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Ecosystem services of the cryogenic environments: identification, evaluation and monetisation – A review

Evgeny Abakumov[1) ✉], Azamat Suleymanov[1), 2)], Yuriy Guzov[1)], Victor Titov[1)], Angelina Vashuk[1)], Elena Shestakova[1)], Irina Fedorova[1)]

[1)] Saint Petersburg State University, 16 line 29 Vasilyevskiy Island, 199178, Saint-Petersburg, Russia

[2)] Ufa State Petroleum Technological University, Ufa, Russia

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Abstract: The article discusses the valuation of ecosystem services in connection with the economic activity of the Russian Federation in the Arctic zone. It also considers the categories of ecosystem services in general and the assessment of ecosystem services in the Arctic in particular. The article also considers types of negative impacts on the Arctic ecosystems, their assessment, and investment risks existing in ecosystem services. It is shown that the application of the methodology and ecosystem services contributes to the adequate assessment and creation of a hierarchical classification of "usefulness" and "benefits" for society derived from the existence, use, and non-use of ecosystems. The concept of Arctic ecosystem services consists of three components: identification, monetisation, and ecological risk assessment. Identification, classification, and initial assessment, mainly at the qualitative level, allow us to determine and classify services for further improvement of life quality and regulation of socio-economic effects of environmental changes. Quantitative assessment is related to the identification of the degree of ecosystem service amenability. The example of the Arctic ecosystems shows that the possibility to assess and the accuracy of the assessment can be quite different and largely depends on the type of service. The analysis of possible ecosystem services and their relationship with the quality of life in the Russian Arctic indicates significant investment risks.

Keywords: amenability, Arctic, cryogenic environment, economic assessment, ecosystem services, monetisation

INTRODUCTION

The ecosystem service theory and practice remain in the primary focus of integrated interdisciplinary research [Constanza 1992; Constanza *et al.* 1997; Haines-Young, Potschin 2017, SEEA 2021]. The environmental responsibility imperative has become increasingly important in the context of the development of green economy, ecological and environmentally friendly management, and the introduction of local intensive agrobiotechnology [Dyakonov, Doncheva 2002; SEEA 2021]. The presumption of environmental responsibility of a business entity requires us to consider monetisation and parameterisation of responsibility, which, in turn, necessitates the development of mechanisms to assess the value of usefulness and benefits associated with the functioning and existence of ecosystems. The concept of ecosystem services has not been fully accepted by ecologists, biologists, and economists, as well as by other sciences, as discussions continue and criticism is expressed about the possibility of valuing and monetising services derived from ecosystems [Rosenberg 2014]. Nevertheless, the amenability for the valuation of services can be classified [Haines-Young, Potschin 2017; Peter *et al.* 2008; SEEA 2021], and indices and parameters of environmental impact can be verified for various natural zones. In this context, the concept of ecosystem benefits or services is part of environmental impact assessment theory and the practice of environmental design methods. Some estimates of the ecosystem value and ecosystem services, as well as plots of land, are very broad [Bobylev, Zakharov 2009]. They should function as a model of calculations and estimates, rather than the expression of effects produced by the functioning of the ecosystem. The same problems apply to the land appraisal in Russia and the USSR. Ballroom indices were developed first, and followed by verification, analysis, improvement, and reuse. All these are stages of a complicated evaluation of sophisticated systems that do not have additive properties.

Nowadays, in Russia, the level of development of the theory of ecosystem services is at the stage of their identification and classification [Bobylev, Zakharov 2009]. In many publications on ecology, geography, soil science, nature protection, environmental biology, economics, environmental law, problems with ecosystem services begin to appear. The most well-established definition of an ecosystem service is the benefit that can be obtained from the use or non-use of a particular ecosystem and its functions or processes [Constanza *et al.* 1997; Rosenberg 2014]. The main difficulty faced by the evaluator is the classification of ecosystem services and the determination of their amenability to be evaluated. The environmental burden from economic activity should be monetised or at least parameterised. This requires to develop a system for calculation and verification of environmental costs [Bobylev, Zakharov 2009]. Ecosystem services can also become an element of international legal relations, where supranational legislation applies. For example, in the case of the system under the International Antarctic Treaty [Lukin *et al.* (eds.) 2002], when the reputation and responsibility for methods of conducting business in the territory entrusted to a particular state is more important than the valuation of damage or, conversely, preservation of the ecosystem component [The Madrid Protocol 1991]. The concept of ecosystem services could become an essential part of polar biology and ecology, and a cryosphere as a specific part of gnoseology, related to the cryogenic macroenvironment [Melnikov *et al.* 2013], which spatially dominates in Russia [Stolbovoi, McCallum 2002].

