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REVIEW

The current state of knowledge of ecosystems and ecosystem services in Russia: A status report

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Abstract This paper focusses on a conceptual overview of ways to address a comprehensive analysis of ecosystem services (ES) in a country as large and heterogeneous as Russia. As a first step, a methodology for assessing the services for the federal subjects of Russia was chosen, i.e., its constituent provinces and similar entities, in physical terms. Russia harbors a great diversity of natural conditions and ecosystems which are suppliers of ES, and likewise a variety of the socio-economic conditions that shape the demand for these services and their consumption. The methodological approach described permits several important tasks to be addressed: the evaluation of the degree of satisfaction of people's needs for ES, the identification of ecological donor and acceptor regions, and zoning of the country's territory for ES assessment. The next step is to prepare a prototype of a National Report on ES in Russia, for which we are presenting the planned structure.

Keywords Biodiversity · Climate regulation · Ecosystem functioning · Environment · National ecosystem assessment · Russia

INTRODUCTION

During the 1990s, with the increasing human demands upon the limited resources of the earth, and in view of the growing burdens upon nature, manifested, too, in biodiversity loss and in the problem complex of energy and the climate, the concept of ecosystem services (ES) entered into the international environmental discussion, starting from the western world (e.g., de Groot 1992; Costanza et al. 1997; Daily 1997). Important milestones included the Millennium Ecosystem Assessment (MEA 2005), the international TEEB study "The Economics of Ecosystems and Biodiversity" (http://www.teebweb.org), and the Strategic Plan for 2011–2020 adopted at the Tenth Conference of the Parties of the Convention on Biodiversity (CBD 2010). At the same time, numerous countries began to get involved in the national TEEB processes, with the goal of revealing facts and figures that reflect the values of nature and encourage policy advances to maintain ES and biodiversity at the national, sub-national, and corporate levels.

One important challenge for the coming years in this context is the task of bringing the Russian Federation (RF) and the Newly Independent States (NIS) of North Eurasia into the TEEB process and supporting them, since the ecosystems of the RF and northern Eurasia generally are a key factor in the overall biosphere. Merely on the basis of their size, the countries Russia, Ukraine, and Kazakhstan are of global importance. In view of the growing anthropogenic pressure and continued climate change, it will only be possible to prevent the rapid and massive degradation of natural ecosystems and to maintain their services in the region if effective measures for the integration of the values of ES into the economic and political decision making processes of these countries are developed and implemented there.

Germany is supporting Russia in this process under a bilateral environmental agreement, and will contribute to the drafting of national TEEB studies in Russia and other selected post-Soviet states. In 2013, the Biodiversity Conservation Center (BCC Moscow) and the Leibniz Institute of Ecological Urban and Regional Development (IÖR Dresden), with the support of the German Federal Agency for Nature Conservation (BfN), launched the project "Ecosystem Services Evaluation in Russia and other NIS Countries of Northern Eurasia: First Steps". The goal of the project is to initiate a process for the development of a system for assessing ES. The scientific community, policy-makers, government, business, and civil society should be involved, and the process should include quantification, analyses, initiation, and communication of successful examples for the social and economic valorization of the natural capital of Russia and the NIS countries (Grunewald et al. 2014a).

The goal of the project is moreover to develop close cooperation with Russian policy-makers and the scientific community in order to provide impulses for making the benefits and values of nature clearer and more visible, particularly in economic decision making. Strategic proposals are to be jointly developed, so as to better integrate the performance and benefits of ecosystems and landscapes into public and private decision making processes over the long term, and to maintain the natural resources and the biodiversity of these countries and their regions.

The focus is primarily a biophysical investigation of terrestrial ecosystems. Coastal and marine ecosystem services are not covered in the first step, but they are of great importance, especially in light of Russia's expansive Arctic coastline and other important coasts including the Black and Caspian seas.

However, is it possible and legitimate to apply current Western concepts for spatial ecological evaluation and planning to the specific conditions in Russia? The present paper compiles the current state of analysis and evaluation of the Russian ecosystems and their services at the national level. In addition to elucidations of the status quo of the ES analysis and evaluation, key points for a systematic National Report are presented. Initially, terminological and conceptual issues—frameworks, classifications, and indicator systems—as well as the problem scales and data availability are central. This achieved level, drafted by the Russian experts, is to be verified in the context of a bilateral project, in order to take into account both the international connectability and the specific peculiarities of Russian conditions.

RUSSIA: KEY POINTS OF ENVIRONMENTAL POLICY AND THE ES APPROACH

Russia, officially the Russian Federation (RF), is the largest country in the world in terms of area, with 70 million sq km and with 143 million inhabitants (2013); it is among the most thinly populated countries worldwide, with eight inhabitants per square kilometer. Russia has a leading position globally as a producer of energy and exports major quantities of oil and gas, as well as iron and steel, wood, and agricultural products. Some 30 % of the land—220 million ha—is considered potential farmland (DZZ 2011).

Administratively, Russia is subdivided into so-called "federal subjects" (regional entities), with twenty-one republics, forty-six *oblasts* (regions), nine *krays* (territories), four autonomous districts, one autonomous *oblast*, and two city-states, together with 23 000 municipalities, as of January 1, 2013. From a natural-spatial point of view, all the climatic zones of terrestrial ecosystems with the exception of the tropics are represented there. Russia is characterized by eight mega-landscapes (Dyakonov 2007): (1) the Eastern European Plain, (2) the Western Siberian Plain, (3) the Northern Siberian Lowlands, (4) the Central Siberian Highlands, (5) the Southern Siberian Mountains, (6) the Central Yakut Depression, (7) the Eastern Siberian Highlands, and (8) the Eastern Siberian Lowlands.

Russia has a traditional, complex system of natural protected areas. It consists primarily of *Zapovedniks* (total reserves), *Zakazniks* (federal and regional reserves with different regimes of nature protection), national parks, MAB biosphere reserves, and wetlands under the Ramsar Convention. The protection and use of the forests are regulated under the Forest Law. Russia has more than 12 000 national, regional, and local protected areas, covering 200 million ha, or 12 % of the country (Krever et al. 2009).

Russia has responsibility not only for the development and management of its own huge territory and natural resources, but also, in the context of international agreements, for such matters as the Arctic and Antarctic, protection of the oceans, climate protection/reduction of global CO_2 emissions (although Russia ratified the Kyoto Protocol in 2004, it currently has no obligations to reduce emissions under that agreement), and the Convention on Biodiversity (Russia ratified the CBD in 1995 and adopted its first National Biodiversity Conservation Strategy in 2001; the second version of the National Strategy is currently being prepared).

The environmental situation and environmental protection provide an ambivalent picture: on the one hand, half of Russian territory is largely uninhabited and in a natural condition—a situation which applies on only 2.8 % of the area of Europe; on the other, the Russian Federation, particularly as a successor to the former Soviet Union, is associated with impacts and environmental pollution of catastrophic dimensions, including radioactive environmental pollution stemming from nuclear weapons testing and the storage of radioactive waste, as well as environmental protection due to oil. In this context, environmental protection organizations particularly complain of the lack of standards and binding regulations, and also of unclear responsibilities (e.g., Yablokov 2010).

