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Connecting biodiversity and human dimensions through ecosystem services: The Numto Nature Park in West Siberia

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Abstract An assessment of the socio-ecological system of the Nature Park “Numto” in West Siberia was carried out based on ecosystem services (ES) mapping, applying a “cascade approach” which was modified according to the specific conditions of low commercial land-use by Indigenous Peoples and adopted with a focus on making it practicable and understandable by decision-makers. The ES values were defined through stakeholder analysis, while the mapping was based on the biophysical traits of the ecosystems and related spatial distribution of ecosystem functions. The mapped ecosystem values differ from the perceived ones. The assessment identified conflicting land uses and groups of stakeholders, including Indigenous Peoples vulnerable to future climate change-induced deficits in access to ES. The ES that are important for climate change mitigation and adaptation are not valued highly by Indigenous Peoples. ES mapping is suggested as an appropriate method for the development of straightforward recommendations for Nature Park management.

Keywords Ecosystem services · Indicators of ecosystem functions · Indigenous People · Land-use · Mire · Socio-ecological systems

INTRODUCTION

The concept of ecosystem services (ES) came to prominence almost 20 years ago as a way of integrating biodiversity management and conservation issues into land-use policy (Costanza and Folke 1997; Costanza et al. 2017). However, the practical application of the ES concept still has only a vague theoretical background and no clear methodological guidelines, although many related projects have been implemented (Bouma and Van Beukering 2015). Most progress in bringing together land use regulation frameworks and the ES concept comes from Australia, the United States, China, the UK and EU countries. The latter were requested to map ecosystem services on a national level in line with Target 2 of the European Biodiversity Strategy (European Commission 2011), which initiated the task of integrating the ES approach into economic regulation frameworks.

The ES concept has not so far been implemented widely in Russia, but could have the following applications: strategic impact assessment of development projects (Hanson et al. 2012), including ES based cost–benefit analyses (Markandya 2016); integrative environmental impact assessment (Vorstius and Spray 2015); spatial planning, zoning and prioritisation of territories for conservation; assessment of ecosystem restoration projects (e.g. Tolvanen and Aronson 2016; Gann et al. 2019); integrating ES in monitoring, reporting and verification (MRV) algorithms in climate-related projects (Joosten et al. 2015), as well as incorporating ES into an organisation’s performance disclosure (Hanson et al. 2012); development of market mechanisms (Silvis and van der Heide 2013), including eco-compensation (Yu et al. 2019) or fiscal based-regulation and tradable permit schemes (e.g. Ring 2008; Droste et al. 2019).

West Siberia is a good starting point for introducing the ES approach into the practice of economic regulation and governance. On the one hand, West Siberia is recognised worldwide as hosting vast areas with natural biodiversity and as a home to large groups of different Indigenous Peoples, partly maintaining their traditional lifestyle

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(Callaghan et al. 2021). On the other hand, over the course of several waves of land-use expansion in Siberia (Savelieva 2007), there were significant losses of biodiversity, ecosystem functions, and the capacity of ecosystems to maintain the traditional land uses (Tishkov and Shekhovtsov 2014). The socio-ecological systems (SES sensu Berkes et al. 1998) in West Siberia are rather complicated. The stakeholders involved are Indigenous communities which depend directly on the natural resources, local communities formed by migration waves of different periods and origins, and seasonal workers associated with oil and gas businesses. The top-down governance system built up over the past twenty years aims to manage and regulate all actors; however, it has not been successful in fostering a market economy (Hill and Gaddy 2006).

The landscapes are dominated by mires and water-logged forests—perceived as having low biodiversity (Minayeva and Sirin 2012) and considered by a number of experts as a source rather than as a sink of greenhouse gases (Frolking et al. 2011). The latter is the result of an oversimplified interpretation of the regulatory functions of peat-dominated landscapes and is still under examination (e.g. Günther et al. 2020; Kirpotin et al. 2021).

Land-use planning in Siberia requires an integrative ES based approach, which brings together biodiversity with related ecosystem functions and human dimensions, based on a scientifically sound methodology that can be easily transformed into practical recommendations or simple algorithms. The changes in the access of different groups to ES could be a clear integrative indicator in the national reporting (sustainability, climate change adaptation and mitigation, biodiversity) and risk management by large corporations.

The Russian national assessment of ecosystem services (Bukvareva et al. 2015) was carried out using The Economics of Ecosystems and Biodiversity (TEEB) methodology (Wittmer et al. 2013). The study presents an inventory of ES in Russia, including the West Siberian region and ES spatial variation at the national level. The research brings together valuable information but is not applicable directly for land use planning at the site level for two reasons. Firstly, the TEEB Russia assessment is very general and relates to national level reporting only. Secondly, and especially for West Siberia, the peatland-dominated landscapes have specific features which complicate the direct application of the methodologies recommended by TEEB (Sirin et al. 2010; Bonn et al. 2016).

The goal of our research is to find a way to implement the ES concept in Russia for land use improvement under conditions of climate change. The related tasks of the study are: to adopt the ES mapping cascade method for a site-focused ES assessment understandable by decision-makers and apply it to describe the pilot SES within a nature-protected area; to identify the ecosystem functions (EF) vulnerable to changes in land use and climate; to identify the groups of stakeholders vulnerable to the changes to ES access; and to designate ES important for climate change mitigation and adaptation.