Nowadays, the theory of ecosystem services has become a key challenge for applied ecology and environmental science. Russia, especially its permafrost affected part is underestimated and under investigated in terms of ecosystem services. The current re-expansion of industry, urbanisation, and agriculture to the Arctic belt requires modern research of ecosystem services nature, peculiarities, and diversity in the cryogenic terrestrial and aquatic ecosystems of cryolithozone.

MATERIALS AND METHODS

This review article is based on analyses of recent and classic publications and new findings regarding the implementation of the concept of ecosystem services in Arctic belt with special emphasis on analyses of the Eurasian experience in the largest part of Arctic, namely the Russian Arctic.

RESULTS AND DISCUSSION

CLASSIFICATION OF ECOSYSTEM SERVICES

Anthropogenic activity affects the spatial structure of natural environments and transforms the structure of ecosystems [Telega 2019]. Interrelations between human activity and ecosystem can be described through the concept of ecosystem services [Nyka 2017]. Anthropogenic impact results not only in the local transformation of ecosystems [Jouquet *et al.* 2011] but also the transformation of biodiversity and ecosystems functioning on a regional [Santarem *et al.* 2019] and global scales [Bhattarai 2017]. The concept of ecosystem services has currently been expanded even to polar regions [Verbitsky 2018], including Antarctica. Ecosystem services have recently become an essential part of environmental and land management [Gomes *et al.* 2021; Keestra *et al.* 2018], thus the spatial planning of anthropogenically affected landscapes currently uses the ecosystems services concept and terminology [Pereira *et al.* 2021; Yang *et al.* 2020]. Russia is a large country that includes polar, boreal, subboreal and subtropic bioclimatic belts. At the same time, about 54% of the country's territory is located in cryolithozone [Stolbovoi, McCallum, 2002]. The sustainability of anthropogenic ecosystems here is affected seriously by the presence of continuous, discontinuous, and sporadic permafrost, which regulates key biogeochemical processes in the cryolithozone. The Russian Arctic is a unique example of intensive impact on the environment and the diffusion effect natural resources have on the economy of the whole country. In this context, our review aims to: (i) assess the current status of ecosystem services in the Russian Arctic, and provide key examples and assess the possibility of their monetisation; (ii) use the ecosystems of the region as an example, assess the accuracy and amenability of different ecosystem services to valuation; and (iii) analyse the negative impact on Arctic ecosystems and assess investment risks.

In general, ecosystem services are classified using functional criteria [Alcamo *et al* (eds.); Haines-Young, Potschin 2017; Millennium… 2005; SEEA 2021; TEEB 2008] and are divided into four large groups: provisioning, supporting, regulating, and cultural. The provisioning services is the most amenable for evaluation, since the services are related to the real sector of the economy, energy resources markets, and law enforcement in the field of environmental and ecological management. The monetisation of these services raises the issue of not only analysing the contribution of two types of land rents, but also the problem of assessing the accumulated environmental damage; the question of the potential buffering of the spatial basis for regular and constant influences of one kind or another.