The Russian Federation has adopted important strategic documents of state policy in the field of nature protection and sustainable ecological development:

- The National Strategy of Biodiversity Conservation in Russia (2001);
- The Ecological Doctrine of Russia (2002) proclaimed the important role of biodiversity and defines "preservation and restoration of landscape and biological diversity, sufficient for maintaining the ability of natural systems to regulate and offset the effects of human activities" as one of the main objectives of state environmental policy (http://www.scrf.gov.ru/documents/24.html);
- The Foundations of the State Policy of the Russian Federation in the Arctic for the Period through 2020 and the Perspective Beyond (2008) provide for "the maintenance of biological diversity of Arctic flora and fauna" (http://www.scrf.gov.ru/documents/98.html);
- The Foundations of the State Policy of the Russian Federation in the Area of Ecological Development for the Period through 2030 (2012, http://kremlin.ru/acts/15177) proclaim sustainable development and protection of biodiversity as strategic goals of the state policy of Russia.

One might also refer to the UNDP Reports for Russia (UNDP 2010, 2011), the compilation of Russian sustainability issues by the Civil Chamber (Zakharov 2011), and the sketching of the contributions of the country to the Rio 20+ process (Authors' Collective 2012).

Thus, the idea of the crucial importance of biodiversity and natural ecosystems for the welfare of the population and the country is enshrined in a number of key government documents.

The framework conditions for land use and land-use decision making are key for the future condition of the ecosystems and for the safeguarding of ES. For this purpose, a corresponding further development of ecological planning approaches, environmental and welfare balancing, financial and subsidy policy in the context of the value discussion, and the comparison of alternatives are needed (Grunewald and Bastian 2015). While these evaluations may not constitute any patent recipes, they may nonetheless contribute to overcoming the lack of an economic perception of nature that has often lead to mistaken political and economic decisions and ultimately to the destruction of nature, ecosystems, and biological diversity, and will continue to do so in the future (Ruckelshaus et al. 2013).

For Russia, the ES concept is of importance particularly for the following reasons (Bobylev et al. 2014):

- As an economic justification for the protection of major new natural areas.
- As a justification of additional expenses for conservation.
- To enable a prioritization and ranking of investments for the use and protection of ecosystems.
- To create incentives for the local population to preserve nature.
- To ensure the adequate establishment of the most important development indicators of a region or of the entire country.
- Additionally awareness rising in society to preserve the natural resources.

In Russia, various research projects for the evaluation of ES have been carried out, particularly under scientific and conservationist aspects (e.g., Tishkov 2005; Pavlov et al. 2010; Bobylev et al. 2014); however, state interest has remained somewhat reserved to date. For instance, additional attempts have been undertaken to evaluate the global importance of the ecosystems of Russia on the basis of ecological and monetary parameters, and also to introduce evaluations at the regional level (Bobylev and Zakharov 2009). Concrete projects have addressed such issues as ES in the regions of Kamchatka, the Altai, Lake Baikal, and the lower Volga and have produced such publications as a manual on the Economy of the Preservation of Biodiversity. In other words, initial conceptual and concrete regional experiences for the evaluation of ES already exist (Grunewald et al. 2014a, b).

Overall, however, Russia is hardly present in the Ecosystem Services Partnership organization (ESP), and Russian authors are hardly a factor at all in international ES literature (Costanza and Kubishewski 2012). This is on the one hand due to deficits in work on the object of this research, including deficits of a methodological nature, and on the other to the reticence of the publication activities in international English-language journals. A methodological adaptation of the ES concept by means of a linkage with Russian scientific traditions and the peculiarities and focal points of Eastern European landscape research, and their targeted further development may be suitable to provide valuable substantive impulses for the ES concept, especially for Russia, but also in an international context (Bastian et al. 2015).

THE GLOBAL SIGNIFICANCE OF RUSSIAN ECOSYSTEMS

The ecosystems of Northern Eurasia provide a huge package of ES which are very important not only for the region but also on a global scale, e.g., for carbon storage, water cycles, and biodiversity. Global climate regulation depends to a large degree on the ecosystems of this region. Thus, ecosystem functioning in the RF and the NIS countries is crucial for the sustainable development of these countries and of the whole world. On the one hand, these countries are old civilizations of great geographical and demographic importance, with rich natural assets; on the other, they are undergoing rapid economic and societal transformation which also includes the goal of improving environmental conditions and the need for development and poverty alleviation (Grunewald et al. 2014a).

A number of key areas for stabilizing important geobiospheric processes exist on the territory of the Russian Federation. For example, Russia's ecosystems can be considered long-term carbon sinks and depositaries of global importance. Since the ES at issue is primarily that of climate regulation, this ecosystem function is to be addressed as an example herein.

The quantity of carbon stored in the vegetation and the soils of all Russian natural areas amounts to 336 Gt (40 Gt in the vegetation and 296 Gt in the soil), or 16 % of worldwide reserves—in spite of the fact that Russia occupies only 11 % of the land area of the earth (Zavarzin and Kudeyarov 2006).

Russia is number one worldwide in terms of forest area and number two in terms of the carbon content in the biomass of its forests, after Brazil; in tropical forests, biomass per hectare is greater than in the North. On the other hand, the quantity of carbon in the soils of the Russian forests is greater than in the tropics. For this reason, the total quantity of carbon in the Russian forests is the greatest worldwide (Fig. 1). The soils and the phytomass of the forest stock, including forests, non-forested areas, and boglands, contain approx. 290 Gt of carbon (soil: 253–257 Gt C; phytomass: 33–36 Gt C), and the agricultural soils 45 Gt C (Sohngen et al. 2005; Zamolodchikov et al. 2005).

The carbon content of the wetlands of Russia amounts to between 113 and 210 Gt, depending on the source (NEESPI 2004; Parish et al. 2008), which corresponds to between 20 and 50 % of the total worldwide amount of peat. Approximately half of that—some 70 Gt—is concentrated in Western Siberia (Smith et al. 2004).

And finally, the world's greatest reservoir of carbon in terrestrial ecosystems is found in Russia's permafrost. This area covers approx. 11 million sq km, i.e., 65 % of the surface area. According to various estimates, Russia has approx. half to two-thirds of worldwide permafrost areas (NEESPI 2004). It should be noted that this permafrost soil is not only a potential source of huge quantities of CO_2 and CH_4 (Lenton et al. 2008), but also a risk factor for anthropogenic catastrophes.