THEORETICAL FRAMEWORK

The following terms and concepts are in use for this study. Biophysical traits (characteristics) of ecosystems—are specific biotic and abiotic parameters unique for ecosystem types that combine biological and physical structural features such as vegetation, hydrography, relief, and climate, among others. Ecosystem functions (EF) are considered as the ecological processes that control the fluxes of energy, nutrients and organic matter through an environment that are specific for the exact ecosystem type. The ecosystem biophysical traits determine as well as indicate the potential of the ecosystem type (land class) to perform the relevant EF, as presented, for example, by Wong et al. (2015). Ecosystem services (ES) are the benefits that stakeholders get from the functions performed by ecosystems.

Many studies addressing ES mapping use the "cascade" approach (Haines-Young and Potschin 2010) to evaluate ES. The method was heavily criticised by Costanza et al. (2017) for simplifying the processes. The steps of the cascade are land cover classification, describing biophysical traits of the ecosystem types, assigning EF and their values to the land cover units, interpretation of EF to ES, and interpretation of the spatial distribution of ES values within the site. Simplification and the use of understandable algorithms are useful ways to communicate the ES concept to the broader public and integrate it into practice (Fischer and Eastwood 2016).

We applied several assumptions in our study, including a simplification of land cover classes and identification or predicting of EF through an analysis of biophysical traits.

The modifications to the method are:

1) The value of an ES was determined not through the market price of the benefit derived from the ES, like in the classical cascade method, but through stakeholder analysis.
2) The ES were organised in bundles related to the resources sectors rather than the Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin 2017). Each ES was assigned to one of the three bundles "biota", "soil" (including minerals), and "water", similar to how sectoral land use management in Russia is organised. This makes the exercise more understandable for Russian users who are not dealing with the ideal

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concept of ES, but with coherent biophysical parameters.

Generally, the flow of our study is not as linear as a standard cascade but still follows its logic.Such a transformation of the cascade from linear to circular, when applied to SES, was also described by B. Reyers et al. (2013). The ES flow in the absence of ES markets demonstrates pluralistic connections when decisions are driven mainly by the local needs and ecosystem qualities, and in some cases, by policy and market. For example, the decision-maker will react to data on water pollution rather than to the increased price of fish.

MATERIALS AND METHODS

The study area

The method of ES based SES assessment was tested on the Numto Nature Park, a protected area in West Siberia. In line with Russian legislation, limited land use is allowed within the borders of Nature Parks (Danilina et al. 2016). The Numto Nature Park, with an area of approximately 6000 km^2, is located in the centre of the West Siberian Plain (63.5° N, 71.4° E) on the northern slope of the Siberian Hills, where the major West Siberian rivers Kazym, Nadym, Pim and Tromyogan originate (Moskovchenko 2017). Lake Numto (translated from Nenets as "Celestial Lake") at the south-east of the area is sacred to the local community of Indigenous People (Forest Nenets and Kazym Khanty).

The study area lies in the temperate taiga zone. Despite being continental overall, the climate shows a relatively high mean annual precipitation (550 mm), one-third of which falls in winter. The frost-free period lasts 100 days. The long-term mean annual temperature is − 6 °C; the absolute minimum temperature for January was − 56 °C, the absolute maximum of July + 34 °C (1958–1991). Permafrost has a sporadic distribution (Yershov 1989).

Flat and slightly convex waterlogged watersheds with mineral islands and ridges dissected by river valleys predominate within the Poluy Upland (80–100 m a.s.l.). The southern part of the area belongs to the Siberian Hills (150 m a.s.l.) and has a topography of undulating uplands with an amplitude of vertical dissection of 15–20 m. Three-quarters of the park's territory consists of inland lakes, ridge-hollow raised bogs, plateau-like flat palsa mires with frozen mounds and sparse high-mound palsas with signs of progressive degradation. Mesotrophic mires, meadows and Siberian pine forests are associated with floodplains. Common pine forests and deciduous serial forests of post-fire succession occupy all sand ridges and uplands (Fig. 1).

Fig. 1 An image of the typical landscape in the central part of the Numto Nature Park (photo by Ilya Filippov): 1 and 2—the hollow-ridge and hollow-pool-ridge parts of raised bogs; 3—forested pine dwarf shrub peatlands (ryam); 4—mesotrophic herb-tall-sedge moss mires along the oxbows and at marginal swamps; 5—pine-lichen forests on dry sands; 6 – the valley needle-leaf forest; 7—aapa-mires; 8—flat palsa mires with pools

The Numto Nature Park has experienced land-use conflicts since it was established in 1997. Almost a quarter of this regional nature protected area is assigned for oil and gas plots leased to the company *Surgutneftegas* LTD. Around one-fifth of the area is officially tenured to families of Indigenous People. The stakeholder analysis helped to identify several fundamental conflicts of interests: between oil and gas industry and traditional land use; between both of named land-use types and maintenance of ecological features of the Natural Protected Area, especially as habitats of migrating waterfowl; and inside the Indigenous People communities between "progressives" and traditionalists, as well as between the community of Numto village that has no land tenure and families in the northern part of the Nature Park who has benefited from the land tenure. The conflict analysis was carried out simultaneously with the current study on ecosystem services and was published earlier (Pristupa et al. 2017; Tysiachniouk and Olimpieva 2019). Both the conflict analysis and our current study were used to develop and propose to the Nature Park Administration several scenarios for zoning of the Numto Nature Park.