This provisioning of ecosystem service includes resources that humans can obtain from nature. This group includes resources for basic human needs, such as food and water resources, fuel and timber [Rolando *et al.* 2017]. Water access and quality is a major global issue, which is also an actual problem in the Russian Arctic. Despite the huge flow of freshwater into the Arctic Ocean, villages and cities in the Arctic often suffer from a shortage of drinking water of appropriate quality [Rospotrebnadzor 2010]. So, in the Yamalo-Nenets Autonomous Okrug (Rus. Yamalo-nentskiy avtonomny okrug), water designated for consumption is abstracted, to a greater extent, from underground sources. In 2016, the volume of water taken from natural water bodies of the district amounted to 224.1 mln m^3, of which 22.29 mln m^3 (about 10%) from surface water bodies, 200.41 mln m^3 (about 89%) from underground, and 1.40 mln m^3 (<1%) from seawater. Of 25 surface sources of drinking water in Nadym, Priuralsky, Yamalsky, Tazovsky, and Labytnangi city, 60% (16 facilities) do not meet sanitary and hygienic standards. Often, when planning water use and calculating water balances, water cycle and climate change are not taken into account. For example, water management sites are located within the Yeloguy and Dubches rivers (catchment of

Pyasina River) covered by the scheme of complex use and protection of water bodies [Rosvodresursy 2014]. Limits on abstracting water in the region are growing linearly from 0.66 to 19.35 mln $m^3 \cdot y^{-1}$, although river runoff has been decreasing. Nowadays, the problem of underestimating the natural component of aquatic ecosystems is aggravated by the degradation of permafrost, which leads to complex changes in the hydrological regime, water quality, and aquatic ecosystems in general.

The Russian sector of the Arctic is home to about 80% of all living endemic species [WWF-Russia 2014]. Moreover, the most typical Arctic landscapes are represented in the Russian sector. Arctic flora and fauna are vulnerable due to their ecology and way of life. Acute problems in the region, such as ice melting, poaching, and oil extraction, can lead to the decline or even extinction of certain species. However, the indigenous population of the Russian North depends heavily on fishing, foraging, and hunting. The traditional lifestyle of small indigenous populations is a crucial aspect and has a strong influence on their culture and traditions. In this regard, the Constitutional Court of the Russian Federation has allowed members of northern peoples to hunt according to their centuries-old traditions [Federal Law … 2009].

Regulatory ecosystem services include services that are necessary for the functioning and maintenance of all other ecosystem services. This group includes the water cycle, photosynthesis, soil formation, nutrient circulation, etc. Regulatory ecosystem services in the Arctic are affected by the presence of permafrost in a continuous, discontinuous intermittent, and sporadic islands. At least 60% of the land of the Russian Federation is in the zone of direct or indirect influence of permafrost [Roshydromet 2008]. The problem of permafrost is directly linked to access to and quality of drinking water. Due to the vertical movement of permafrost, groundwater in some polar regions reaches a certain depth, which creates problems for drainage. Local people use water bodies, sometimes with stagnant regimes, which they share with wildlife. There is no central water supply in many settlements. There are no water drainage routes, since permafrost blocks the natural runoff.

The presence of permafrost leads to the deposition, conservation, and stabilisation of huge amounts of carbon, the formation of large reserves of organic matter, which makes Russia the main storage of carbon in the world. This, however, has not been reflected in international agreements. The fact that up to 80 kg of carbon of organic compounds can be stored on an area of 1 m^2 of the tundra [Zubrzycki *et al.* 2014] indicates that the ecosystem service providing deposition and stable conservation of carbon and nitrogen in the ecosystems of the North is very important. Nevertheless, the parameterisation of this service is based on extremely clustered data, since in Russia, there is no network monitoring carbon deposition in soils, except some facilities in regions of the Arctic that are subject to scientific studies, e.g. Komi River (Yamal-Nenets Autonomous Okrug), Krasnoyarsk region, and the delta of the Lena River. In this context, the accurate assessment of carbon sequestration is possible only for individual ecosystems, and a general error of the estimate may reach 25%, which is a serious methodological problem.

