formation and maintenance of natural conditions for different types of recreation. The names "productive", "environment-forming" and "informational" retain the designations of the main groups of life-supporting functions of biodiversity in the National Strategy of Biodiversity Conservation in Russia (2001).

Table 10.1 Methods for assessing ES in the prototype report

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	

(continued)

Table 10.1 (continued)

ES	Methods*			
	1	2	3	4
Information on structure and functioning of natural systems that can be used by humans			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

*Numbers correspond to the assessment methods noted in the text

With regard to the assessment of landscape ES, the following differences between our ES classification and other ES classifications should be explained. A significant part of the territory of Russia, especially in the European part of the country, is occupied by agricultural and cultural landscapes that combine natural and anthropogenic elements. For these landscapes, approaches to evaluating recreational and provisioning ES are especially important. In contrast to the CICES, we do not incorporate recreational and information ES in a single category of cultural ES. Instead, we consider provisioning, regulating and informational ES as the main categories and separately identify recreational category as integrative ES that are coupled to all of the first three ES categories to various extents depending on the type of recreation. For example, regulating ES which provide good quality of environment is the most important for recreation at summer cottages and resorts; productive ES such as game and fish production are the most important for sporting, hunting and fishing; informational ES such as aesthetic, educational, ethical and spiritual importance of natural systems are the most important for educational tourism in nature, etc. (Bukvareva et al. 2019). Another important feature of our ES classification applies to agricultural production. CICES includes ES related to food production by humans (crops, livestock, aquaculture), but we do not consider them as ES since we believe that ecosystems create natural conditions for these industries (soils, water, climate), which is taken into account in regulating ES. Moreover, ES related to food production by humans include a certain amount of purely human resources (machines, technologies, fuel, labor of humans and domestic animals). Generally, agricultural production negatively depends on the share of the area of natural ecosystems in the region and, in fact, is in direct opposition to other ES (Sect. 5.4). Accounting for agricultural production as ES can lead to conflicting results when assessing ES, and especially when assessing the relationship between ES and the state of ecosystems and biodiversity.

10.2.3 Methods of ES Assessment

The following methods of ES assessment were used depending on the data availability and methodological clarity.

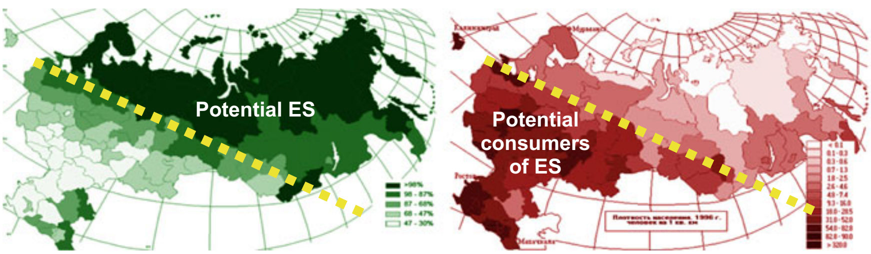
1. **Direct quantitative ES valuation** was possible if values of supplied, consumed and demanded ES are presented in the public statistical databases and reports. Today, possibilities for this valuation method are extremely limited. In total, supplied and consumed volumes only for five out of 31 ES were directly evaluated to a relatively complete extent (Table 10.1): the ES wood production (Fig. 10.3)—on the base of data of FSSS (Rosstat 2013) and the Federal Agency for Forestry of the Russian Federation, the ES of game production—on the base of statistical digest of the Department of State Policy and Regulation of Hunting and Conservation of Hunting Resources of the Ministry of Natural Resources and Environment of the Russian Federation (Lomanova et al. 2011), the ES of non-wood production of terrestrial ecosystems (on the base of data on harvest and stocks of mushrooms and berries in the second half of the 1980s from statistical compilation by Egoshina (2005), the ES of carbon storage and regulation of CO_2 flows (Fig. 10.4)—on the base of data from national reports due to Russia's obligations to implement the UN Framework Convention on Climate Change (National Report 2013).
2. **Indirect quantitative evaluation** of ES was applied in case of a lack of direct statistical data but in the presence of cartographic and statistical data that allowed us to evaluate the desired indicators. This method of ES evaluation corresponds to the indirect measurement of ES as defined in Vihervaara et al. (2017) and to the extrapolation of primary data as defined in Martínez-Harms and Balvanera (2012) and consists in the transformation of cartographic and statistical data using known coefficients and simple equations that can be classified as conceptual and deterministic physical and chemical models (Dunford et al. 2017). Six ES were assessed by this method: one provisioning ES and five regulating ES (Table 10.1; Figs. 10.5, 10.6, 10.7).
3. **Estimation of ES score** was applied if there was no data to evaluate the ES themselves and it was only possible to estimate factors affecting them. We believe that supplied ES is determined by natural factors (e.g., the area of natural ecosystems) while consumed and demanded ES are determined by socio-economic factors (including polluting emissions as a result of human activity). 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). To combine several factors their scores in a region were summed up and the resulting total value was translated into a 10-point scale. Nine ES were estimated by scores: four regulating ES, three informational ES and two recreational ES (Table 10.1; Fig. 10.8).
4. **Statement of the task** of ES assessment, if methodological approaches for ES assessment are not ready or data were not available.

In total, about one-third of considered ES was quantitatively evaluated (five ES were directly evaluated and six ES were indirectly evaluated), one-third (nine ES) was assessed with scores and one-third (ten ES) was not assessed (Table 10.1, for details, see Bukvareva et al. 2019).

10.3 Assessment of Supplied, Demanded and Consumed ES

The extreme diversity of natural and socio-economic conditions in Russia requires estimation of ES, which are supplied by ecosystems and ES, which are demanded and consumed by people. The supplied ES are generally correlated with the area of ecosystems. The demanded and consumed ES are linked to 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. This pattern is evident almost everywhere because economic activity in general leads to disturbance of natural ecosystems, and it is most clearly manifested in the large and diverse territory of Russia (Fig. 10.1, Bukvareva et al. 2015; Bukvareva and Zamolodchikov 2018). In order to have the possibility of an adequate comparison of very heterogeneous regions, we used "supplied-demanded-consumed" approach for the national ES assessment in Russia.

Supplied ES were defined as ES provided by ecosystems regardless of the presence or absence of people, for example, annual allowable cut (Fig. 10.3a), abundance of game animals, biomass and productivity of mushrooms and berries, productivity of natural pastures, carbon content in ecosystems (Fig. 10.4a), amount of pollutants that could potentially be neutralized by ecosystems, volume of water that could potentially be purifies by ecosystems (Figs. 10.6a and 10.7a), runoff provided due to regulation by ecosystems.



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

Fig. 10.1 Comparison of the distribution of potential ES provided by ecosystems and potential consumers of ES in different regions of Russia

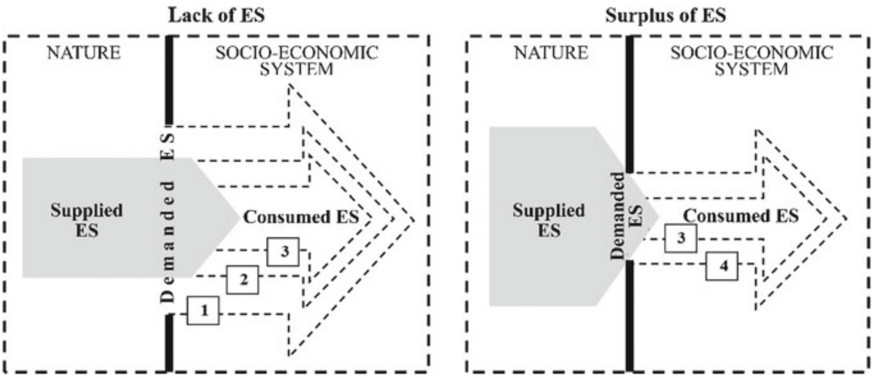


Fig. 10.2 Possible ratios of volume of supplied, demanded and consumed ES: 1—consumed ES is equal to demanded ES and exceeds supplied ES (possible for provisioning and recreational ES); 2—consumed ES is less than demanded ES because of lack of provided volume (all ES); 3—consumed ES is less than demanded ES because of lack of technological, legal or economic means of ES use (all ES); 4—consumed ES is less than supplied ES because of low demand for a service when demanded ES is less than supplied ES (all ES)

Indicators of supplied ES should be assessed taking into account the sustainable use of ecosystems and their components, i.e., it is equal to the volume of provisioning and recreational ES that can be used by people without disturbance of ecosystem structure and functioning (regulating and informational ES cannot be overused as discussed below). However, data from open databases allowed us to correctly estimate the supplied volume for only one ES—wood production (annual allowable cut indicator, Fig. 10.3a), while other supplied provisioning ES were estimated by proxy indicators such as the total population number of game species and productivity of natural pastures.