Identifying and mapping land classes, land-use changes, ecosystem biophysical traits and ecosystem functions

To identify land classes, we used the mapping scale of 1: 500 000 to match the large pilot area size (600 000 ha) and to contribute to the task of protected area management

Table 1 Examples of direct links of ecosystem biophysical traits (indicators) and ecosystem functions (EF)

Biophysical trait (indicator)	Ecosystem function	Direct/indirect indication
Some rare and endangered species from the entire species list	Maintain populations of rare and endangered species	Direct
Some provisioning plant species from the entire species list	Maintain populations of provisioning plant species	Direct
Emission factor of the ecosystem type in line with IPCC or other data	GHG sink/source, climate change mitigation potential	Direct
Soil texture; position on the slope; organic layer/peat layer presence and depth	Resilience of ecosystems to physical damage	Indirect
Soil texture; position on the slope; organic layer/peat layer presence and depth, presence of permafrost	Protect permafrost	Indirect
Primary production, soil organic carbon content, position on the slope	Carbon/matter accumulation	Indirect
The presence, cover and primary production of reindeer moss (*Cetraria islandica);* soil texture	Maintain the reindeer population	Indirect

planning. The appropriate mapping units are ecosystem types with a size of 10^2–10^6 m^2. The landscape unit at this spatial level is called "microlandscape" (Larin 1926). It is also used for the classification of mire landscapes (Galkina 1946) and is known in technical English as a "microtope" (Joosten et al. 2017). The land classes interpreted as "ecosystem types" presented in the results section were designated based on the vegetation map, landscape map, soil map, satellite images and verified by ground truthing.

The list of biophysical traits and their values depending on the ecosystem types were derived from field and desk studies carried out between 2004 and 2016, including field soil studies, inventory of transformed land areas, floristic and faunistic surveys and 500 complete geobotanical relevés carried out by the authors and supplemented by a literature study (Appendix S1, S7). The biotic characteristics of land classes include a complete geographically attributed list of vascular plant, bryophyte, lichen, fish, bird and mammal species, with special attention to those which are rare and endangered, migrating species, species unique for particular habitats and provisioning species, annual biomass of the ecosystem associated with the land class (Appendix S6—Table S1). The abiotic characteristics include soil texture, type and depth of organic layer other than peat, presence and depth of peat, organic carbon content in the soil, position at the slope and its steepness, presence or absence of permafrost, and greenhouse gases (GHG) emission factors of land classes.

Over the course of the desk study, a GIS was compiled, including ninety layers and a meta-database of published sources and unpublished reports on ecosystem monitoring provided by the Nature Park Numto and *Surgutneftegaz* LTD. As a result, we prepared a list of ecosystem biophysical traits, and every land class got a fixed value of every biophysical trait characteristic (Appendix S6—Table S1). Further, the measured values were converted to a linear 5-point scale (Appendix S3) using the Min–Max Stretch method (Schowengerdt 2006). The connections between ecosystem biophysical traits and EFs were identified by causal non-statistical analysis. The connections are both straightforward (one biophysical trait—one function) or could be derived from several ecosystem biophysical traits based on an integrative analysis (Table 1). The EF indicator value for every land class formed the basis for the vector maps with polygons showing values of EFs indicator or their combination at the scale from 1 to 5. The land-use change rate in the Nature Park Numto was assessed by comparing the area and spatial distribution of the industrial disturbances based on the 2011 and 2018 satellite images (Moskovchenko et al. 2020). The climate change rate was retrieved from the literature analyses.

Identifying stakeholders and their connection to EF and ES

The stakeholder analysis included three phases: a desktop study aimed at identifying stakeholders and analysis of demographic, ethnographic, and socio-economic information; a field study focused on interaction with all stakeholders and collection of qualitative data; and analysis of the obtained data. The study followed the methodologies of Devyatko (1998), Kovalyov and Shteinberg (1999), Tolstova and Maslennikov (2000), Schwarz (2007), Sheynov (2010).

Stakeholders were divided into two large groups: primary (affected) and secondary (interested). The "affected" stakeholders are Nenets and Khanty Indigenous Peoples settled within the Numto Nature Park borders and whose

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livelihoods and ethnocultural identity are directly related to the status of the surrounding ecosystems. The objective of the study of this stakeholder group was to identify the vulnerability of the “affected” stakeholders to the changes of the ecosystems of the Numto Nature Park. In total, the local community was comprised of 212 people. The interviews with Indigenous Peoples were conducted during two field expeditions and included face to face interviews with two community leaders and 12 community members and winter visits to nine from 25 ground reindeer herding camps in which key community leaders accompanied researchers. Indigenous People pointed out by schematic drawings places of traditional land use: pastures, fishing sites, and places of cultural heritage. This visualisation and in-depth open-ended stories highlighting the use of natural resources helped to identify the specific connections of the affected stakeholders to EFs.