The Russian ecosystems also constitute the greatest CO_2 sink with regard to long-term carbon storage in the terrestrial ecosystems, particularly with regard to their northern location (Bukvareva 2014). The cold and moist climate is a precondition for carbon accumulation. The temperature maximum for destruction is higher than for production. For this reason, production can, under cold conditions, exceed destruction, so that the excess biomass is then stored in long-term reservoirs. Another additional factor contributing to the suppression of destruction and the deposit of carbon is excess dampness. Such conditions are especially common in the north. Most important carbon concentrations of terrestrial ecosystems are found in the soils, and this is primarily true of northern ecosystems. Globally, the carbon content of the soil can exceed that in vegetation by a factor of 3–5; in Russia, that factor is as

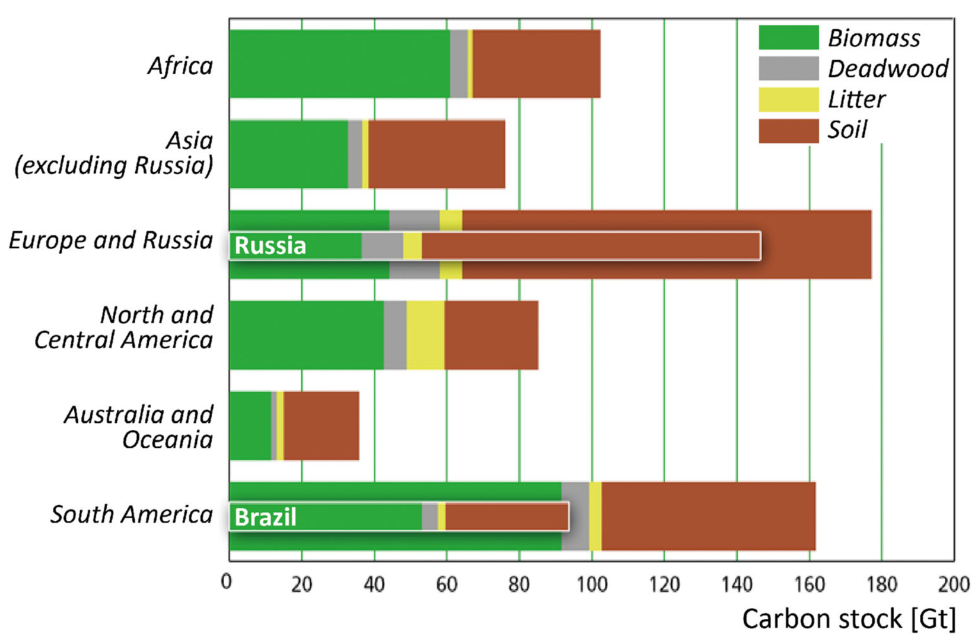

Fig. 1 Carbon quantities in forests by world regions (Pavlov and Bukvareva 2012)

high as 7.5. The accumulation in the soil of Russia constitutes one-fifth of all global soil contents of carbon (Zavarzin and Kudeyarov 2006).

PRELIMINARY CLASSIFICATION OF ES IN RUSSIA

Since in spite of numerous studies in the field of ES, no consistent classification system for them has been developed, and the Status Quo Report of the Russian Federation used a preliminary classification system based on three major groups: (1) productive ES, (2) environment-forming (regulatory) ES, and (3) cultural/informative ES (Table 1). A fourth group is that of recreational services, which are complex and depend on all of the first three groups to differing degrees. This classification generally corresponds to international standards, the TEEB and CICES classifications (Grunewald and Bastian 2015), and to the categories of sustainability; it also corresponds with the subdivisions of the Russian National Biodiversity Strategy. This preliminary classification is being discussed further by experts of the projects in order to reach a decision regarding the classification of ES which is the most suitable for the conditions in Russia.

BASIC ECOSYSTEMS AND ES IN RUSSIA: A BRIEF OVERVIEW

The Status Quo Report on ES in Russia provides a rough overview of all ES classes shown in Table 1, albeit in varying substantive, spatial, and temporal detail, depending on the data availability and the state of project work (Bobylev et al. 2014). We show this in the following using one example of each main ES group from Table 1.

Productive ES by example of wood products

Table 2 shows the dynamic of forest areas and stocks in Russia between 1988 and 2008. A clear tendency towards increase has been shown, both of forest areas and of the quantities of wood. However, not all forests are available for use. The categories in which timbering is banned include forests in protected areas and protected forests. If no wood use is planned for the coming twenty years, the forests are classified as reserve forests. In 2008, the commercial share of the forests amounted to 43.9 % of the area and 49.5 % of the stock of wood. It should be noted that areas and stocks of wood in the commercially used forests were reduced during the period 1988 through 2003. This trend is associated with the certification of forests as protected areas on a large scale. After 2006, the tendency was reversed, and reserve forests began to be classified as commercial forests.

The quantity of wood in the forest is an important characteristic; however, the determination of acceptable commercial quanta from a forest should be based on its wood production. According to the criteria of sustainable forest management, the withdrawal of wood must be compensated by growth in other forest areas. For this reason, restrictions on forest use categories are imposed upon the territorial forestry operations, i.e., maximum limits for annual felling have been established. In 1995, the authorized withdrawal quantity for Russia was 545.6 million cu m; in 2004, it was 495.3 cu m. This reduction corresponded to the reduction of the annual harvest of wood resources in the commercial forests during the period 1993–2003 (Table 2).

The wood stocks in the forests characterize the potentially available ES. The utilization of the service timber production is quantified by the actual wood withdrawal. The amount of legal felling is statistically registered with Rossleshoz or Rosstat. Archive data for the extent of timber production for the years 1946 through 1995 have been published (Forest Report 1996). In the 1960s through the 1980s, the total of wood production in Russia (Fig. 2) was approx. 350–370 million cu m. After the end of the Soviet Union (1990–1998), it dropped to between 130 and 160 million cu m per year, and in the 2000s, it varied between 160 and 180 million cu m per year. Annual harvests of about 350 million cu m of wood from the mid-1950s through the late 1980s contributed to a sustainable forest age structure, for the annual removal of wood corresponded to the annual growth rate. With the reduction in felling, the forest areas and stocks increased (Table 2).

The values shown in Fig. 2 characterize the legal logging withdrawals from the Russian forests. According to various estimates, the illegally harvested quantities amount to 10–25 % of the total volume of timber (Ptichnikov and Kuritsyn 2011). The bulk of small-scale illegal logging is carried out by the local population, via selective felling (Morozov 2000), which hardly leads to destructive impacts on the forest stock.

Environment-forming ES by example of biogeochemical regulation of climate

With respect to biogeochemical climate regulation services, the terrestrial ecosystems can be categorized according to two aspects: (1) the rate of carbon intake from the atmosphere and (2) the quantity and stability of fixation, the removal of carbon from the biogeochemical cycles. The significance of an ecosystem changes in accordance with priorities: if the rapid intake of carbon is the most important factor, young forests have the greatest

Table 1 Preliminary classification of ES for Russia (Bobylev et al. 2014)