When evaluating of ES score, the indicator of supplied ES reflects the capacity of natural factors that form ES. For example, supplied volume of the ES of soil self-purification was assessed on the basis of a map of soil capacity for self-purification from the National Atlas of Russia (2004–2008); supplied volume of the ES of aesthetic and educational importance of ecosystems was estimated by a combination of three indicators (the share of natural ecosystems in a region, the number of species of vascular plants per unit of area of a region, the number of types of ecosystems per unit of area of a region); supplied volume of the ES of forming natural conditions for tourism in nature (Fig. 10.8a) was also estimated by a combination of three indicators (the level of comfort of the natural conditions, the quality of the environment and an indicator for landscape diversity (Basanets and Drozdov 2006).

Some authors include anthropogenic inputs (e.g., energy, machinery, fertilizers, pesticides, labor, etc.) in the volume of ES supply (Burkhard et al. 2014; Martínez-Harms and Balvanera 2012). When physical ES evaluation in the Prototype Report, we did not consider anthropogenic inputs as part of ES. As noted

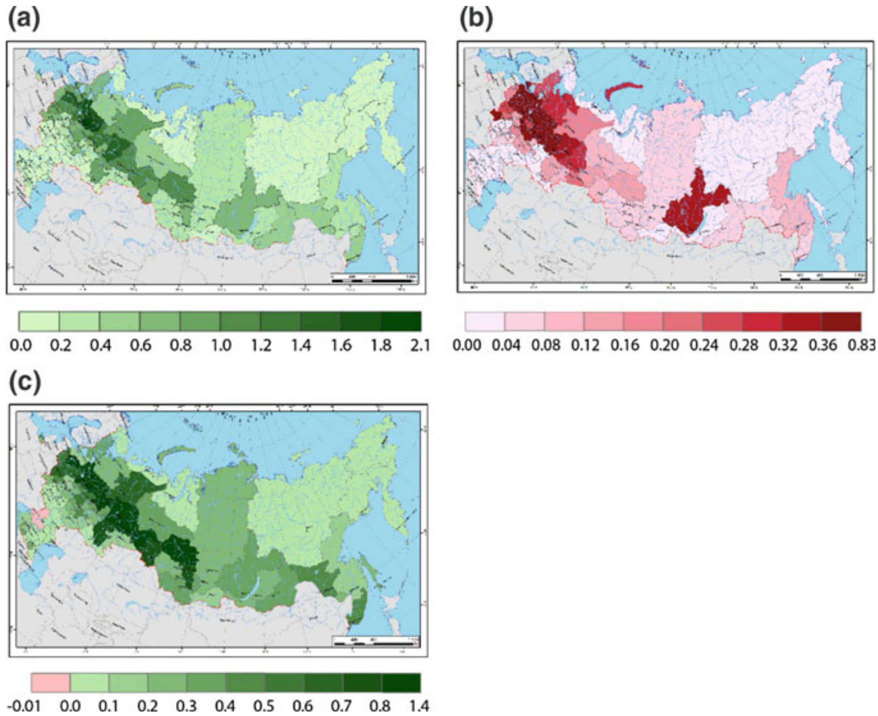


Fig. 10.3 ES of wood production: **a** supplied ES-annual allowable cut (m^3/ha/yr), **b** consumed ES-timber felling (m^3/ha/yr), **c** the degree of ES use-unused residual of allowable cut (m^3/ha/yr) (negative values indicate that timber felling exceeded the allowable cut)

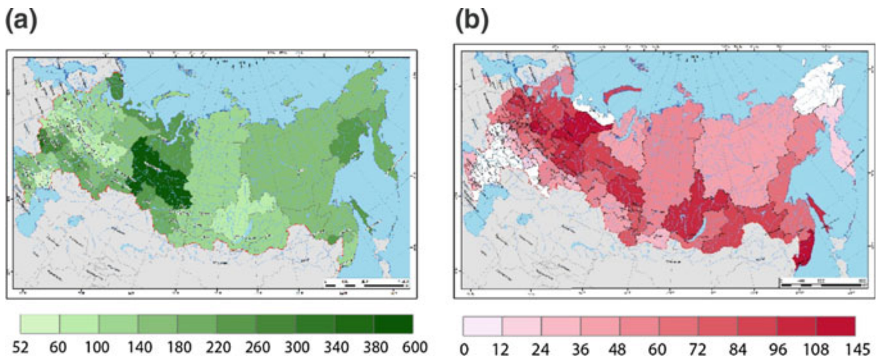


Fig. 10.4 ES of the carbon storage: **a** supplied volume-total carbon content in phytomass and soil (tC/ha), **b** consumed volume-carbon content in managed forests (tC/ha)