Supporting services include ecosystem buffering which prevents the violating of the level of biodiversity, chemical pollution, and physical impact. Other issues include the release of pollutants from the permafrost into the soil, surface layer of the atmosphere, and water. Permafrost meltdown poses certain risks as well, e.g. deformation of building foundations, accidents at infrastructure facilities, especially oil and gas pipelines, etc. The maintenance of a certain level of buffering is critical in areas of intense urbanisation [Kart Aktas, Yildiz Donmez 2019], especially in cases where urbanisation is strictly localised. Another supporting ecosystem service is the preservation of soil fertility in agricultural areas in the Arctic zone. Abakumov *et al.* [2020] reported that the transformation of arable land to fallow decreases soil fertility. Self-purification of terrestrial and aquatic ecosystems is also a supporting ecosystem service. A biotic system can not only accumulate contaminants (see buffering) but also purify the environment by passing substances through its body. For example, aqueous hydrobionts, by filtering water, contribute to its purification from suspended particles and hazardous pollutants. Notwithstanding the harsh Arctic climate, filtration rates in lakes can only reach a few hours, and the bottom lake sediments may have a cation exchange capacity between the bottom water layer and the upper layer of sediments with values similar to Chernozem soils. This indicates a high degree of self-purification capacity of the Arctic. However, it is necessary to indicate the presence of hydrometeorological risks in the coastal parts of the Arctic Ocean and wormwood zones. Thus, under conditions of cryolithozone, the slowdown of biological cycle processes and certain landscape processes can be an example of a prolonged activity of individual ecosystem services.

Regulating services provide unquestioned benefits for the ecosystem, in terms of air, water, and quality, decomposition, and carbon sequestration and storage. In the Russian Arctic, the services regulate the flow of water from terrestrial to adjacent ecosystems – transit between the river, lake, and the sea. Separately, one can distinguish swamps and wetlands, widespread in the Arctic zone. Water regime and water holding capacity of the soil-permafrost complex are decisive for the global runoff in the Russian Arctic. These functions are determined by the variety of physical parameters of the geogenic basis of the landscape, morphometric characteristics of the relief, and the annual hydrometeorological situation. In this context, the assessment, parameterisation, and approximate monetisation of the hydrological ecosystem service of the Arctic become very relevant. The river and lake water levels show significant positive trends in increasing liquid sediments in the Arctic. They can be quantified by calculating the duration of navigation and the number of goods transported by water, taking into account the increase in water flow to the surface and underground water sources, and calculating the catch of commercial fish as a function of water content and water temperature. For large marine ecosystems (coastal Arctic seas), one can show the change in the number of species of commercial fish and the volume of biomass caught with the change of hydrophysical sea parameters (mainly temperature). Thus, temporary restrictions on the catch of aquatic biological resources can be considered as a tool for maintaining regulatory ecosystem service. Until the end of 2017, brown trout fishing in the Murmansk region was limited from 1st January to 31st October. The ban applied to all estuaries and streams of salmon spawning. The removal of natural resources reduces the value of ecosystem services. In this case, catch limits help to curb the rate of decline and balance the fish resource. Furthermore, measures to rebuild depleted fish stocks have an impact on carbon storage. This brings additional benefits in the form of increased carbon storage capacity and its value [MARTIN *et al.* 2016].

For swamps and wetlands, the following regulatory ecosystem service includes the high pollutant adsorption capacity of peat, low degree of drainage, and water exchange which allows keeping pollutants in peat. On the one hand, this is a regulatory service that is very useful from an anthropocentric point of view, and on the other hand, the process will inevitably reduce the uniqueness of the ecosystem. Moreover, after exceeding the buffer capacity or during degradation of the swamp massif, pollutants will transit to aquatic ecosystems. Monetisation of the hydrological ecosystem service is closely related to the group of services associated with geocryological risks, e.g. an increased risk of destroying supporting structures, as well as degradation of the entire spatial basis of economic activity.

Cultural services provide non-material benefits related to nature. They include tourism, recreation, and inspiration for art and creativity, and aesthetic parameters of the ecosystem. Recreational services are extremely specific for the Arctic belt. Tourism is rapidly developing on the Yamal Peninsula, the New Earth archipelago, Yakutia, and many other regions of the Arctic. This type of service is one of the most easily measurable and monetisable, as it is related to the tourism services market. Currently, there are 11 nature reserves and 9 reserves in the Arctic. Tourism develops only in 4 reserves. This, of course, preserves natural values, but does not contribute to the development of cultural ecosystem services. Until now, the potential of rivers and lakes is poorly used for transportation and recreation. There are no tourist water routes at mouths of almost all major Arctic rivers and large lakes; water routes offered by tourist companies are uniform and expensive, which indicates that there is a great potential for the service to be monetised.