The study’s objective focused on “interested” stakeholders was to identify a connection between stakeholders and ecosystem functions and the relative value of ecosystem services. A list of secondary stakeholders at the district, subnational, national and global scale was generated based on the analysis of stock sources and public information on the Internet. With 40 representatives, the interviews were set up. For each group of secondary stakeholders, an “information package” was formed. The data collected were analysed in two ways: the “content analysis” and the “analysis of the semantic core” of the information packages. The material obtained made it possible to identify a list of the most relevant ES for each secondary stakeholder type and to identify the risks associated with the possibility of losing access to such ES due to land use and climate change. The details on both primary and secondary stakeholders’ interview methods and outcomes are presented in Appendix S2.

Ranking of ecosystem functions against stakeholders’ interests in ecosystem services

The stakeholder survey data were formalised and used for transforming ES values to land class values. The outputs of both stakeholder survey and biophysical ecosystem traits causal analysis included a list of stakeholders, a list of ES, a matrix connecting stakeholders to ES, a matrix connecting EFs and ES. From these four data sets, we derived the following SES features: number of interested stakeholders per ES (the weight of ES for stakeholders); the number of ES per stakeholder (the dependence or vulnerability of stakeholders); the number of ES per EF (the weight or relevance of EF) and finally, the value rank of every land class (Appendix S4). The primary data are provided in the supplementary materials (Appendix S6, Table S1). The potential land-use conflicts are indicated by the ratio between the number of EF supporting the ES and the number of stakeholders interested in these ES. Technically, the data obtained do not provide the possibility of assigning ES values to the land classes. Instead, we used the EF for each land class, adjusted based on the weight of the stakeholder analysis (Table 2, and Appendix S6—Tables S1–S4).

Table 2 List of ecosystem functions and their weight for stakeholders

Ecosystem function	Number of supported ES	The summed-up weight of ES for stakeholders
Water retention and storage	23	14.12
Ecosystem primary production	21	11.29
Capacity for permafrost protection	15	9.47
Habitat for plant species	14	7.41
Peat accumulation capacity	13	8.47
Habitat for mammal species	10	5.59
Water discharge capacity	10	6.76
Suitable habitats for fish	8	5.12
Habitat for migrating waterfowl	8	5.12
Habitats for reindeer moss	8	4.41
Habitats for other provisioning plant species	8	4.24
Matter accumulation capacity along with the position on the slope	8	5.65
Matter accumulation capacity along with soil texture Gradient from light to heavy	8	5.65
Water purification capacity	8	5.29
Habitats suitable for Siberian pine	7	4.24
Habitat of rare bird species	6	3.71
Habitat of sedentary bird species	5	2.88
Habitat of the endemic bird species	5	3.12
Habitat of rare plant species	5	2.88
Habitat of hunted mammal species	5	2.41
Soil organic carbon accumulation, other than peat	5	3.47
Habitat of rare mammals	4	2.12
Habitat for endemic plant species	4	2.29
The capacity of ecosystems to be sink or source of GHG	4	2.59
Habitat for hunted bird species	3	1.41

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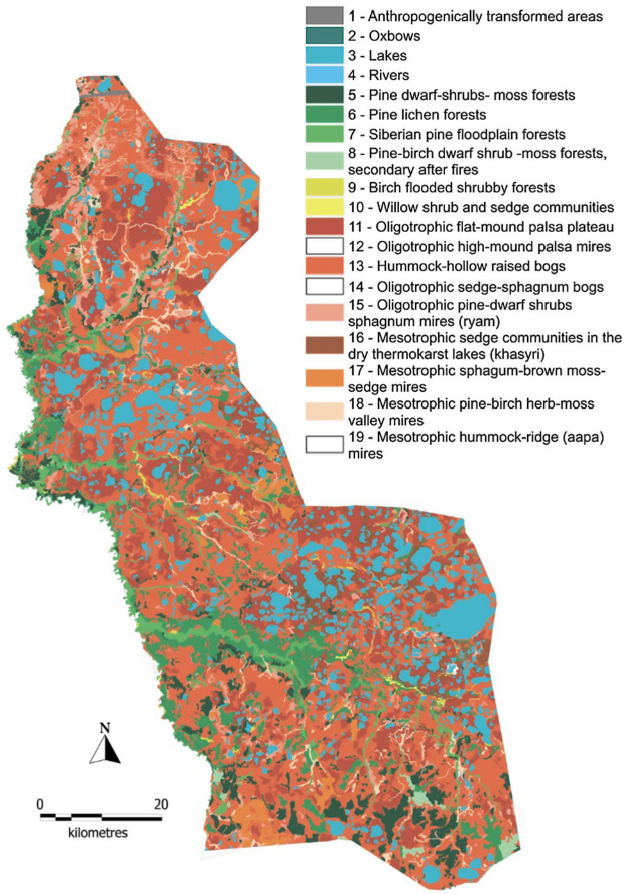

Fig. 2 The land cover map of the study area based on the ecosystem types at the spatial level of microtope

RESULTS

Ecosystem biophysical traits and functions of Nature Park Numto

The nineteen land classes included one class of the anthropogenically transformed technogenic areas, three types of water bodies, and fifteen vegetation classes grouped in forests, transition vegetation types and mires or peatlands (Fig. 2). Mires dominate the landscape (80% of the study area) and present the largest ecosystem diversity. One-fourth of the mires' area have permafrost.