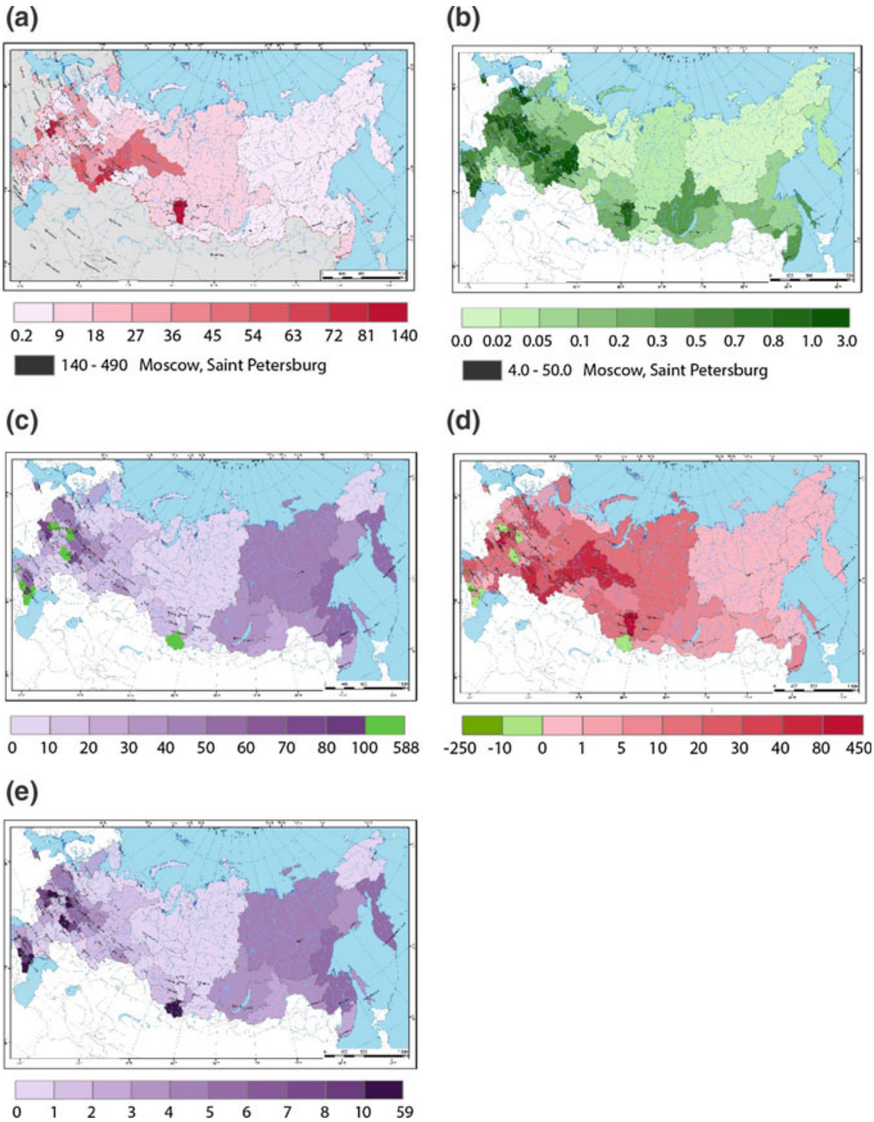


Fig. 10.5 ES of air purification by suburban forests: **a** the demanded ES: the amount of emissions of toxic gases (t/ha/yr), **b** the consumed ES: the amount of toxic gases actually absorbed by suburban forests (kg/ha/yr), **c** the degree of potential meeting the demand for ES: the share of toxic gases that can potentially be absorbed (violet) or the excess of toxic gases, which can be absorbed by suburban forests over real emissions (green) (%), **d** the excess or deficit of the ES: the residual of toxic gases which cannot be absorbed by suburban forests (red), or the excess of toxic gases over real emissions, which can be absorbed by forests (green) (kg/ha/yr), **e** the degree of actual meeting the demand for ES: the share of toxic gases absorbed by suburban forests (%)

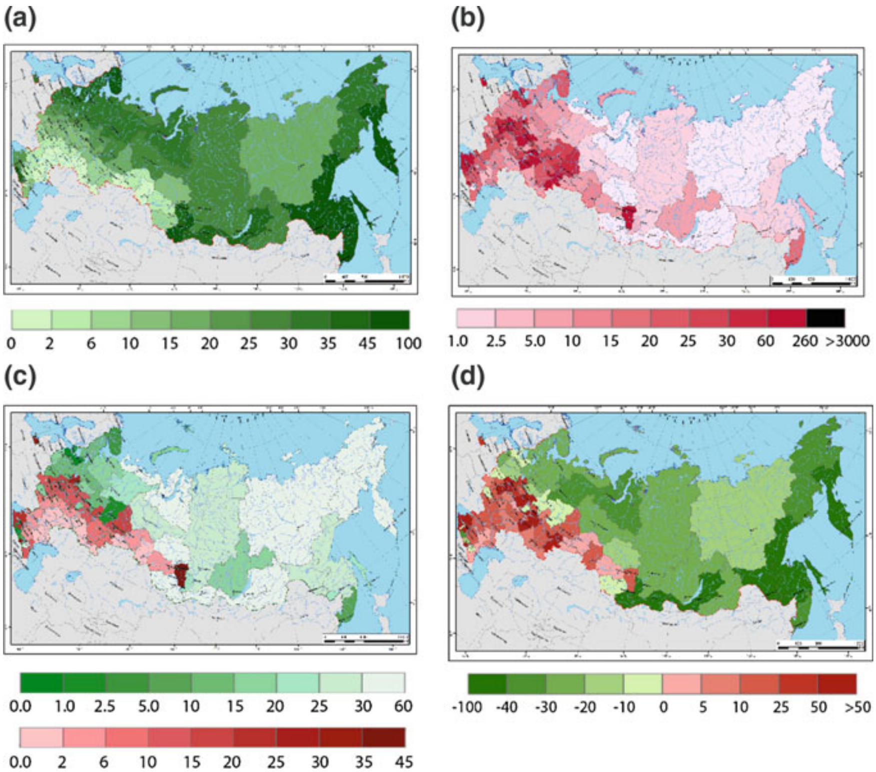


Fig. 10.6 ES of assurance of water quality by freshwater ecosystems: **a** supplied ES-the amount of wastewater that can potentially be purified to a safe concentration of pollutants due to dilution and transformation of pollutants (m^3/ha/yr), **b** demanded ES volume-discharge of polluted wastewater (m^3/ha/yr), **c** consumed ES volume-volume of actually purified wastewater (m^3/ha/yr), green spectrum—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; red spectrum—regions where the volume of wastewater discharge exceeds the capacities of ecosystems to purify it, the consumed ES volume equals the supplied ES volume, **d** deficit or excess of the ES—untreated wastewater remainder or unused ES volume (m^3/ha/yr)

above, the inclusion of anthropogenic inputs in ES evaluation is a questionable approach. This issue can be resolved in the future comprehensive economic evaluation of ES of Russia.

Demanded ES were defined as ES that are necessary to fulfill needs of the population and economy of a region, for example, logging volume, fish take, hunting production, amount of natural fodder, etc., that are necessary for regional business and household welfare, volume of runoff needed for the population and the economy, amount of pollutant emissions that be neutralized by ecosystems, the number of tourists in nature that is necessary for regional business.

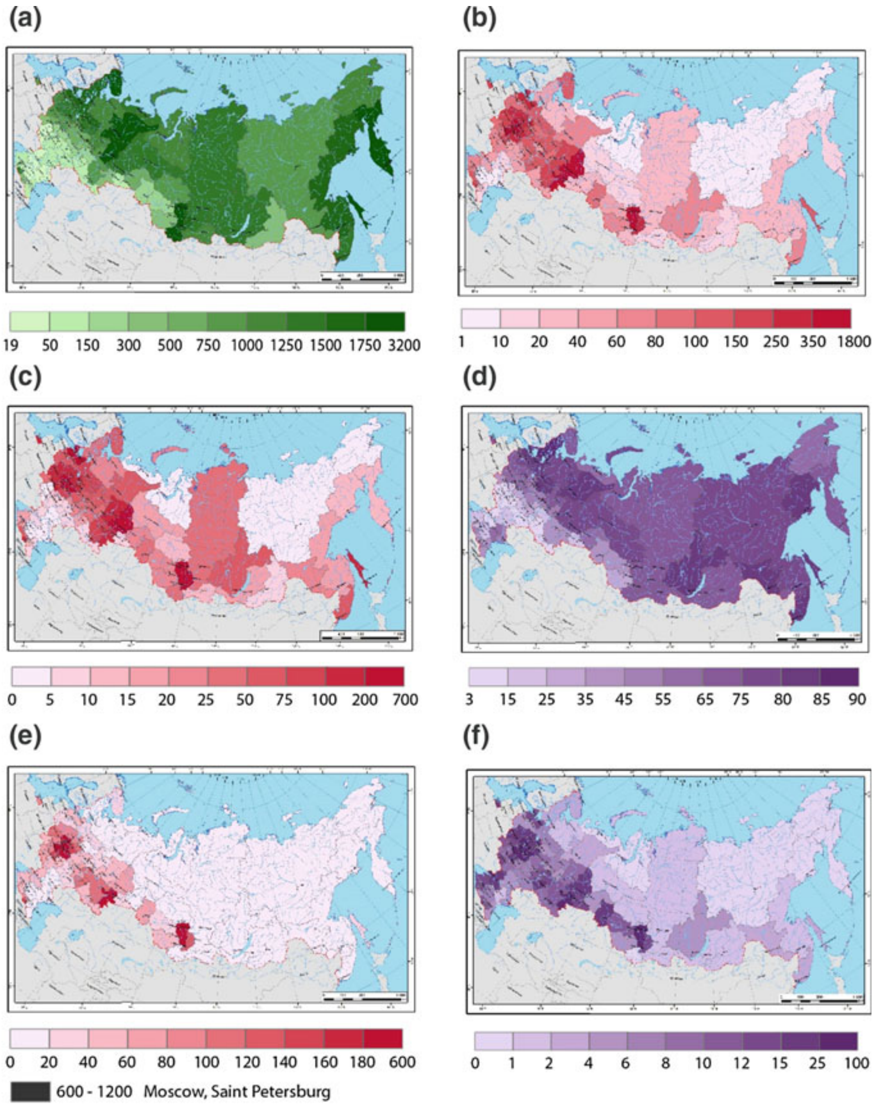


Fig. 10.7 ES of assurance of water quality by terrestrial ecosystems: **a** the supplied ES: potentially purified runoff (m^3/ha/yr), **b** the demanded ES: polluted runoff (m^3/ha/yr), **c** the consumed ES: purified runoff (m^3/ha/yr), **d** the degree of actual meeting the demand for ES: the share of polluted runoff purified by ecosystems (%), **e** the volume of unmet need for the ES: the residual of polluted runoff unpurified by ecosystems (m^3/ha/yr), **f** the degree of ES use: the share of actually purified runoff in the potentially purified runoff (%)