No.	ES (definition) and sub-classes
1	*PRODUCTIVE* (Production of biomass which is removed from ecosystems by people)
1.1	Production of timber and firewood
1.2	Production of non-wood plant resources (mushrooms, berries, nuts, bark, medicine plants, etc.)*
1.3	Production of fodder by natural pastures and hayfields
1.4	Production of fresh-water seafood
1.5	Production of game resources
2	*ENVIRONMENT-FORMING (supporting and regulating)* (Formation and maintenance of the environmental conditions conducive to human life and economic development)
2.1	Regulation of atmosphere and climate
2.1.1	Biogeochemical regulation of climate (carbon cycle, flows of greenhouse gases)
2.1.2	Biogeophysical regulation of climate [regulation of energy flows between Earth surface and atmosphere (albedo, heat flows, wind speed); reduction of wind speed and damage from storms and hurricanes; regulation of water flows between Earth surface and atmosphere (forming of clouds, impact on the amount of precipitation)]
2.1.3	Cleaning of air by vegetation
2.2	Regulation of hydrosphere
2.2.1	Regulation of hydrological regime of territories: regulation of water run-off, cleaning of water by terrestrial ecosystems, and reduction of damage from floods
2.2.2	Biological cleaning of water in reservoirs and streams
2.3	Forming and protection of soils
2.3.1	Forming of bioproductivity of soils
2.3.2	Biological cleaning of soils, removal of pollutants
2.3.3	Protection from water and wind erosion, prevention of landslides and dust storms
2.3.4	Regulation of cryogenic processes
2.4	Regulation of biological processes which are important for economics and safety
2.4.1	Regulation of economically important species: agriculture pests, forest pests, and pollinators
2.4.2	Regulation of species which have medical importance (components of natural focuses of disease, carriers of disease)
3	*INFORMATION* (Information which can be useful for humans and other non-material benefits)
3.1	Genetic resources of native species and populations
3.2	Information about the structure and functioning of the natural systems that can be used to create artificial and technological analogs
3.3	Eesthetic and cognitive value of natural systems
3.4	Ethical, spiritual, and religious significance of natural systems
4	*RECREATION (COMPLEX)* (Services that combine the components of the first 2 or 3 groups)—Formation of natural conditions for the following types of recreation:
4.1	Daily recreation next to the house (clean air, vegetation, water)
4.2	Weekend recreation, the country house recreation, fishing, hiking, mushrooms, and berries (not including commercial non-timber products)
4.3	Excursions and educational tourism in nature (beautiful scenery, bird watching, etc.)
4.4	Active tourism in nature, sport fishing, and hunting
4.5	Wellness recreation at resorts

* Crop production is not included in the present analysis because at this stage of research we consider ES only of natural ecosystems. Expanding the evaluation on anthropogenically transformed areas including agricultural systems is the task for the future

value, especially those planted on former farmland (agroforestry systems). If longer term and more sustainable carbon storage is the main issue, old forests, steppes, and boglands have greater priority, since they harbor the greatest carbon stocks per unit of area.

The inventory process of greenhouse gas flows and carbon budgets in the various ecosystem types and their territorial expression are popular research focus areas in Russia and worldwide (e.g., Crowley 2000). However, the uncertainties and inconsistencies in the existing surveys are still great. In Russia, there is no official or complete carbon accounting of the terrestrial ecosystems. The forests are an exception, as Ross-Hydromet has assumed responsibility for reporting here and submits the data to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). Greenhouse gas sinks in managed

Table 2 Dynamic of areas and timber reserves in Russian forests (Zamolodchikov et al. 2011)

Category	Characteristic	Accounting year				
		1988	1993	1998	2003	2008
Forests	Area, kha	758 716	750 953	763 826	767 474	787 148
	Stock, million m^3	81 123	79 504	80 798	81 153	82 378
Commercial forest	Area, kha	388 453	351 096	331 461	329 789	345 449
	Stock, million m^3	47 595	43 467	40 279	39 630	40 814

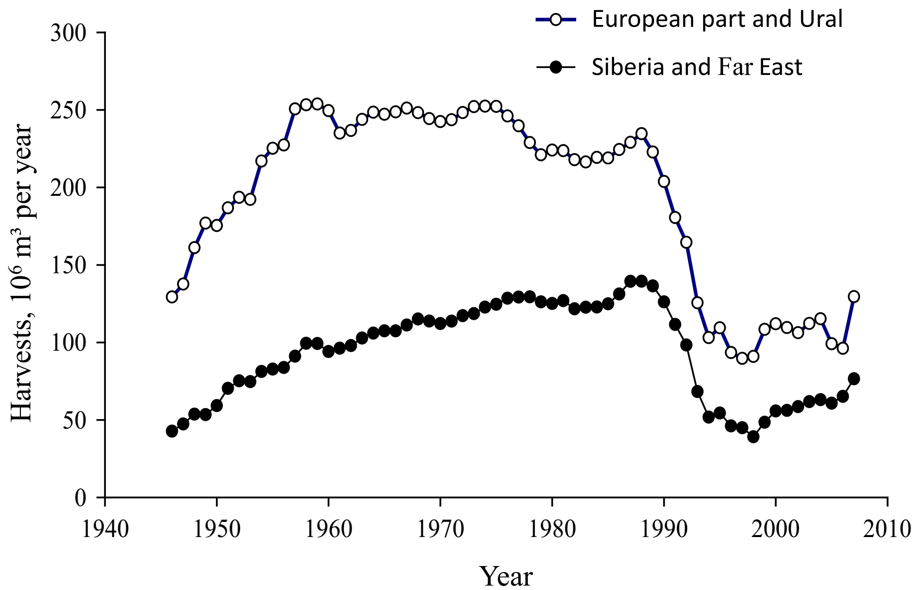

Fig. 2 The dynamics of timber felling in the Europe-Ural region and in the Asian part of Russia (Zamolodchikov 2012)

forests are recognized in the national budgets in the contexts of the UNFCCC and the Kyoto Protocol. The Russian Federation submits the respective annual reports to the UNFCCC bodies.

The greatest contribution to the binding of carbon is provided by forests, not only due to their vast surface area, but also due to their current ecological state. The carbon stocks in the living and dead forest biomass of Russia amount to 49.4 Gt C (Dolman et al. 2012).

The forests currently existing in Russia—their enormous surface area has been addressed above—consist primarily of secondary forests of various age stages, which means that they can sequester large amount of carbon. At the beginning of 2011, the total forest area of Russia, both wooded and non-wooded, amounted to 1183.3 million ha, including the Forest Fund areas (1144.1 million ha), according to the State Forestry Register (GLR). The total forest area of Russia included forested lands, temporally non-forested lands (clear cuts, burnt areas), and non-forested lands (sparse forests, wetlands) inside borders of forest management units. The Forest Fund areas do not include areas under the Defense Ministry, city forests (6.2 million ha), protected areas (OOPT; 26.2 million ha), or forest areas of other categories (total: 6.8 million ha). The actual wooded area of Russia amounts to 797.1 million ha and that of the Forest Fund, 770.6 million ha.

In second place in terms of area are grass and shrub ecosystems, which are primarily located in tundra (at north of Russia), steppes and semi-desert (at south) zones, and mountain-tundra areas. Total area of actually existed steppes (excluding croplands) in Russia is estimated near 50 million ha in Russia (Smelansky and Tishkov 2012). Carbon storage in this area is about 35 Gt C (Smelyanskiy 2012). The peculiarity of carbon intake in steppe ecosystems is that it takes place over the long term and is very resilient. This is due to the fact that the bulk of the carbon is fixed in the soil, where its mobility is low and, in undisturbed steppe ecosystems, the possibilities for emission are minimal. Significant emissions occur in the case of anthropogenic intervention, particularly plowing. The protection of existing steppe ecosystems from plowing ensures that (a) carbon from the atmosphere amounting to some 1.5 t/ha per year is fixed (Belelli Marchesini et al. 2007); and (b) carbon deposits amounting to some 700 t/ha (Smelyanskiy 2012) are preserved over the long term (scale of centuries). The overall annual potential of long-term carbon fixation in the steppe ecosystems is 75 Mt C per year (Smelyanskiy 2012). The primary productivity of steppe ecosystems in the temperate zone is generally estimated at 6–13 t C/ha per year (Bazilevich 1993). It should be noted that the productivity of steppe ecosystems can vary by a factor of up to 10, depending on the degree of humidity and other climatic influences.