The 25 EFs designated by causal analysis are listed in Table 3. The spatial distribution of ecosystem functions indicator values shows the limited distribution of the areas with high value for biodiversity conservation (only 3% with rate 5), and quite common are ecosystems with the medium value for biodiversity (60% with rate 4). 47% of the map polygons have the highest rank of value for soil-related functions and almost 60%—the highest rank of water-related EF (Fig. 3 and Appendix S6).

Connection of stakeholders to ecosystem services

The study had designated seventeen types of stakeholders for the Numto Nature Park area that are listed in Table 4, along with the level of their dependence on the ecosystem services (direct and indirect) as retrieved from the stakeholder analyses. The number of ecosystem services derived from interviews and desk studies reached twenty-seven out of 29 ES identified by the causal analysis. Of them, 16 are provisioning, eight are regulating, and five are cultural. More than half of them relate to two sections, for example, provisioning and cultural (Table 3). Many local stakeholders do not perceive land use-based greenhouse gas emission as an important issue.

Among "interested" stakeholders (16 types), two groups only have livelihood-driven connections to the Nature Park ecosystems—the local communities (other than Indigenous People) and local small businesses based on natural products (mainly Siberian pine nuts, berries, fishing etc.). All other groups have either institutional (various administrations), logistical (oil and gas businesses and related actors) or spiritual/cognitive (scientists, education sector, youth and children, tourists) connections to the ES of the Nature Park. International involvement of the Multilateral Environmental Agreements (MEAs) derives from the interest of the Ramsar Convention on Wetlands to the area and the presence of the INTERACT research station Mukhrino in the region. The interested groups have clear incentives for both the maintenance of the Nature Park ecosystems and the development of oil and gas fields within the Nature Park.

Indigenous communities (Nenets and Khanty) as primary stakeholders depend heavily on changes in access to ecosystem services. Traditional land use is based on biota-related ES and supports the provisioning needs of the Indigenous communities and cultural values. A small share of the working-aged population, a large share of unemployed and retired people, and the limited labour market make traditional provisioning land use a critical area for self-employment for Indigenous People. It is true for other locals of the surrounding settlements, even though most of them have basic jobs. Many people expressed concerns about the possible loss of ecosystems and displacement of Indigenous People due to the fact that the Nature Park zoning allows operations by extractive industries.

However, the Indigenous communities are a non-homogeneous stakeholder group. They differ in the land-use activities' preferences: reindeer herding, fishing, hunting, and ethnic tourism. The conflicts between some traditional uses themselves and with the biodiversity conservation objectives were detected and described. For example, the usual practice is to direct the reindeer herds to the nesting areas of migrating waterfowl species for eating eggs which

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Table 3 List of ecosystem services and their relation to stakeholders and ecosystem functions

Ecosystem services:	CICES section and division*	Number of stakeholders	Weight of ES	Number of EF, supporting ES	Rate number of EF/number of stakeholders
Landscape stability	RA	15	0.88	8	0.53
Ecosystem-based climate change adaptation	RB	14	0.82	14	1.00
Local water purification	RA, PA	14	0.82	7	0.50
Infrastructure security	RA	13	0.76	7	0.54
Habitats for migrating waterfowl	RB, PB	13	0.76	6	0.46
Historical and cultural places	C	13	0.76	3	0.23
Value for conservation	RB, C	13	0.76	17	1.31
Local water supply	RA, PA	12	0.71	7	0.58
Local fishery	PB	12	0.71	6	0.50
Attractiveness for environment tourism	C, PB	12	0.71	17	1.42
Attractiveness for active recreation	C, PB	12	0.71	14	1.17
Local flood control	RA	11	0.65	6	0.55
Capacity for oil and gas production	RA, PA	10	0.59	8	0.80
Maintenance of habitats for hunted birds	PB	9	0.53	5	0.56
Hunting of large herbivores	PB, RB	9	0.53	4	0.44
Hunting of large predator mammals	PB	9	0.53	5	0.56
Game for fur hunting	PB	9	0.53	2	0.22
Mushroom picking	PB, C	9	0.53	5	0.56
Pine nut harvesting	PB, C	9	0.53	3	0.33
Reindeer herding	PB, C	8	0.47	6	0.75
Timber harvesting	PB	8	0.47	3	0.38
Holy and sacred sites	C	8	0.47	7	0.88
Ecosystem-based climate change mitigation	RB, RA	7	0.41	9	1.29
Berry picking	PB, C	7	0.41	4	0.57
Medical plant harvesting	PB, C	7	0.41	5	0.71
Maintenance of global biodiversity	RB, C	6	0.35	13	2.17
Haymaking for winter fodder	PB	6	0.35	3	0.50
Birch bark harvesting	PB, C	6	0.35	2	0.33
Maintaining an traditional lifestyle	C, PB	5	0.29	16	3.20

*Sections: R—regulation, P—provisioning, C—cultural; Divisions: A—abiotic; B—biotic

contradict the interests of hunters and global biodiversity conservation needs. The families specialising in fishing are interested in better roads and transportation possibilities for reaching markets that contradict herders' interests.