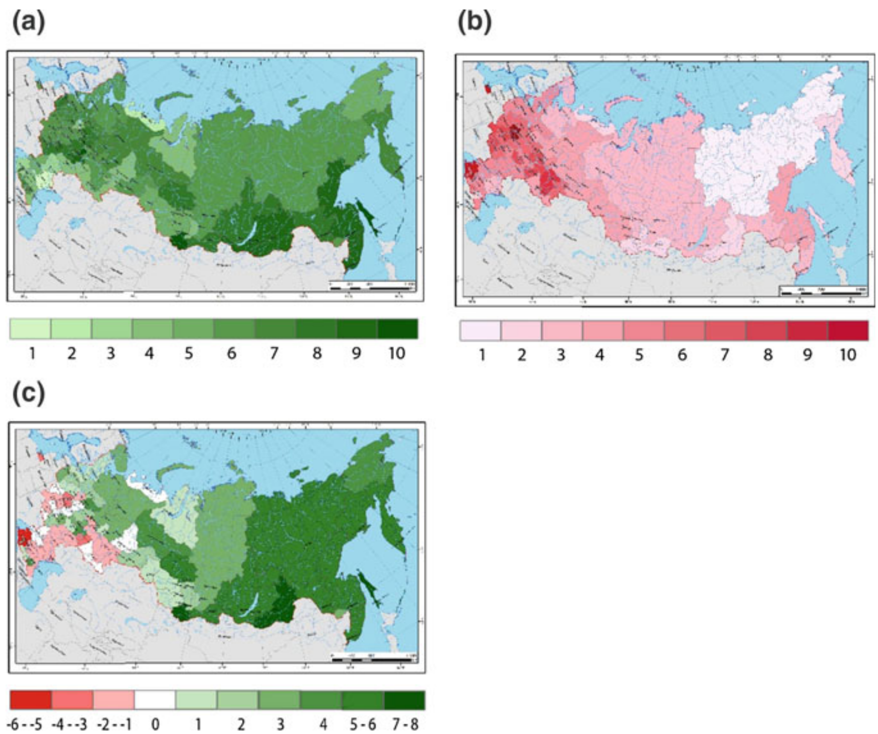


Fig. 10.8 Estimation of the score of the ES of forming natural conditions for tourism in nature: **a** supplied ES, **b** consumed ES, **c** comparison of the natural and socio-economic factors determining the supplied and consumed ES

In the Prototype Report demanded ES were assessed only for ES related to the purification of the natural environment from pollutants. In these cases, the amount of pollutants that must be neutralized by ecosystems may be used as the indicator for demanded ES. In the Prototype Report, annual pollutant emissions (Fig. 10.5a) and annual discharge of polluted wastewater (Fig. 10.6b) and volume of polluted runoff (Fig. 10.7b) were used as a proxy of this indicator. However, maximum permissible concentrations were taken into account in the indicator of supplied ES of assurance of water quality by freshwater ecosystems (Fig. 10.6a). In the future, demanded ES will have to be calculated more accurately as the difference between the amount of pollutant emissions and their maximum permissible concentrations.

For most other ES, demanded volumes are determined primarily by socio-economic features of a region and were not assessed in the first phase of the project since the economic ES assessment was not the task of it.

Consumed ES were defined as ES that are actually used by people, for example, actual logging volume (Fig. 10.3b), hunting production (e.g., the number of elk shot by hunters), mushroom and berry harvest, amount of fodder eaten by cattle in natural pastures, amount of pollutants actually neutralized by ecosystems

(Fig. 10.5b), volumes of runoff and wastewater purified by ecosystems (Figs. 10.6c and 10.7c) and amount of freshwater used by people.

The interpretation of the consumed volume of global climate-regulating ES is a certain problem. For example, for the ES of carbon storage, consumed volume should be the benefit that the people and the economy of a region derive from climate regulation due to carbon storage in ecosystems of that region. Today, both knowledge and data are insufficient to assess these indicators. A simple economic approach could be to calculate the price of stored carbon, but Russia does not participate in the global carbon market and does not have a national market. Thus, the consumed ES volume was assessed as carbon stock in managed forests (Fig. 10.4b). According 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 (National Report 2013),[1] since Russia officially declares management for UNFCCC purposes in this forest category. This evaluation revealed a tremendous discrepancy between the spatial distribution of the supplied ES and the consumed ES attributed to managed forests. The supplied ES, i.e., total carbon stocks in phytomass and soil (according to the database "Land Resources of Russia", Stolbovoi and McCallum 2002) is the highest in regions with vast peat ecosystems (West Siberia) and black earth regions (southern part of European Russia) (Fig. 10.4a). Thus, this ES is poorly recorded just in these regions because of the small area of managed forests.

When evaluating of ES score, the indicator of consumed ES reflects socio-economic factors that determine the use of ES. For example, the consumed volume of the ES of soil self-purification was assessed by a combination of three indicators (population density, the share of croplands in the regions and the share of the polluted area in the regions); consumed volume of the ES of aesthetic and educational importance of ecosystems was estimated by a combination of indicators of population density and transport accessibility; consumed volume of the ES of forming natural conditions for tourism in nature (Fig. 10.8b) was estimated by a combination of three indicators (the investment appeal of the regions, population health and potential tourist demand (Basanets and Drozdov 2006).

The definitions of supplied, demanded and consumed ES adopted in the Prototype Report lie in the mainstream of a common ES understanding, but in some details differ from approaches of other authors (Bukvareva et al. 2017). Short reviews of indicators of supplied, demanded and consumed ES adopted in the Prototype Report is presented in Bukvareva et al. (2017, 2019).

The ratios of supplied, demanded and consumed ES differ between regions, as they depend on properties of ecosystems and socio-economic conditions, which are highly heterogeneous across Russia. A physical analogy to supplied ES would be the total amount of potential ES in a room of nature (the gray arrow in

[1]The cadastre is the report of Russia on greenhouse gas emission/absorption and the GHG balance in managed forests. Carbon stocks in forests are intermediate estimates of the cadaster (National report 2013).

Fig. 10.2). The demanded ES would be compared with a window between the natural and socio-economic rooms, which allows a certain amount of ES to pass from nature to the socio-economic system. The consumed ES corresponds to forces that draw ES through the window from the natural to the socio-economic room (Bukvareva et al. 2017). Supplied and consumed ES form the real flow of ES, while the demanded ES volume can only be considered a condition or restriction affecting this flow.

In densely populated regions, demanded and consumed ES could exceed supplied ES (Fig. 10.2, left). Such regions are 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, demanded and consumed ES could be smaller than supplied ES (Fig. 10.2, right). Such regions are found in the major part of Siberia and in the North of Russia.

Demanded volume may hypothetically exceed *supplied* volume for all ES categories. The Prototype Report contains examples of such situations for ES related to the purification of the natural environment from pollutants. Supplied ES of air purification by suburban forests is less than demanded ES in most regions (Fig. 10.5c, d), although for the preliminary assessment, we considered that supplied ES is determined by the maximum physiological absorptive capacity of trees, the excess of which leads to their death (this amount is ten times the amount of toxic gases that are actually absorbed by trees in cities, as measured). Supplied ES of assurance of water quality by freshwater ecosystems is less than demanded ES in densely populated regions with developed industry and agriculture (red spectrum in Fig. 10.6d). Such cases should be recognized as evidence of a high environmental hazard, when even the maximum capabilities of ecosystems are no longer able to provide acceptable environmental quality.