Education services also need to be valued, as vulnerable Arctic ecosystems are used for practical courses (floating universities, summer schools). Thus, in the Arctic belt, Russia has only one "strong" competitor, i.e. the archipelago of Svalbard with its Norwegian and international educational programmes (e.g. UNIS – University Center in Svalbard).

Monuments of the ethnocultural heritage developed by indigenous people of the North, include sanctuaries, sacred places and places of worship. These are more difficult to assess in terms of cultural ecosystem services.

MONETISATION OF ECOSYSTEM SERVICES

Nowadays, there is a trend to include ecosystem services in national accounting, integrated environmental and economic accounting, and integrated models for assessing ecosystems and ecosystem services in monetary terms. The structure of ecosystem service monetisation is presented in Figure 1.

The avoided cost method takes into account the cost that would have been incurred in the absence of ecosystem services [PASCUAL *et al.* 2010]. Avoided costs are the most important parameter as it allows to valuate natural resource savings. Hedonic costs are a part of an important method that valuates environmental and natural resources which influence market prices and people's willingness to pay for environmental goods and services [SYLLA *et al.* 2019]. The production or market value approach is based on the contribution of ecosystem services to increased income or productivity [MÄLER *et al.* 1994]. For

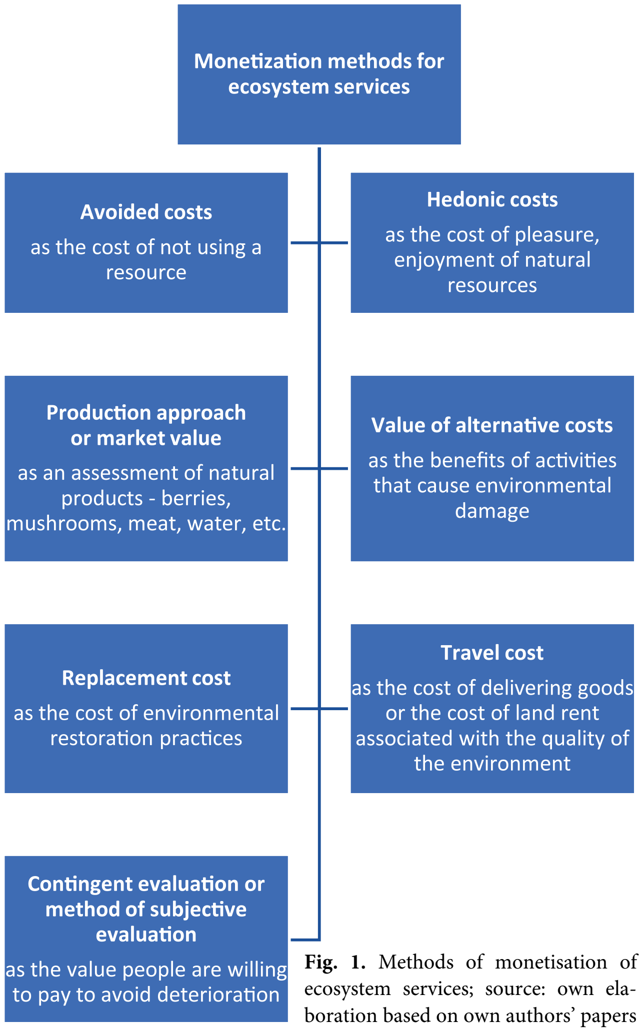

Fig. 1. Methods of monetisation of ecosystem services; source: own elaboration based on own authors' papers

example, the law on organic production and labelling of organic products [Regulation (EU) 2018/848] aimed to meet the demand for organic products, reduce environmental damage and promote environmental innovation. The value of the alternative cost method is the need to diversify environmental risks in the Arctic. In our case, the replacement cost method is useful for the updating of reclamation, regeneration and ecosystem restoration practices, e.g. in the case of exogenous disturbances of the soil cover. The latter two methods are related. The subsoil, water, land, flora and fauna are valuable natural resources which form the natural asset of the Arctic. The natural capital and well-fare of the Arctic are directly transformed into benefits and monetary income. This capital, therefore, has to be efficiently reproduced from economical and natural points of view. This has an impact on how much people can invest in different types of property (land, subsurface, housing, etc.).