More than that, the Indigenous People are part of the benefit-sharing arrangements of the extractive industries (Petrov & Tysiachniouk 2019; Tysiachniouk et al., 2020). Several families in the northern part of Nature Park formally established their land tenure rights, allowing them to receive direct monetary compensation from the oil and gas companies using the land. This group is more open to allowing companies to operate on their land. The inhabitants of Numto village and of the southern part of the Nature park have no such rights. The interviews documented differences in behaviour preferences within Indigenous Peoples' communities, for example living in the village or maintaining the nomadic lifestyle; accepting modernisation (electricity) or not; the level of dependence on nature's spiritual connection.

Ecosystem Services analysis

According to the analysis, the ES, which are most in-demand but with the fewest sources (Table 3) include biodiversity of global significance, capacity for ecosystem-based climate change adaptation and mitigation, attractiveness for environmental tourism and active recreation. Several ES, like the hunting of fur species and large herbivores, haymaking, pine nut harvesting, local fishery, and maintenance of historical places, are limited to specific

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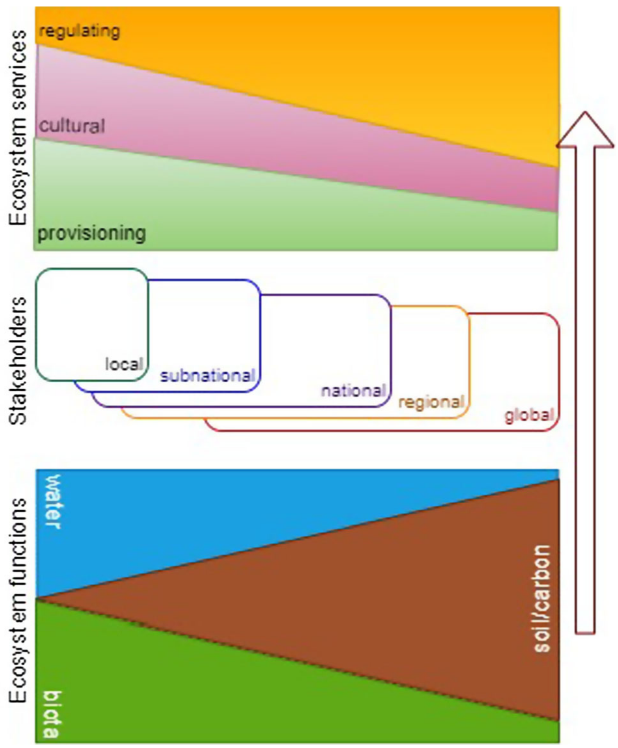

Fig. 3 The perception of EF resource-focused bundles and ES bundles by stakeholders at every level

sparse land classes. The formal assessment of ES vulnerability demonstrates that the "maintenance of the traditional lifestyle" as an ecosystem service is supplied from multiple ecosystem function sources hence is sustainable in the absence of the industrial impact. The analysis of resource-focused bundles demonstrates that ES demanded by stakeholders depend on biota and partly water-related EF (Fig. 3). Stakeholders demand is the main modifier for biota-related EF indicators (Fig. 4, Appendix S5). The stakeholder analysis shows that biota-related EFs are evaluated much higher by most of the stakeholders. However, the importance of water and especially soil-related EF, are not adequately recognised by stakeholders (Table 3). It is evident from the number of stakeholders who are interested in the services connected to water and soil. They are lower than those for biodiversity-related services.

Changes in land use and climate

The area of industrial affected lands of the Nature Park, which was 436 ha in 2011, more than doubled in 2018 (Moskovchenko et al. 2020). The length of roads and pipelines increased 5.7 times, reaching 235.6 km. Most of the disturbed areas in 2018 were hydro-pits with adjacent water bodies and production well pads. Adverse processes leading to landscape degradation (erosion, waterlogging, deflation) in the adjacent areas are rarely traced. They are limited to waterlogging of roadside strips and on-site depressions due to flow disturbance. The waterlogging area was 16 ha (3.6% of total disturbance area) in 2011 and 5 ha (0.6%) in 2018. Mineral contamination of the surrounding area due to washout and airborne transport of soil from pile foundations is low. As of 2018, landscapes with completely disturbed vegetation cover occupy 0.4% of the area of developed fields, while burnt areas occupy 1.3%. The disturbance area under linear objects (transport corridors) is estimated at 4.7 km^2 (0.4%). Thus, 0.8% of the studied area are covered by ecosystems transformed by land grabbing in which the pyrogenic disturbances cover a larger area than the industrial ones. Most disturbances are concentrated in the southern part of the protected area.