Interrelations between *consumed* and *supplied* ES volumes are specific to ES categories. Consumed volume can exceed supplied volume of provisioning and recreational ES (number 1 in Fig. 10.2). That leads to overexploitation (overfishing, overhunting, etc.) or disturbance by excessive recreational load. ES estimations based on state statistics basically do not reveal overexploitation (e.g., is in Fig. 10.3c); however, data on illegal, unreported and unregulated (IUU) harvesting (Sect. 5.3) may change this result.

Consumed ES volume cannot exceed the supplied volume of regulating and cultural ES because the overuse is impossible for these. 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 amount of wastewater exceeds purifying ability of freshwater ecosystems, then consumed ES is equal to supplied ES, since ecosystems purify only the amount of water that they can (Fig. 10.6c, red spectrum). In that 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 overuse it.

Consumed ES volume could be less than 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. 10.2). 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. 10.2). 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. Consumed volume of provisioning and recreational ES can exceed 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 (Bukvareva and Zamolodchikov 2018). Consumed ES volume could be less than demanded volume due to lack of supplied ES (number 2 in Fig. 10.2), for example, when the emission of pollutants exceeds the capacity of forests to absorb them. It is a case of the ES of air purification by suburban forests when pollution is not completely absorbed in any region (Fig. 10.5e). For the ES of assurance of water quality by terrestrial ecosystems, consumed ES is always less than demanded ES (Fig. 10.7b, c). The demand for this ES cannot be entirely satisfied because terrestrial ecosystems are not capable of completely purifying polluted runoff, especially during the snow melt period. All regions therefore have residual unpurified runoff (Fig. 10.7e), i.e., the demand for the service is not satisfied anywhere.

Supplied, demanded and consumed ES volumes can be compared if they are measured in the same units. Maes et al. (2011) suggest expressing ES capacity in total ecosystem area or biomass, whereas ES flow (the partial analog of consumed ES) in units per time period. This approach does not allow them to be compared. The cited authors propose to solve this problem using bundles of ES that include information of both ES capacity and flow. However, direct quantitative comparison may be more efficient.

Ratios and differences of supplied, demanded and consumed ES allowed us to estimate the degree of ES use and degree of meeting the demand for ES, which may be useful for decision-makers. Examples of management interpretation of indicators are shown in Table 10.2.

10.4 Comparison of the Regions

One of the main advantages of assessment of supplied, demanded and consumed ES is the ability to compare regions that are donors and consumers of ES, which is crucially important at national-level ES assessment. Donor–consumer relationships

Table 10.2 Indicators of the degree of ES use and degree of meeting the demand for ES and corresponding messages for decision-makers (V_s—supplied ES, V_c—consumed ES, V_d—demanded ES)

Indicators	Ratios and differences of ES volumes	Examples	Messages for decision-makers
The degree of ES use	V_c/V_s $V_c/V_s \times 100\%$	The ratio of actually purified runoff to the potential purification capacity of terrestrial ecosystems (Fig. 10.7f)	In all regions (except cities of Moscow and St. Petersburg), the potential purifying capacity of ecosystems, on average, significantly exceeds actual purification of polluted runoff
Unused (if positive) or overdrawn (if negative) ES volume	$V_s - V_c$	The unused residual of the annual allowable cut (Fig. 10.3c)	According to official data, wood resources are underused in most regions, especially in forest regions of European part of Russia and West Siberia
The degree of potential meeting the demand for ES	V_s/V_d $V_s/V_d \times 100\%$	The share of toxic gases that can potentially be absorbed by suburban forests (Fig. 10.5c)	The maximum gas-absorbing capacity of suburban forests is insufficient to neutralize toxic emissions in the majority of regions. Many regions have a maximum capacity below 50% of annual emissions
Excess (if positive) or deficit (if negative) of ES	$V_d - V_s$	The residual volume of polluted runoff which cannot be neutralized by water ecosystems or untapped opportunities of ecosystems for wastewater treatment (Fig. 10.6d)	Industrially and agriculturally developed regions in the central and southern European part of Russia and southern West Siberia experience a deficit of this ES that indicates overexploitation of freshwater ecosystems
		The residual of toxic gases that cannot be absorbed by suburban forests, or the excess of forest absorption capacity over real emissions (Fig. 10.5d)	The maximum gas-absorbing capacity of suburban forests is insufficient to neutralize toxic emissions in the majority of regions. Many regions have a significant amount of unabsorbed pollutants under any conditions

(continued)

Table 10.2 (continued)

Indicators	Ratios and differences of ES volumes	Examples	Messages for decision-makers
The degree of actual meeting the demand for ES	V_c/V_d $V_c/V_d \times 100\%$	The share of polluted runoff that is actually purified by ecosystems (Fig. 10.7 d)	Terrestrial ecosystems in industrially developed regions in the central European part of Russia and southern Ural and Siberia cannot cope with severe pollution and purify no more than a third of polluted of runoff
		The share of toxic gases absorbed by suburban forests (Fig. 10.5e)	Toxic gases are not completely absorbed in any region. In the majority of regions, less than 10% of emissions are absorbed
Volume of unmet need for ES	$V_d - V_c$	The residual of polluted runoff unpurified by terrestrial ecosystems (Fig. 10.7e)	Terrestrial ecosystems in industrially developed regions in the central European part of Russia and southern Ural and Siberia cannot cope with severe pollution of runoff. A significant part of the pollution falls into the waterbodies

between regions are important for ES of regional and interregional scale and are not essential for local and in situ ES, for example, pollination or soil formation. In Russia, the overwhelming majority of ES is important at the regional and interregional scales (Bukvareva and Zamolodchikov 2018). Examples of interregional donor–recipient relationships and a preliminary set of indicators for detecting ES donor regions in Russia are presented in BfN scripts (Bukvareva 2014a, b).

The indicators of the degree of ES use (Fig. 10.8f), the degree of actual and potential meeting the demand for ES (Figs. 10.6d, f and 10.8d) and the volume of unmet need for ES (Fig. 10.8e) highlight environmentally hazardous and relatively safe regions and are important primarily for regional government. For example, the indicator of the use of ES of assurance of water quality by terrestrial ecosystems, i.e., the share of actually purified runoff in the potentially purified runoff (Fig. 10.7f), highlights regions where the ES is used almost entirely. The indicators for air purification showed that in many regions even the potential absorption capacity of suburban forests is less than half of the toxic emissions (Fig. 10.5c), and actual absorption everywhere is less than the emissions (Fig. 10.5e). This means that in most regions a large amount of toxic gases remains unabsorbed under any weather conditions (red spectrum in Fig. 10.5d).

The indicators of unused/overdrawn ES volume (Figs. 10.3c and 10.9c) and excess/deficit of ES (Fig. 10.7d) show regions, which tend to be consumers or donors of ES, which are of interregional scale and their supplied volumes can move between regions. For example, uneven use of annual allowable cut in the regions (Fig. 10.3c) can be compensated by transporting excess wood to timber processing enterprises in other regions. The excess of the ES of assurance of water quality by freshwater ecosystems (Fig. 10.6d) and the ES of runoff regulation can be used in other regions if they are located in the proper direction of water flow. The excess of the ES of air purification by suburban forests (green spectrum in Fig. 10.5d) cannot be moved to other regions, so this ES works at a local scale, thus, there are not donor–consumer relationships between regions for this ES. However, ES assessment methodology applied in the Prototype Report does not take into account the relative spatial location of the regions (see Sect. 5.2) that should be corrected in the future evaluations.

As mentioned earlier, only one-third of the ES considered was quantitatively estimated. The inclusion of ES scores in the comparison of regions allowed as to extend the comparison of the regions to two-thirds of considered ES. For this, quantitative indicators were also converted into scores. Comparative matrices show the distribution of supplied and consumed ES scores across regions and differences of these scores (Vsupplied–Vconsumed). Such a matrix is presented in Fig. 10.9. It reflects the qualitative balance of natural factors determining ES supply by ecosystems and socio-economic factors determining ES consumption by the people and the economy in the regions. These matrices are analogous to potential/flow and flow/demand matrices of land cover types (Burkhard et al. 2012, 2014) but estimate regions, not land cover types. Each column of the matrix in Fig. 10.9 represents the balance of factors determining ES supply and consumption by region, that is, corresponds to the maps, examples of which are shown in Fig. 10.8c.