The ability to asses, as well as its underlying reasons and accuracy, depend on the method of ecosystem service monetisation. It also affects the amenability for evaluation. We have highlighted several examples of services, divided by each ecosystem service (provisioning, supporting, regulating, cultural) and the method for their monetisation. The degree of malleability varies from low to high, depending on the type of ecosystem service. Services, such as sustainable local water supply, localised deer meat production, freshwater ecosystem products, stabilisation of building structures, and Arctic recreation, are categorised as highly amenable. Examples of all amenabilities of Arctic belt ecosystem services to valuation are shown in Figure 2.

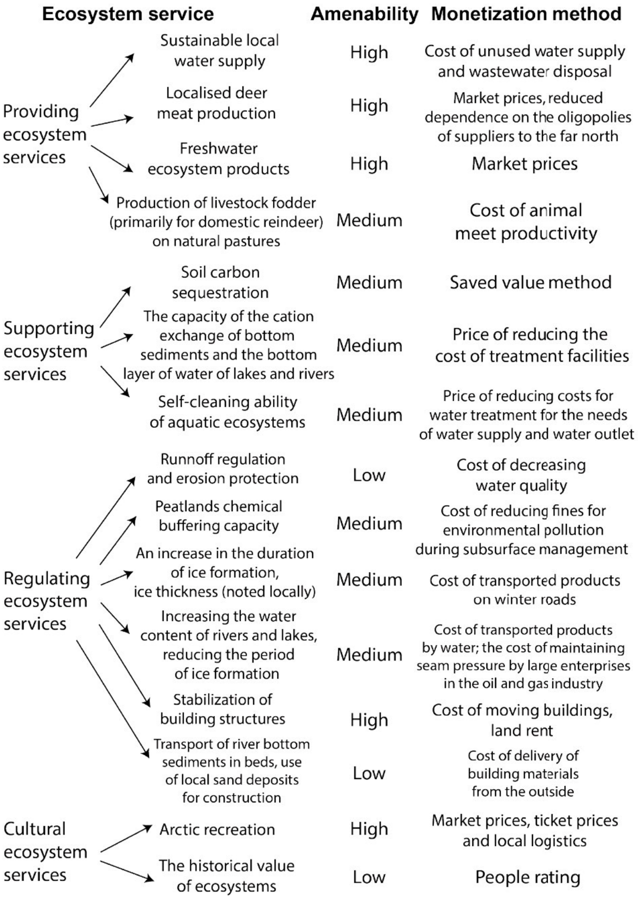

Fig. 2. Amenability of ecosystem services to assessment in the Arctic belt; source: own study

Another approach related to the assessment of negative impacts on ecosystems is possible. In this case, it is the imperative of environmental responsibility of the users and this responsibility can also be monetised to a certain degree. An example of a monetisation model taking into account negative impacts is given in Figure 3. We highlight the construction of buildings, leakage of pollutants from plants and pipelines, hydrocarbon pollution, and the development of Arctic offshore oil and gas fields that pose the highest risk to monetising negative impacts. Depending on their type, the above-mentioned impacts significantly affect the state of nature: water, air, and habitats. Negative effects on these components can also be immediate or damaging over a long period. For example, accidents and subsequent leakage from plants and pipelines cause immediate environmental damage. The construction of various infrastructure and buildings, as well as mining operations, causes damage over a long period.

Ecosystem services markets are developing, which allows to monetise ecosystem functions. The most developed of these is the voluntary carbon market, which sells carbon units, measured in tons of CO_2. Carbon units are issued by competent authorities in their electronic form and turned to records on accounts in the register of carbon units.