Climate change is reflected in the slight increase of the average annual air temperature by 0.35 °C/10 years (StD = 0.7) over the period 1940–2020 (Menne et al. 2012), while for the entire West Siberia, it is 0.74°C/10 years (Katsov 2017). The land classes most vulnerable to the air temperature rise include oligotrophic flat-mound palsa plateau and oligotrophic high-mound palsa mires (Fig. 2), covering 20% of the Nature Park area. They are also of high value for reindeer pastures, hosting habitats of lichens (Appendix S1—Table S6).

DISCUSSION

Formal and perceived assessment of ES

The dominance of mires in the landscape of the Numto Nature Park defines the area's specific biophysical traits. The species biodiversity within the area is low, while the significance of regulating EF connected to water and soil ecosystem components is high. As usual in peatland-dominated landscapes, every significant impact of the development projects in the area will have feedback to the climate by losing stored carbon as dissolved organic matter and emitted greenhouse gases. One-fifth of the area has frozen mire types, which are themselves vulnerable to climate change. However, the perceived value of ES gives preference to biodiversity. The list of ESs retrieved from the interviews is quite comprehensive in this study due to the wide range of actors involved. Some stakeholders in the current survey raised ES that other stakeholders were unaware of, such as ecosystem-based climate change mitigation and adaptation.

The value of biota-related EF doubled after evaluation in line with the ES assessment reflecting a high demand on these services from many stakeholders for various reasons. In contrast, the water and soil-related functions got lower evaluations from most of the stakeholders. The difference

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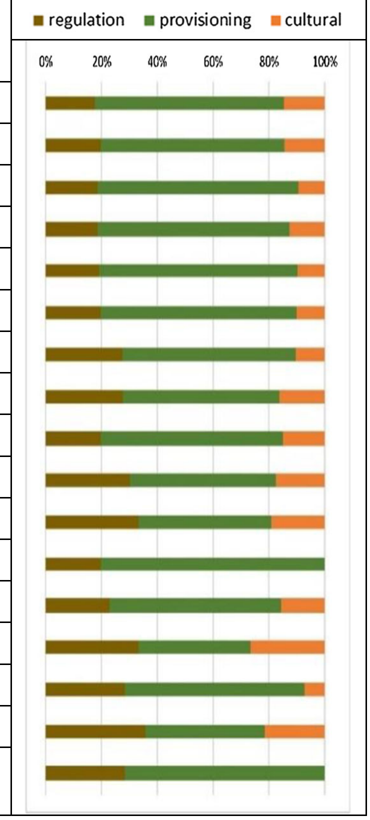
Table 4 The list of stakeholders and their relation to ecosystem services

Stakeholders	Number of ESs demanded by stakeholder	Stakeholder weight in ES demand	The part of ES section bundle in the stakeholders' interests
Indigenous communities	27	0.93	
Regional/subnational administration	27	0.93	
Other local communities	25	0.86	
Local administration/municipalities	25	0.86	
Local small business	24	0.83	
Inhabitants of towns/settlements in the area	23	0.79	
Regional branches of Federal Administration	20	0.69	
Children and youth	17	0.59	
Connected remote business	16	0.55	
Large business (extractive)	15	0.52	
Scientists, conservationists, local teachers	13	0.45	
Poachers	12	0.41	
Tourists	10	0.34	
Multilateral environmental agreements	10	0.34	
Local employees of industry	9	0.31	
Federal Administration	9	0.31	
Seasonal workers in the industry	5	0.17	



between formal and perceived valuing of the landscape explicitly shows the risk of simplified assessments of nature areas based on biophysical features or stakeholder analysis only. The integrative approach is therefore important.

Land management based on ES assessment

The high ranks of biota-related EF highlighted in this study through ES evaluation is not currently integrated into the land-use decision-making scheme. The formal way of taking into account the biodiversity values for oil and gas companies is based on rare and endangered species' presence, which is not a characteristic feature of mire landscapes of West Siberia. From our evaluation, it is clear that the most significant value of biodiversity in the area is in the maintenance of provisioning ES for Indigenous Peoples and local communities. However, the oil and gas business has other than ecosystem conservation ways to compensate losses in provisioning ES. The oil and gas companies policy have designed a way that Indigenous Peoples benefit both directly and indirectly, over the short and long term, from industrial development. Eventually, many locals indirectly support the destruction of the ecosystems. As mentioned above, some land-use practices of Indigenous Peoples are harmful both to biodiversity and regulation EF of the area. Even though Indigenous People understand that the area's value is in biodiversity, they are not ready to change their land use.