The highest percentage of carbon absorption per unit of area occurs on fallow fields. During the 1990s, a major process of abandonment of farmland occurred in the non-chernozem zone of European Russia, during a period of economic depression. The ecosystems which emerged in place of the previous agricultural land now absorb 43 Mt C per year (Kurganova et al. 2014).

The peat bogs in Russia cover an area of more than 140 million ha and constitute the main terrestrial long-term system for the storage of carbon withdrawn from the atmosphere (Dolman et al. 2012). The total carbon stocks stored in the peat bogs of Russia amount to between 33.6 and 67.2 Gt C. Assessments have shown that a total of 53 million t C per year are fixed in the peat bogs (Dolman et al. 2012).

The tundra in Russia covers 280 million ha or 16 % of the territory of the country. The carbon stocks in the humus and peat in the different types of tundra varies between 100 and 200 t C/ha. The total carbon stock in the soil of the Russian tundra is estimated at 28.6 Gt C (Chestnykh et al. 1999). Currently, Russian tundra zone constitutes a small source of carbon released into the atmosphere due to stimulating heterotrophic respiration under influence of climate warming (Zamolodchikov and Karelin 2001; Dolman et al. 2012).

Increased activity in the tundra leads to impairments and ultimately to the degradation of the soil surface, and is reflected in the increasing release of greenhouse gases, which are stored in the permafrost (Chen et al. 2014). Climate change processes also could stimulate or modify CO_2 and methane emissions from tundra ecosystems and underlying permafrost. These processes actively discussed in recent scientific literature (Heikkinen et al. 2004; Merbold et al. 2009; Hartley et al. 2012; Wooller et al. 2012 and many others), but results and conclusions are too diverse to be included for the assessment of ecosystem services.

The state of the ES “Regulation of the carbon cycle” in Russia can currently be seen as relatively good. This is mainly due to the fact that the economic activities of the utilization of land and nature were greatly reduced due to the economic collapse of the 1990s. The decline of logging, the end to the drainage of peatlands, and the increase in fallow land in the steppe and non-chernozem zone—all this created the conditions for a significant increase in carbon storage. However, this should be seen as only a temporary improvement in the ES. Even if there is no increased pressure due to economic factors, the change in the age structure of forests will reduce the carbon sinks over time. Consequently, management measures will be necessary to maintain the high absorption capacity of forests in the future. The greatest dangers in connection with the maintenance of the ES of Russia’s forests are inadequate forest management strategies (for primary forests), illicit logging, and forest fires. The last two are particularly relevant for Siberia and the eastern regions of the country. The condition of the other biomes is already less than satisfactory, and there is a cause for concern that this will worsen in the future. Plowing and burning in the steppes lead to losses of carbon stocks in the soils and to carbon dioxide and soot emissions. The drainage of peat soils favors peat fires and may cause their massive carbon stocks to be reduced. Increased activity in the tundra leads to impairments and ultimately to the degradation of the soil surface, and is reflected in the increasing release of greenhouse gases, which are stored in the permafrost.

Five million hectare of peatlands and wetlands were drained in Russian Federation before 1990s (Minayeva et al. 2009). The social–economic reforms practically complete these practices. Large areas of previously drained peatlands currently are not used in agriculture and produce a high risk of fires in hot and dry weather situations (Sirin et al. 2011). Peat fire rates can increase under the climate warming and affect carbon stocks in drained peatlands.

Information ES by example of ecosystem capacity to host typical levels of biodiversity

The potential amount of the ES for maintenance of genetic resources of native species and populations is determined by the level of species diversity and intra-species diversity. The general pattern in species diversity is decreasing as a number of species moving towards higher latitudes in Russia. The exceptions are the dry regions near the Caspian in the south of Russia, where the number of species is relatively small (Fig. 3).

However, the relatively low species diversity in northern ecosystems does not mean that they are less important for the conservation of genetic resources (Bukvareva and Alecshenko 2013). Therefore, it must be included in the evaluation of information ES along with the diversity of species.

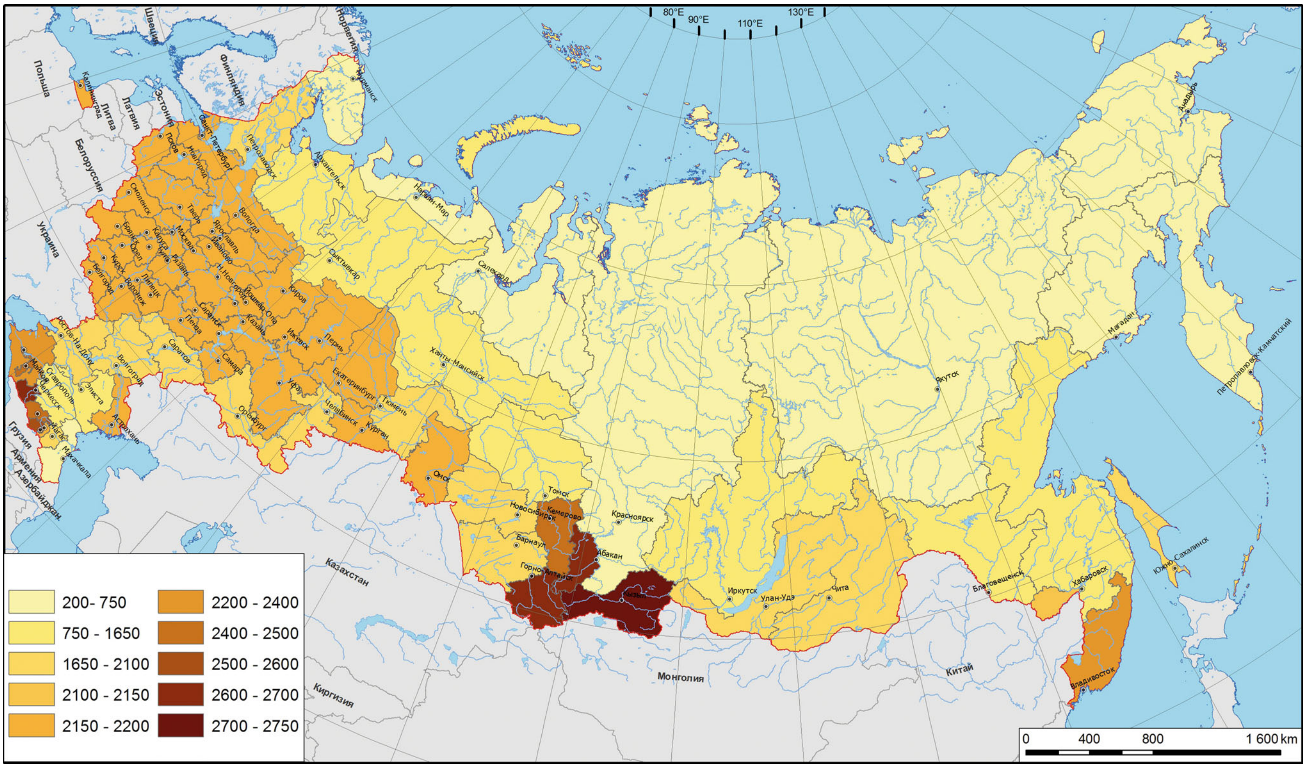

Fig. 3 The number of species of vascular plants per 100 000 km^2 in the regions of Russia (based on data from National Atlas of Russia, Volume 2, 2008)

The potential level of ES in order for the maintenance of genetic resources of natural ecosystems is in the opposite to the degree required for anthropogenic transformation of ecosystems, species, and populations. Anthropogenic reduction of species diversity, disappearance of unique intraspecific forms, and local populations reduces the amount of this ES. This underlines the crucial importance of preserving the remaining natural ecosystems as storages of unique information in highly developed regions of Russia, especially in the south of the European part of the country. At the first stage of evaluation currently available, data on the number of species of vascular plants and the degree of disturbance of natural ecosystems (fraction of the area of natural ecosystems in regions) can be used as the main indicators of the potential volume concerned with ES.