The values close to zero and light colors indicate that in corresponding regions, natural and socio-economic factors have close scores of intensity in comparison with other regions. Green color and positive scores indicate relative predominance of ES supply factors and red color and negative scores indicate relative predominance of ES consumption factors. For example, this matrix shows that supply and consumption factors for provisioning ES are more balanced than for other ES categories (except for a few regions where their consumption prevails). For most of the regulating ES, we see a strong prevalence of supply factors in the North-European and Asian parts of Russia (federal districts 1, 7 and 8), while consumption factors prevail in the remaining territory (except for “carbon” ES due to ambiguities in determining their consumed volume discussed in Sect. 10.3). More detailed analysis can reveal the relative intensity of ES within their categories and for regions within federal districts (Bukvareva and Zamolodchikov 2018).

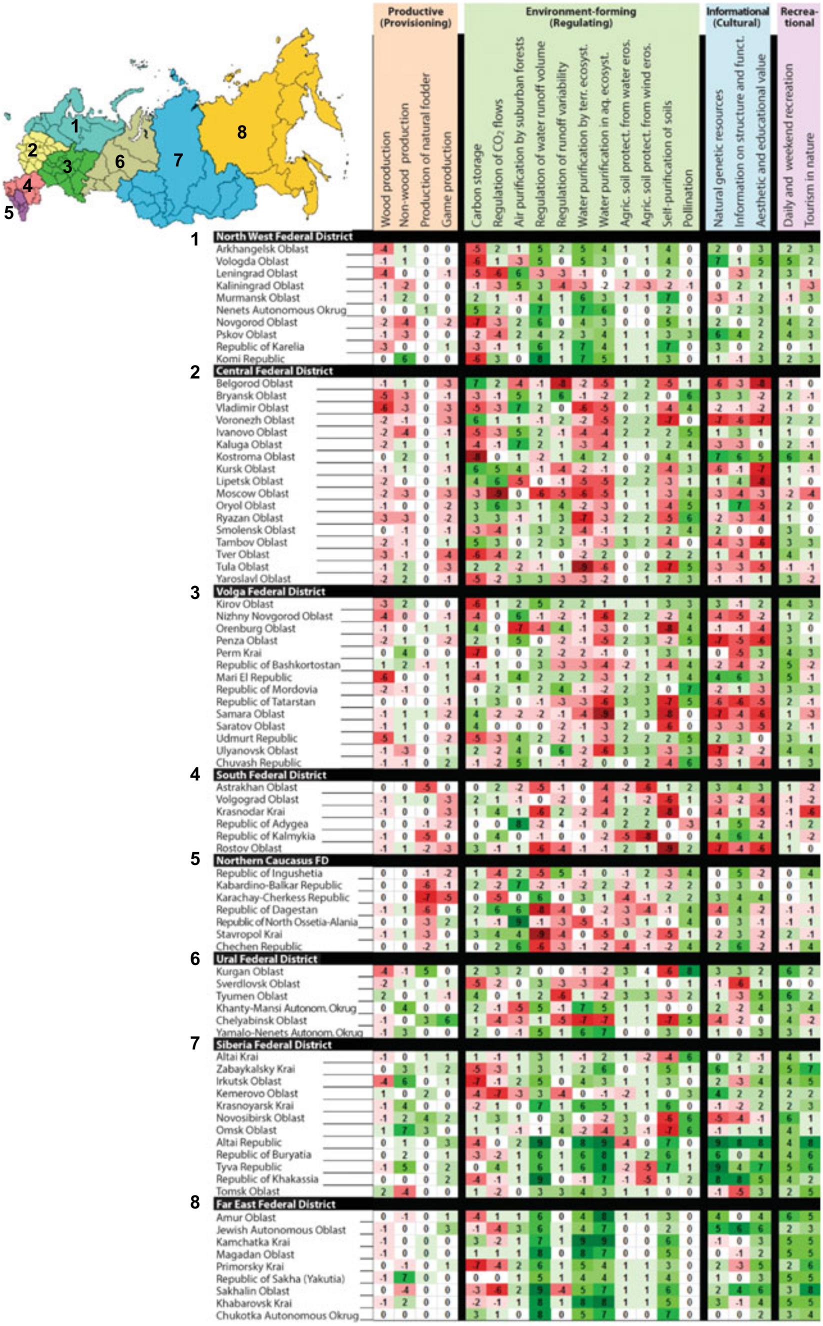


Fig. 10.9 Difference between supplied and consumed ES scores by region

10.5 The Main Problems of Assessment and Future Tasks

The first national ES assessment in Russia demonstrated that ES of terrestrial ecosystems is 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 and natural bioproduction. 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.

Thus, the results of the "TEEB-Russia 1" project prove that 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. However, for this it is necessary to solve a number of methodological problems, the most important of them are briefly discussed below.

10.5.1 Selection of Assessment Units

A significant problem inherent in the use of administrative units in Russia is the extremely unequal area of them. Single values for vast areas such as Krasnoyarsk Krai, Yakutia and other large regions in Siberia, the North and the Far East of Russia could not adequately describe the diversity of natural and socio-economic conditions inside these regions. The territorial subdivisions of the largest regions are required for future ES evaluations.

Another important problem is the incorporation of data organized according to river basins into the general ES assessment performed according to administrative regions. This is necessary because water-related governmental agencies and scientific institutes operate according to river basins. Moreover, water-related ES requires modeling at the basin scale for their adequate evaluation. Freshwater fishery management and partly water management are carried out at the basin scale. However, a comparison of ES and regions requires a uniform grid of valuation units. Therefore, it is necessary to find the most effective algorithm for translating data on basins into administrative regions and management recommendations, and back from the grid of administrative units to the basins.

10.5.2 Spatial Interrelations Between Regions

Evaluation of supplied, demanded and consumed ES allows to compare regions that are donors and consumers of ES. For a more accurate detection of donor–recipient relationships ES spatial characteristics, directional ES flow and user movement should be considered (Costanza 2008) as well as distance between regions and their position relative to the water flows, currents, prevailing winds and animal migrations. Methods of ES flows spatial analysis are developed primarily at the regional level (e.g., Bagstad et al. 2013; Nedkov and Burkhard 2012; Stürck et al. 2014; Syrbe and Walz 2012), but the principles can be further used for interregional comparisons at the national level. The concept of "providing/benefiting areas" (Syrbe and Walz 2012) should be extremely useful in the future ES assessments in Russia, given the highly uneven distribution of ecosystems and population in the territory.

10.5.3 The Lack of Data

National ES assessment and monitoring can be based on a nation-wide regularly updated system of data collection. Today, such a system is mostly absent. Annually updated governmental databases allowed us to completely quantitatively evaluate only one ES (wood production) as well as separate indicators for three regulating ES (air purification by suburban forests, regulation of runoff volume and assurance of water quality by freshwater ecosystems). In total, more than 30% of the indicators (9 out of 25 quantitative indicators and 6 out of 21 indicators, which were used for evaluating ES scores) were obtained from governmental databases and statistical compilations. 70% of the indicators were either obtained directly or calculated using data from statistical compilations, analytical reviews, and cartographic and remote sensing materials that are produced by various institutions and are not updated at a fixed frequency.

A significant problem for assessment of consumed volumes of provisioning ES is the large amount of illegal, unreported and unregulated (IUU) bioresource harvesting in Russia. For example, with regard to ES of wood production, illegal forest harvesting in some regions makes up tens of percent above official data (Gryaznov et al. 2011; Kotlobay et al. 2006; Ptichnikov and Kuritsyn 2011). IUU harvesting remains an important obstacle for evaluation ES of game and freshwater fish production in Russia (Bukvareva and Zamolodchikov 2018).