All this contributes to the complexity of relations between ecosystems types, EF, ES, and stakeholders, causing multiple deviations from the bilateral connections favourable for modelling and decision making. Ecosystem disturbance and losses in ecosystem functions due to climate change are already taking place in the Numto Nature Park and are a real but not well-understood threat to local

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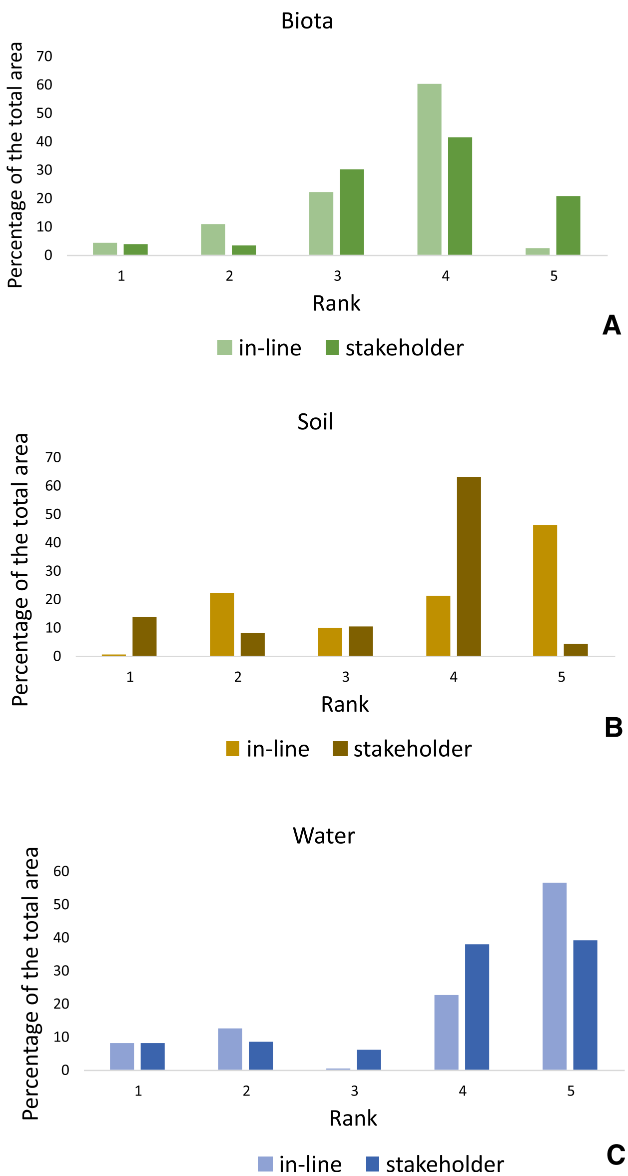

Fig. 4 The percentage of the Numto Nature Park area covered by land classes assigned to the ranks in line with the EF indicators' values only (left bar) and based on the EF values weighted by the results of stakeholder analysis (right bar). The EFs are within the bundles related to biota (**A**), soil (**B**) and water (**C**)

communities. The straightforward management based on the ES assessment could be a solution to address the maintenance of the ecosystems, which is beneficial to a wide range of stakeholders.

The assessment of the Numto Nature Park SES

The formal identification of conflicting ES and land uses and prioritisation of areas in line with vulnerability and value for ES maintenance could be a key for better SES management. The transformed and simplified assessment method allowed us to describe the characteristics of the SES of Numto Nature Park as a background for further decision making. The wide range of stakeholders (17 types in total) in such a remote area is a result of diverse and polarised economic sectors like traditional land use by Indigenous People and extractive industries and involvement of the International Community through the conservation and scientific networks. The engagement of the MEAs, the federal government, subnational administrations and large corporations reflects the recognition by some stakeholders of the importance of climate change adaptation and mitigation related ES. Maintaining the soil carbon and water balance will also increase among local communities as the impact of climate change progress. However, the formal description of SES, which highlights the significance of regulating ES, could help to make land-use decision-making straightforward.

The simplified cascade approach suggested in this research could be a possible algorithm for studying SES in Russia. The application of the method, however, demonstrated some trade-offs. The study was faced with gaps in biophysical data. The habitat specificity concept of Wagner and Edwards (2001) could have been used to fill these gaps, but the non-random sampling structure did not allow this. The biophysical data, in many cases, rely on literature data about the connection of ecosystem traits with ecosystem types. In our case, the biophysical data quality was not a bottleneck due to the large area. Generally, the situation with data will be similar in many parts of Russia. Very detailed and long-term data are available for some areas, while only limited sectoral information is available for others. The methodology of statistically-based predictive mapping of biophysical traits could be part of the ES mapping algorithm.

CONCLUSIONS

According to the Numto Nature Park's assessment based on biophysical traits, every land use in this peatland-dominated area could be harmful to global climate due to the land-use induced GHG emissions. At least one-fifth of the area has frozen peatlands vulnerable to climate change. The area also has other global roles, playing a crucial role in maintaining biodiversity and global waterfowl flyways. However, the stakeholder-based ES analysis reports that most stakeholders do not recognise the global significance of the area. The connected regulating ES are supplied by a limited number of EFs and are threatened. Most of the stakeholders highly value biodiversity-related ES, which also support the Indigenous Peoples livelihoods and cultural values. However, as current land-use planning procedures do not address the whole range of biodiversity features, this group of ES is also threatened. The

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recommendations for land use management based on the Numto Nature Park assessment include the promotion to local stakeholders of the global significance of the Numto Nature Park area, exclusion of any further land disturbances, and balanced land-use planning in line with SES assessment with the maintenance of all groups of ES based on conflict resolution. The outcomes of the study were presented during the public hearings on Numto Nature Park zonation and caused many discussions. However, the decision on the zonation was taken in favour of the oil and gas industry. The SES assessment method could be recommended for further improvement of the decision making procedures and application throughout Russia.

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