The factor affecting the consumed volume for this information service is mainly the intensity of the study of natural genetic resources. An available indicator for the assessment of this factor could be the costs of carrying out scientific research in the Russian regions or the expenditure actually paid as a sign of the willingness of the society to develop this ES.

Complex-ES by example of recreation

Recreational ES have been assigned to the group of integrated services, considering that ES from a variety of groups are important for the various types of human recreation; these include productive, environment-forming (regulatory), and informative ES. The provisional Russian classification should be discussed in this context, since many different conditions in other ES play a role here. Here, we have the phenomenon of intermediate ES (Boyd and Banzhaf 2007). It would be beneficial in the future to evaluate only final ES and to show their relationship to welfare categories. This should be based on the CICES classification (Haines-Young and Potschin 2010) and the ES indicator approach in Switzerland (BAFU 2011).

Environment-forming (*regulatory*) ES are crucial, since without a healthy and favorable environment recreation is almost unthinkable. Within the group of *productive* ES, the most contributing are fishing and hunting (for sport hunting and fishing in inland waters) as well as non-wood products, such as mushrooms, berries, and other wild fruits (for collecting mushrooms and berries which are popular in Russia among both rural and urban residents). *Informative* components (the beauty of natural landscapes, natural elements of cultural landscapes, species diversity) are important for the ecological and educational tourism and recreation (bird watching, admiring the beautiful scenery, etc.).

The potential level of services towards formation of natural conditions for everyday and weekend recreation and summer cottage recreation is defined by the following factors: the level of comfort climate, absence of pollutions, and degree of disturbance of natural ecosystems. In the latter case, the dependence of the potential level of ES is probably not linear, since a large number of people prefer to spend holidays not in completely wild sites but in cultural landscapes with the optimum combination of natural and cultural components with an economic infrastructure. The consumed volume of these services is determined by the population density and transport accessibility of the territory. This type of recreation is especially important in the suburbs of large cities, especially in the European part of Russia.

Nature and the traditional culture of Russia offer great potential for the development of ecotourism. There are still many areas in the North, in Siberia, and in the mountains which are not covered by urbanization and intensive agriculture. Their diversity, uniqueness, and attractiveness are very high. However, the combination of high sensitivity and fragility of many Russian ecosystems remains significant limitations for the development of ecotourism.

PROBLEMS OF SCALE OF ES IN RUSSIA AND ESTIMATION OF PROVIDED AND CONSUMED SERVICES

In determining appropriate standards for the analysis, evaluation, and monitoring of ES, and for their regionalization, the size of Russia deserves special attention. Therefore, in the first stage of the project, a preliminary analysis has been conducted of the spatial scales of the essential ES and their values in Russia (Bukvareva 2014). Examples of the different spatial scales of ecosystems and ES are shown in Table 3.

Various ES "work" at different scales, which is why the mechanisms of integration of their values into the economy and into the decision making process also take place at different levels. Ecosystems with their structures, processes, and functions provide different potentials for ES. The real value of ES for the welfare of the people is defined through the use of these services, i.e., by the presence of users in the appropriate scale (Costanza 2008; Fisher et al. 2009; Syrbe and Walz 2012; Bagstad et al. 2013). Consequently, the determination of the spatial scales of ES is important for ES management, for compensation mechanisms, and for the integration of values into the economy. This includes a reference to the area, which provides ES and spaces in which they are used/consumed (Bastian et al. 2012).

The ES on a local scale must be secured and compensated primarily by residents and local businesses. Soil conservation measures on site, for example, are not paid for by neighboring regions, except in cases where water and wind erosion leads to a deterioration of environmental indicators in those regions, nor do they contribute to the preservation of springs and small rivers if these have little effect on the water in the lower reaches. Therefore, it is necessary for the maintenance of ES of local importance to develop mechanisms for the payment for their value, which must be negotiated between different stakeholders and companies with the participation of the public.

ES which extend across several regions, e.g., if forests in the upper river basin regulate the flow in the lower areas, require the development of interregional compensation and market mechanisms. For example, large cities in the lower reaches could pay for the conservation of natural

Table 3 Examples and expert-based weighting (high–medium–low) of Russian ES in various spatial scales

ES (No. see Table 1)	Spot and local scale	Regional scale	Interregional and national scale	International and global scale
PRODUCTIVE				
1.1	High	High	Medium	High
1.2	Medium	Low	Low	Undetermined
1.3	High	Medium	Medium	Undetermined
1.4	High	High	Medium	Low
1.5	Medium	Low	Low	Undetermined
ENVIRONMENT-FORMING				
2.1.1	Absent	Low, in perspective medium	Absent, in perspective high	High
2.2.1	High	High	Medium, in perspective high	Medium
2.2.2	High	High	Medium	Low or medium
2.3	High	High	High	Low
RECREATION				
4	High	Medium	Low, in perspective medium	Low, in perspective medium

ecosystems in the upper areas, to improve water quality. An example for this is the city of New York, which has invested to improve drinking water quality in the ES of the catchment area from which it receives its water (Chichilnisky and Heal 1998). Good experiences in this context were made also with water fund investments in Latin America (Natural Capital Project; e.g., Goldman-Benner et al. 2012).

Salzman (2005) pointed out that payments, property rights, prescription, persuasion, and penalties are ways to protect ES. We think that payments, property rights, and penalties are most economically, institutionally, and culturally appropriate in Russia recently (UNDP 2011).

Functions of the storage and binding of carbon are key ES for climate regulation on a global scale. Costanza (2008) refers to the intermediate ES "C-fixation" as a "global non-proximal service." The biggest threats to these ES in the terrestrial ecosystems of Russia stem from such anthropogenic disturbance of natural ecosystems as deforestation, peat extraction, the drainage of wetlands, mining, and fires.

The local population living in the region, which provides the bulk of "carbon"-ecosystem functions, is not only not in a position to compensate economically for the reduction of such effects on ecosystems; rather, it is usually on the contrary actually interested in an intensification of resource extraction, as this sector provides it with employment. For the companies extracting the raw materials, measures which provide for a reduction in impacts on ecosystems are simply an additional difficulty and an imposition. That means that in this case, the local population and the local economy basically have no interest in maintaining the global ES "Regulation of the carbon cycle." The only exceptions are the indigenous peoples who lead a traditional economic existence and are interested in the conservation of natural ecosystems; however, they concentrate on all other ecosystem functions, but not on carbon services. The international community must consider the consumers and beneficiaries of these ES; it is they who can create mechanisms to maintain it. Examples of such mechanisms are the Kyoto Protocol or the Convention on Biological Diversity. It is on this basis that the international markets for carbon regulation, such as the REDD+ program, have been established. If Russia wants to assume greater responsibility for improving the carbon ES, it would be quite possible to develop a national market for it. That means that in this case, in the absence of national and very limited access to international carbon market, the local population and the local economy basically have no interest in maintaining the global ES "Regulation of the carbon cycle."