Another tool for monetising ecosystem services may be programmed in the form of payments for ecosystem services

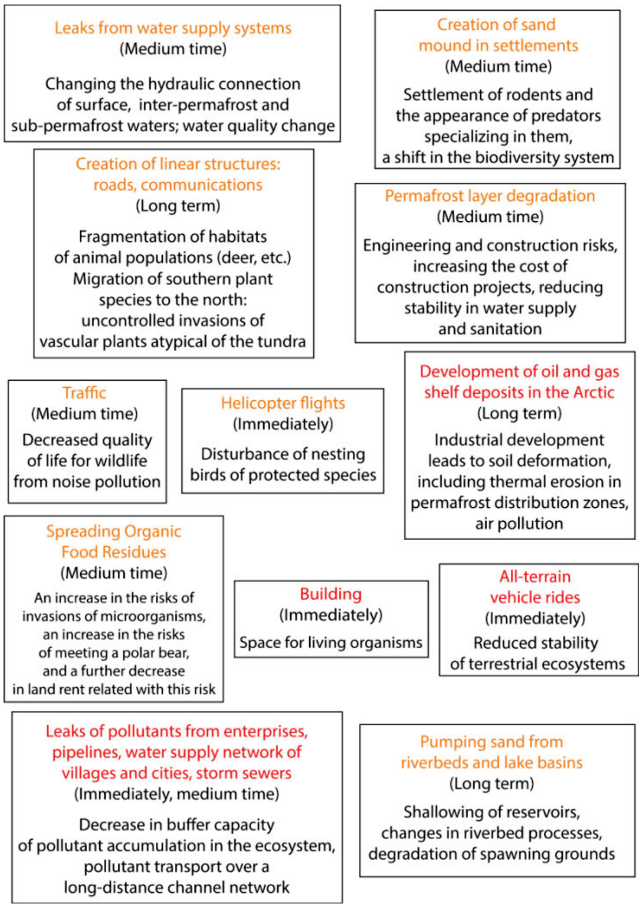

Fig. 3. Monetisation of negative impacts on ecosystems (colour marks risk to nature: red – high, orange – medium; time scale is given in brackets); source: own study

(PES) based on contractual relationship between stakeholders to provide or support to an existing ecosystem service. The implementation of the PES has proven effective in achieving sustainable provision of ecosystem services.

Best practices in the application of PES schemes in the business environment are shown by countries in Europe and the United States. Public-private types of PES schemes, in many cases funded by international organisations, are developing in Asia, Latin America, and Africa.

At present, there is no comprehensive economic assessment of the ecosystem services provided by the Russian Arctic. Some attempts have been made at the model sites in protected areas. For example, the total value of individual ecosystem services in protected areas of the Pechora-Ural Arctic varies from RUB 33.8 to 43.5 mln (USD 434–584 thous.) per year [Tikhonova 2017].

ECOSYSTEM SERVICES AND INVESTMENT RISK ASSESSMENT

The decision-making process in the Arctic zone of the Russian Federation has a significant impact on the intervention strategy, as well as on those who create favourable conditions for strengthening or shortening of the adaptation to changing circumstances. Taking into account their feasibility, the generally accepted norms related to the decision-making in uncertainty and risk analysis, [Dietz 2003; Hemmati 2001; Petkova *et al.* 2002; Stern, Fineberg 1996] specify several desirable conditions for development.

1. Use the best information. However, it is important to note that it is rather difficult to generate such information supporting decision making in the Arctic belt. For example, the uncertainty related to the impact of climate change on the Arctic, primarily warming, can produce different effects. On the one hand, transportation accessibility improves, on the other hand, due to the intensification of atmospheric circulation processes, the power of atmospheric pressure can increase, which in turn is likely to increase the drift of both warm and cold air masses. It is also important to note that at present, information on navigation conditions (including status of ice cover) is obtained primarily from foreign satellites.
2. Openness and the widest possible participation of stakeholders, which is rather difficult due to the anomalous nature of the weather in the Arctic zone and the severity of the climate, as severe weather conditions hurt technical devices and require additional measures for adaptation.
3. Justice and vulnerability, as well as cognitive and organisational strengths and weaknesses. For example, the Vorkuta city has been a centre for the study of permafrost since the 1930s. Based on past decisions, standards for the construction of infrastructure at high latitudes have developed. However, one should also take into account that when solving various issues, the understanding of the situation among members of the local community is necessary [Berkes 2002; Dietz, Stern 1998]. Thus, educational and organisational strengths and weaknesses can be defined as a result of interaction with those who have local experience.
4. Lessons learned from past decisions and conservation alternatives. The importance of scientific research on the peculiarities of the development of the Arctic is a necessary and economically feasible element in making decisions that allows to reduce the uncertainty of climate forecasts and mitigate consequences of its change. It is important to emphasize that, for example, the theory of substitution of factors (capital) is not effective in this case. There simply is no alternative to science.
5. Accountability.
6. Effectiveness. In our opinion, the effectiveness of decision-making on the development of the Arctic of Russia should be built based on an explicit and structural understanding of internal and external factors for the development of the territory, a reasonable establishment of performance indicators with their threshold values and based on the development of a methodology for assessing strategic decisions.
7. Cumulative and cross-scale effects. For example, the Declaration of the Arctic Council in 2009 [Tromsø declaration 2009] introduced a provision which requires to harmonise national legislation (members of the Arctic Council) pertaining to the development of oil and gas management on the shelf in the Arctic. This includes the strategic environmental assessment, and the assessment of the cumulative effect of various investment projects implemented. It is useful to note that in Russian practice, environmental impact assessment has been used for a long period, and strategic environmental assessment is a fairly new mechanism.