A potential source of data that can be regularly updated in the future is the map of terrestrial ecosystems obtained from satellite imagery. In the Prototype Report, four quantitative indicators were calculated using this map. Two more indicators based on this map were used for estimating ES scores. Regular update of this map and development of a set of algorithms for indirect ES quantification on the basis of vegetation cover can make this map the basis for assessing the significant part of ES that cannot be directly evaluated on the basis of statistical data.

With regard to biodiversity assessment and monitoring, the current national system of data collection is able to make it only fragmentarily. Most of the data needed for biodiversity monitoring are not available at the national level, as they are present only in individual studies for individual regions, or none at all. Only changes in exploited species are formally tracked by federal bioresource-related agencies (Bukvareva et al. 2019).

10.5.4 The Need for a Comprehensive Assessment of All ES Categories

The priority management of only one part of ES can lead to wrong and harmful decisions due to ES trade-offs (e.g., Allan et al. 2015; King et al. 2015; Maes et al. 2012; Raudsepp-Hearne et al. 2010; Turkelboom et al. 2018). In the most striking form, ES trade-off manifests itself showing negative correlation between indexes of ES which are provided by natural ecosystems (e.g., regulating ES) and agriculture production which CICES also considers as ES (e.g., Casalegno et al. 2013; Felipe-Lucia and Comín 2015; Qiu and Turner 2013).

As discussed above (Sect. 2.2), we do not consider agriculture production as ES. Indicators of agricultural production in the regions are determined by the share of agriculture land and negatively depend on the share of natural ecosystems (Fig. 10.10a). For the vast majority of ES, which are provided by natural ecosystems, the opposite is true (e.g., see in Fig. 10.10b). Generally, agricultural production and most regulating ES are in direct opposition to each other.

With regard to possible trade-offs between ES considered in the Prototype Report, the conflict between the use of productive and recreational ES, on the one hand, and the maintenance of environment-forming and informational ES, on the other hand, is extremely relevant in Russia. Exploitation of bioresources, primarily forest, is a significant sector of the economy. In the overwhelming majority of cases, the highest priority is to maximize the product that can be extracted

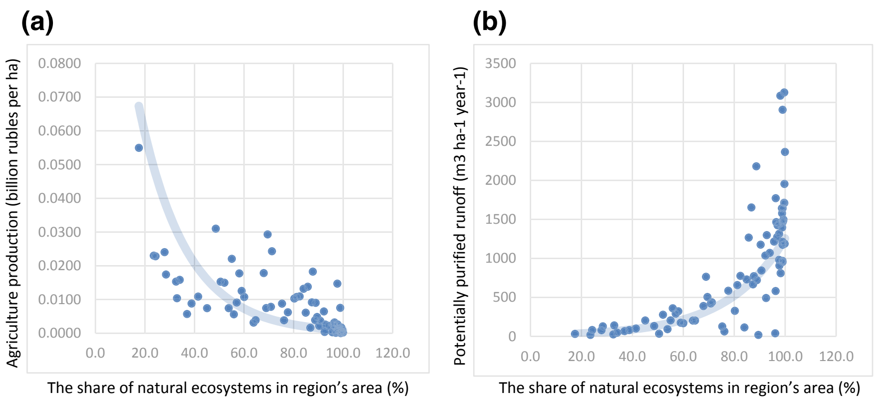


Fig. 10.10 Dependence of **a** agriculture production and **b** supplied ES of assurance of water quality by terrestrial ecosystems on the share of natural ecosystems in region's area

sustainably from ecosystems (timber, seafood, game production). Harvesting of bioresources inevitably disturbs natural ecosystems, their functions and biodiversity, that is, environment-forming and informational ES. This is an old and well-known conflict. A relatively new conflict in ES management goals arose between recreational and informational ES in strictly protected areas called in Russian “zapovedniks” (Concept of the development of the system of nature-protected areas of federal importance until 2020). Traditionally, the priority task of zapovedniks was the preservation and study of natural complexes undisturbed by man, that is, the maintenance and use of information ES for the preservation of information of natural ecosystems. However, the presence of tourists, even for educational purposes, inevitably disrupts the functioning of natural populations and ecosystems, that is, it conflicts with this information ES.

Based on current state statistics, productive ES can be assessed better than all other categories of ES. However, prioritizing only productive ES will lead to an inadequate understanding of the whole value of ES and biodiversity and to the wrong management decisions.

10.5.5 Landscape Approach to Optimization of Tasks of Biodiversity Conservation and ES Maintenance

Biodiversity is the structural basis of ecosystem functioning (EF) and is a key factor in determining the mean level and stability of ecosystem functioning (Cardinale et al. 2012; Hooper et al. 2012; Tilman et al. 2012, 2014). Positive effects of species diversity and intraspecific diversity on EF (productivity, biomass, rate of nutrient cycling, invasion resistance, stability, etc.) were confirmed by hundreds of experiments (Bardgett and van der Putten 2014; Gross et al. 2014; Handa et al. 2014; Forsman 2014; Forsman and Wennersten 2016; Hughes et al. 2008) as well as surveys of real-world systems (Lewandowska et al. 2016). The evidence obtained for grasslands (Grace et al. 2016; Maestre et al. 2012) and forests (Baruffo et al. 2013; Cavanaugh et al. 2014; Nadrowski et al. 2010; Paquette and Messier 2011; Vilà et al. 2013,; Wang et al. 2011) may be the most interesting for landscape research in Russia. Relationships between biodiversity and ES are still not so clear. However, despite negative or mixed relationships between some ES and biodiversity the majority of ES positively depend on biodiversity (Cardinale et al. 2012; Harrison et al. 2014) and sustaining the long-term flow of many ES require high levels of biodiversity (Science for Environment Policy 2015). Changes in biodiversity inevitably lead to ES change.

Thus, the tasks of biodiversity conservation and ES use and maintenance cannot be separated from each other. This issue is one of the main topics in the next phase of the project (TEEB-Russia 2). However, the work done to date allows us to make some preliminary judgments on this issue today and outline further studies.

The principle of optimum biodiversity (Bukvareva 2014c, 2018; Bukvareva and Aleshchenko 2013) may be one of possible theoretical approaches to this issue. According to this principle, species diversity and intrapopulation diversity are inseparable adaptive characteristics of interacting hierarchical biodiversity levels—communities and populations—to environmental conditions. The optimum values of diversity provide maximum efficiency and survivability of communities and populations and thus, the maximum EF. The optimal diversity values depend on the degree of environmental stability and the amount of available resource. The optimal values of intrapopulation diversity decrease in more stable environments. The optimal values of species richness increase in more stable and rich environments. Thus, natural undisturbed communities that are adapted to rich and stable conditions tend to consist of a large number of species with low intrapopulation diversity, that is, specialists with narrow ecological niches. Communities that are adapted to scarce unstable conditions tend to consist of a small number of species with high intrapopulation diversity, that is, generalists with wide ecological niches. In rich unstable and scarce stable environments, we may expect some intermediate optimal diversity values.

The crucial question is on what scale is the relationship between diversity and functioning a significant factor for decision-making.

Comparisons of indicators of biodiversity and EF/ES on a large scale (global, continental, national) only show that communities adapted to different climatic and geographical conditions differ in EF and capacity to produce ES. For example, negative correlation between species richness and carbon content in ecosystems revealed for Britain (Anderson et al. 2009) does not mean that we need to reduce species diversity for better carbon storage. This means that ecosystems that store carbon are located in the north of the country and their low species diversity is optimal in those climatic conditions.