The spatial scales of ES and their characteristics vary considerably in the regions of Russia, a factor which needs to be considered both in the analysis and evaluation of the ES and in the integration of their value in economic decision making. To solve this problem, it is necessary to counterpose the distribution of natural ecosystems and ES on the land to the factors of regional socio-economic growth that determine the main use of ES. The most important socio-economic factors are population density, the relative proportions of urban and rural populations, the predominant forms of land use (agriculture, industry, traditional natural use, etc.), the standard of living, and the willingness to innovate in the realms of environmental management and policy.

As stated above, the conversion of ecosystem potentials to ES occurs through the presence of consumers at the appropriate scale: global functions are always current and relevant; interregional ES are realized when the population or economy of a neighboring region (e.g., at a lower altitude) avails itself of such a service; and local ES are only used by local people (Costanza 2008; Fisher et al. 2009; Syrbe and Walz 2012; Bagstad et al. 2013). Figure 4 shows the great heterogeneity of natural and socio-economic conditions of the territory of Russia. The naturalness of regions is considered as a general index of the potential volume of ecosystem services. Percentage of natural areas in regions was defined on the map of terrestrial ecosystems of the North Eurasia (Bartalev et al. 2004). Ecosystems, identified on the map, were divided into two groups: "natural" and "anthropogenic." The "anthropogenic" group includes settlements, agricultural fields, and complexes of natural ecosystems (forests, meadows, steppes) and agricultural fields with a predominance of the latter. The "natural" group includes all other types of ecosystems. The area and percentage of "natural" ecosystems was calculated for all regions. The population density is considered as the general index of the used volume of ecosystem services. Population data by regions are taken from the Federal State Statistics Service of the Russian Federation (2012).

The major part of natural ecosystems and potential ES is located in the north and in Siberia (Fig. 4). These peripheral and sparsely populated areas are characterized by rural depopulation and land abandonment, or climates unfavorable for widespread human settlement. But the bulk of potential consumers are located in the more densely populated central and southern regions of the European part of Russia. Here, numerous competing use claims arise. This dualism has forced us to make decision to evaluate each service according to two indices: (1) the capacity of the service provided by ecosystems and (2) the actual use of ES (flow or demand/consume by people; Schröter et al. 2014). The proposed approach corresponds to the "cascade model" of ecosystem services (Potschin and Haines-Young 2011). The provided volume of ecosystem services

Fig. 4 Schematic comparison of supply and demand for ES in Russian territory (project TEEBi-RUS according to the data of the Federal State Statistics Service of the Russian Federation, 2012)

Table 4 Examples of provided and consumed volumes of environment-forming services

Ecosystem service (No. in Table 1)	Supply (provided volume)	Demand (indicator or consumed volume)
Regulation of variability of water run-off and reduction of damage from floods (2.2.1)	Reduction in variability of water run-off (reducing the probability of flooding) Reduction in flood zone	Prevented damage to human health and to economy
Purification of water by terrestrial ecosystems (2.2.1)	Soil protection and prevention of pollutions from land to water	Consumption of clean water by people
Cleaning of air by forests (2.1.3)	The volume of dust and toxic gases absorbed from air by trees (kg)	Prevented damage to human health and to economy
Protection of soils from water and wind erosion (2.3.3)	Reduction in the intensity of soil erosion	The gain of agricultural products, which is really obtained due to reduction in the intensity of soil erosion

corresponds to "final services," and the consumed volume corresponds to "benefits." The preliminary indexes for the provided and consumed volumes of several services are shown in Table 4.

TOWARD A NATIONAL ES REPORT PROTOTYPE

A goal of the TEEBi-RUS project is to develop the prototype of a National Report on ES Russia (Terrestrial Ecosystems). Built on the preliminary work described and in line with international studies (e.g., guidance manual for TEEB-country-studies, TEEB 2013), this is to include the following priorities:

- Assessment/description of ecosystems of Russia and their conditions (brief overview).
- An ES classification of Russia.
- A brief characterization of the basic ES of Russia, including: present condition; special characteristics on the territory of Russia; opportunities and challenges for the development of the evaluation system; and regional, national, and global importance.
- Natural and anthropogenic factors that affect the ecosystems; trends and changes in the ecosystems and ES.
- Approaches to scientific and economic methods for the valuation of ES in Russia, with sample reviews for particular services.
- The importance and value of ES for sustainable development in Russia and worldwide.
- The main principles of the Russian zoning process for rating ES and for the development of methods for the integration of their values in economic and decision making processes.
- Creation of reliable indicators to indicate the status and the development of ES over time; proposals for the development of a monitoring system for ES in Russia.
- Awareness raising of ES in society to avoid deterioration of ecosystems.
- Proposals for the development of systems of economic valuation of ES, and for mechanisms for the integration of these values into the economy and into the decision making process at various levels of management.

The data that are essential for the creation of such a National Report on ES can be classified into three groups:

- Data needed for the creation of maps of ecosystems in Russia in terms of their functionality.
- Data needed for the scientific evaluation of selected ES (assessment of ecosystem capacity or potential of ES provision).
- Socio-economic data needed for the evaluation of the distribution of demand for ES in Russia.

Analysis of the currently available data has shown that the best way to carry out a primary evaluation of ecosystem services is to assess them by the federal subjects of Russia. The main sources of data are:

- The public data base of the Federal Service of State Statistics (2012–2013).
- The international project "Land Resources of Russia" (2002, http://webarchive.iiasa.ac.at/Research/FOR/russia_cd/guide.htm)—e.g., maps of crops, types of cattle feeding, natural pastures, and evapotranspiration—provided by the Institute of Geography of Russian Academy of Sciences.
- The Satellite Map of Vegetation of Russia (2002–2005), provided by the Institute of Space Research of the Russian Academy of Sciences.
- Particular data bases and investigations (2005–2010)—e.g., the National Atlas of Soils, which shows the percentages of areas with eroded soils, or the Yearbook of Game Resources of Russia, with such information as a map of elk numbers by region.

During the first phase of the project, an expert-based assessment was carried out of the available and easily accessible data necessary for the creation of the prototype of the National Report, and data which might be of importance in coming years in connection with ES valuation in Russia (Bobylev et al. 2014).

Taking into account the limitation of available data at the moment, we chose a methodology for the preliminary assessment of services for the federal subjects of Russia in physical terms, which may in the future be transformed into economic indicators. The second decision is to assess each service according to two characteristics: the volume of a service provided by ecosystems and the volume of each service which is consumed by people. The simplest task is the valuation of productive services. For some, we have data permitting a direct estimation both of provided and consumed volumes (Fig. 5).

The most complex but also the most important is the assessment of environment-forming (regulatory) services.