An analysis of possible ecosystem services and their relationship with human well-being in the Russian Arctic indicates significant investment risks. Under these risks, it is possible to understand with certain probability that actions or potential decisions in this zone can cause significant harm to people. It can be detrimental to basic material elements of normal life, freedom of choice, health, etc. The assessment of the risk using the unique example of the Russian Arctic is especially important, since the decision-making process is rather complicated and uncertain due to specific features of the Arctic (physical and geographical features, difficulty of predicting solar activity, etc.).

The importance of assessing investment risks in the Arctic belt allows us to distinguish several values. Firstly, this analysis allows you to accumulate a competent base on a dynamic complex of animal, microorganism, plant, and non-living environment communities in a scientific, traditional, and unprofessional form, which is a logical source for substantiating rational decisions. Such an analysis should be based on alternative solutions and allow to increase benefits, minimise risks, and possibly create conditions for their complete elimination or fair distribution of benefits and risks. Considering the above, it is important to assess the nature and magnitude of uncertainty related to the assessment of activities in the Russian Arctic.

Secondly, it is quite difficult to justify rational decisions in the Arctic belt without thorough and rigorous methodological work. This has been confirmed several times by Dietz and Stern since 1998 [Dietz, Stern 1998]. Their research emphasizes the importance of a detailed study, including circumstances and motives, which is especially important for the Arctic belt to link potential benefits and risks. Many investment projects in the Arctic belt may have a high degree of uncertainty. Thus, a decision-making strategy requires adaptive management.

CONCLUSIONS

A review of the literature has shown that we have only began to use the apparatus of ecosystem services to assess and parameterise benefits of Arctic ecosystems. The region has specific features than enable to classify ecosystem services of varying degree of amenability for evaluation and monetisation. Two critical aspects of the apparatus implementation are highlighted. The first one is the identification, classification, and primary assessment, mainly at a qualitative level. The second is the identification of the degree of amenability of the ecosystem service with the assessment and further monetisation of the ecosystem service.

The highest amenability for evaluation is in provisioning services characterised mainly by access to and quality of water, as well as conservation of flora and fauna. Negative impacts on Arctic ecosystems, such as increased pollution and degradation of natural environment components under increasing anthropogenic pressure, and waste accumulation. The global climate change and melting glaciers and permafrost have their major impact. The above factors point to the need to verify the monetisation apparatus using field, laboratory and model studies.

The example of Arctic ecosystems has shown that the amenability for evaluation and the accuracy of the assessment can be completely different and largely depend on the type of service in under classification. Qualitative and verified monetisation makes it possible to assess investment risks and analyse the influence of accumulated environmental damage on the components of investment risk. The analysis of possible ecosystem services and their relationship with the quality of life in the Russian Arctic indicate significant investment risk. The example of the Russian Arctic is unique and the assessment of intense environmental impact is a priority, especially in the context of the preparation and implementation of a programme for the socio-economic development of the Arctic zone. It is particularly important, since the decision-making process is rather complicated and uncertain due to the specific nature of the Arctic territory.

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