Preliminary results obtained in the project "TEEB-Russia 1" showed that relationship between ES indicators and species richness should be considered as a correlation, and not as a causal relationship. The average values of ES indicators in the regions depend primarily on climatic conditions, relief and the share of natural ecosystems in regions' area. Species richness that is typical for regional ecosystems is also determined by climate and relief. Thus, we have correlation but not causal relationship between species richness and EF/ES (Fig. 10.11). Examples of such

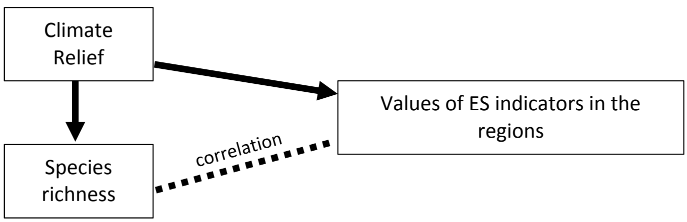


Fig. 10.11 Correlation and causal relationship between species richness and ES at national and landscape assessment scales (solid arrows show causal relationships and dotted lines show correlation

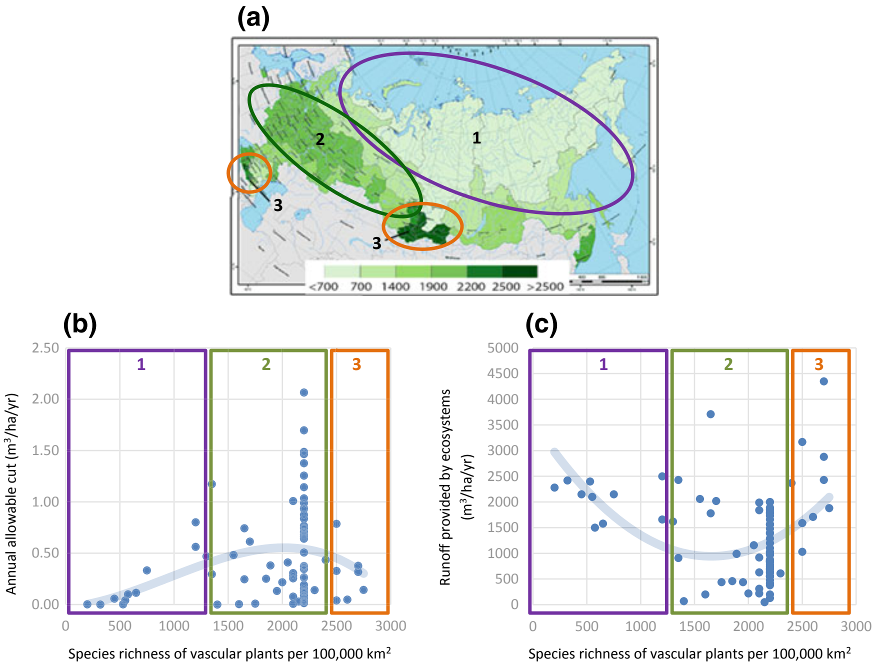


Fig. 10.12 Correlation between species richness of vascular plants and supplied ES: **a** number of species of vascular plants per 100,000 km^2 (according to the National Atlas of Russia); **b** correlation between species richness and supplied ES of wood production, **c** correlation between species richness and supplied ES of runoff regulation. 1—northern regions with a cold harsh climate, 2—temperate lowland regions, 3—temperate mountain regions

correlations are shown in Fig. 10.12. The relationship between supplied ES of wood production and species richness of vascular plants per 100,000 km^2 has unimodal humpback form with maximum ES values when diversity values are of around 2000 (Fig. 10.12b). The relationship between supplied ES of runoff regulation and species richness has unimodal U-shaped form with minimum ES values when diversity values are of around 1800 (Fig. 10.12c). These are only preliminary data and a comprehensive analysis with the identification of significant variables and dependencies will be a matter for future project phases, however, some of the most likely explanations can be made already now. In this example, climatic conditions and relief determine both species richness and supplied ES volumes. Species richness has minimum values in the northern regions (1 in Fig. 10.12a) and medium values in the temperate regions (2 in Fig. 10.12a), which reflects the adaptation of communities to the regional climatic conditions. The highest species richness characterizes mountain regions (3 in Fig. 10.12a) due to the large diversity of communities in altitude gradients. Supplied ES volumes also depend on climate and relief. Maximum wood production is a feature of lowland temperate regions and decreases both in northern and mountain regions. Runoff regulation by ecosystems, in opposite, is minimal in lowland temperate regions because ecosystems provide the highest volume of runoff in sufficiently moistened northern regions and in mountain regions (Bukvareva and Zamolodchikov 2018).

A causal relationship between species richness and EF/ES occurs at the landscape level when comparing plots of communities (habitats) of the same type that are disturbed to varying degrees. On a landscape, anthropogenic and natural disturbances transform the mosaic of communities adapted to natural conditions (relief, soils, water supply, etc.) pushing biodiversity away from the optimal state. The optimal biodiversity values can be broken due to anthropogenic changes of environmental conditions and because of direct disturbance of populations and communities (Bukvareva 2018). The general direction of anthropogenic changes of the environment is destabilization. Direct anthropogenic impact on populations and communities is expressed primarily in reduction of species richness and intrapopulation diversity. As a result, populations and communities leave their optimal state and move to suboptimal state. The further they move away from the optimal state, the weaker and more unstable is their EF and ES. Thus, in the landscape scale, interconnections between indicators of biodiversity and EF/ES can be useful background for decision-making. With regard to species diversity, two main management consequences can be formulated.

First, the optimal species diversity can be relatively low in unstable or scarce conditions. Despite this, it provides the maximal effectiveness of a community under these conditions. Thus, the criterion for the choice of conservation priorities should be the distance of anthropogenic shift away from the optimal diversity, but not high formal diversity indexes (e.g., species richness). The ultimate goal should be preservation of diversity of typical communities for a given landscape or region, including natural communities with low species diversity.

Second, the optimal biodiversity concept may be an additional approach to resolve ES trade-offs. For example, intensive use of provisioning services, especially food, fiber and biofuel production, greatly simplified ecosystem structure. This simplification enhanced certain provisioning services, but reduced others, particularly regulating services (Cardinale et al. 2012). One of the reasons for this trade-off is the different response of biodiversity to management for regulating and provisioning ES. While the first requires conservation of the optimal diversity values, the latter push populations and communities away from the optimal state. Thus, landscape planning should consider the conflict between goals of biodiversity management for different ES.

10.6 Conclusion

Russian landscapes provide important ES and are crucially important for the economy and people of the country. It is necessary to immediately start forming a national system of ES monitoring and assessment. The main methodological approaches to national ES assessment were proposed in the Prototype National Report "Ecosystem Services of Russia. Volume 1. Terrestrial Ecosystem Services" (Bukvareva and Zamolodchikov 2018).

Quantitative evaluation of supplied, demanded and consumed ES allows to assess the degree of ES use and the degree of satisfaction of the demand for ES in the regions and to reveal environmentally hazardous and relatively safe regions as well as regions, which tend to be consumers or donors of ES. ES assessment methodology applied in the Prototype Report does not take into account the relative spatial location of the regions that should be corrected in the future ES assessments.

However, only one-third of the services reviewed were quantified by the currently available data. In order to expand the range of ES when comparing regions, we used ES scores. Scores of supplied ES reflect natural factors that determine the capacity of ecosystems to perform ES. Scores of consumed and demanded ES reflect socio-economic factors that determine the need for ES and their use by humans. The comparison of the regions by the balance of supplied and consumed ES scores shows where natural factors dominate, and where socio-economic factors prevail.

Despite a significant data gap for a full ES evaluation the formation of a national system of ES assessment can be started on the basis of the current federal system of data collection. Priority attention should be paid to solving in the short term the following methodological problems.

- elaborate methods allowing (a) to take into account spatial diversity of natural and socio-economic conditions within the largest constituent entities of the Russian Federation and (b) to translate data for ES evaluation and estimates of ES between river basins and administrative regions,
- determine the methods of accounting for ES spatial characteristics, directional ES flow and user movement as well as spatial interrelations between the regions,
- ensure the availability and regular updating of data related to ES assessment, which are already collected by federal agencies and of the map of terrestrial ecosystems of Russia based on satellite imagery, develop a set of algorithms and models for indirect quantitative ES assessment,
- ensure a comprehensive assessment of all ES categories, and avoidance of priority accounting of the only easily calculated economic value of provisioning and recreational ES.

An important task to be addressed in the future is to assess the links between ES and biodiversity in order to optimize the objectives of biodiversity conservation and ES maintenance and use. This task should be addressed primarily at the landscape level, taking into account the adaptation of populations and communities to environmental conditions.

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