The approach described permits several important tasks to be addressed: the evaluation of the degree of satisfaction of people's needs for ES, the identification of the ecological donor and acceptor regions (Syrbe and Walz 2012), and the zoning of the country's territory for ES assessment.

CONCLUSION

The rapidly increasing international assessment of the ES concept has also awakened the interest of scientists and policy-makers in Russia. In view of the continuing overexploitation and even destruction of nature and the services

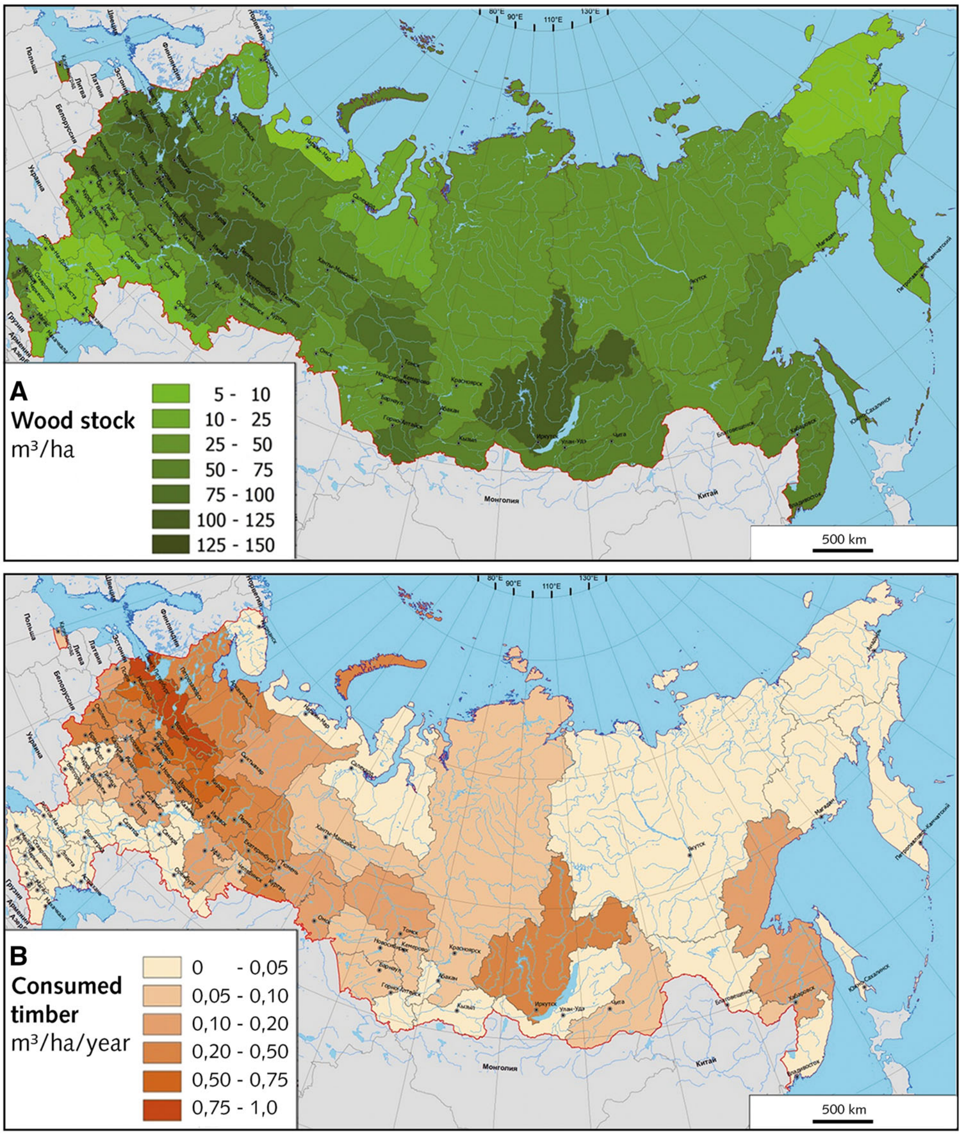

Fig. 5 Ecosystem service of timber production by natural ecosystems in Russia: **a** provided volume is estimated as wood stock, m^3/ha (in future, this figure should be specified as the allowed amount of the cutting forest area taking into account the growth rate of the forest); **b** consumed volume is estimated as timber production, m^3/ha/year (project TEEBi-RUS according to the data of the Federal State Statistics Service of the Russian Federation, 2012)

it delivers, the ES concept will only be successful if it refers to a major extent to the peculiarities of the ecosystems concerned. Especially integrated geosystem and landscape- and/or landscape planning-based approaches (Wende et al. 2012; Bastian et al. 2015) are relevant in a national context (e.g., for Russia, Antipov et al. 2006), as they link up with national scientific traditions and the specifics of the country, but others are also relevant in an international framework and are already being applied there, at least to some extent (e.g., Maes et al. 2014). This should be linked to the System of Environmental-Economic Accounting (SEEA) and Wealth Accounting and the Valuation of Ecosystem Services (WAVES) that aims to promote sustainable development by mainstreaming the value of natural capital accounting in development planning and national accounting systems (e.g., NU-IHDP and UNEP 2014).

We consider a further development and application of the ES concept in Russia as worthy of recommendation, since it could provide a common, systematic understanding of the benefits of nature from a number of different viewpoints. With German support, a Russian working group, with the Status Quo Report, has laid the foundations for a national ES processing system (Bobylev et al. 2014). The basic approaches and work have been presented in the article.

Due to the size and heterogeneity of the country, with its ecosystem diversity and its multi-layered administrative system, and due, too, to the numerous socio-economic reforms, e.g., remodeling of the structure of authorities and institutions currently being undertaken, this is not an easy task. The primary focus must be on capacity-building, on the identification of the main tasks, problems, and blind spots, on the selection of ES, and on problems of scale and data. It has already been possible to implement preliminary classifications and data evaluations, and—in view of the tight project budgets—simple overview-like assessments and maps.

According to the TEEB approach, the primary issue, in Russia as elsewhere, is the recognition of the values of nature, their presentation—including in economic categories, in order to support decision making—and the ascertainment of these values in the context of mechanisms and instruments designed to include ecosystems in decision making processes. One such value, for instance, is the high net contribution of Russia to global environmental quality and climate regulation, which needs to be adequately quantified and communicated. But this also includes addressing accumulated and current environmental problems. The awareness in the Russian public in this respect, and its willingness for active process participation, varies widely. The results of ES assessment could, as an information and communication tool, lead to an improvement in human–environment relations.

The development of a "TEEB Russia", with comprehensive national assessments and the chance of implementation in Russian and international policy, ensures a huge but rewarding challenge for the coming years. At issue is a perspective on the specific properties of ecosystems in Russia and the services they can provide for the future design of policy measures. For this purpose, the next step will involve the further development of a framework methodology and an indicator system, taking international standards and specific Russian conditions into consideration.

The goal is to prepare a prototype of the National Report—first of all on terrestrial ES. The project is the first in Russia with the goal of assessing ES at the national level. An analysis of the currently available data has shown that the best way for a primary evaluation of ES is to assess services for and/or by the federal subjects of Russia, primarily in physical terms, which in future can be expanded to economic indicators. Russia should play a more important role in the international ES debate, since the ecosystems and ES of Russia are of global importance, and Russia has both significant scientific traditions and great resources.

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