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ECONOMIC AND ENVIRONMENTAL EVALUATION OF LAND USE CHANGES IN KARELIA

A change in the type of land use and in the type of economic activity often results in unexpected effects for local ecosystems. There is a need to perform preliminary calculations and analyze comparison of different kinds of economic and environmental transformation with due regard to benefits and costs not only for business and population but also for the environment in general. The potential economic efficiency of changing the specialization of an enterprise for a ten years' run is shown by the example of one animal husbandry farm in Karelia. Among other land use types, we chose peat mining and wetland conservation. Each type of activities was complexly evaluated with regard to different types of costs and benefits. In our work, we use a method of evaluation of land use change consequences with an account of the value of ecosystem services. Pecuniary values of ecosystem services were given with respect to foreign analogs and taking into account local realities. Our results showed that wetland conservation is the most beneficial for the society and the environment because of being used for picking berries, which are highly appreciated on the market, and due to low costs for third parties since wetlands perform regulative and cleaning functions of local ecosystems. In contrast, peat mining is a profitable business, but it pollutes the environment because of carbon emissions into the atmosphere. The current use of lands for animal husbandry is also not an optimal solution because of low profitability of the farm. The results of the research may be used for the elaboration of recommendations to improve the regional policy of agriculture and nature management economy to retain the ecological balance between human activities and the environment.

Keywords: Ecosystem services, land degradation, nature management economy, development scenarios, wetlands, peat mining, animal husbandry, comparative analysis, Karelia, Russia

Introduction

A change in the type of land use and in the type of economic activity often results in unexpected effects for local ecosystems. In a bid to earn income and develop effective production, we may cripple the environment and then pay a long price for the recovery of land degradation consequences. There is a need to perform calculations and analyze comparison of different kinds of economic and environmental transformation with due regard to benefits and costs not only for business and population but also for the environment in general.

In this article, we understand "transformation" as changes in the ecosystems resulting from the change in economic activity and change in the land use. Our work continues the discussion on the consequences of agriculture development for the environment and on the estimated losses of ecosystem services as a result of changes in the economic activity.

The expansion of crop lands produces a severe impact on the environment and results in the loss of ecosystem services and high indirect costs [1]. Intensification of agriculture affects global ecosystems by way of depletion of their resources (fresh water) [2] and through nitrogen and CO_2 emissions [3, 4]. Transfer of extensive territories to plow lands destroyed many natural areas and threatens the biodiversity of our planet [5].

However, improved management and environmentally favorable production practices may increase agricultural productivity and mitigate the impact of the agriculture on climate changes [6–8]. In particular, removal of low-yield lands from use and increase in perennial plantations allow sequestering carbon in soil and supporting the necessary volume of biomass [9].

The growth of production or use of one ecosystem service (e.g., food production) usually results in a reduction of the production (support) of other type of ecosystem services [10]. Therefore, elaboration of business plans and development scenarios for the territories requires accurate prioritization and evaluation of the consequences of agricultural and industrial activity and measurement of ecosystem services, which are not sold on the market but may be exposed to degradation, and thus also need evaluation afterward.

Translation

The total economic value concept [11] is used for pecuniary valuation of ecosystem services. The concept consists not only in the accounting of the market value of ecosystem services but also in the accounting of what cannot be sold on the market. The embodiment of the concept in actual calculations and results may differ a lot depending on the purpose of the research and actual data. It stipulates the need to study specific evaluation methods for ecosystem services and their possible application on the local level.

This article shows the calculation of potential economic efficiency of changing the specialization of an enterprise for a ten years' prospect on the example of one animal husbandry farm in Karelia. Among other land use types, we chose peat mining and wetland conservation. Each type of activities was complexly evaluated with regard to different types of costs and benefits. In our work, we use a method of land use change evaluation, including the value of ecosystem services. Pecuniary values of ecosystem services are given with respect to foreign analogs and local realities.

Theory

Monetary (pecuniary) valuation of ecosystem services is necessary to determine the importance of ecosystem services for people. Conversion into money allows evaluating the influence of ecosystem services on the economy of the object of research. A lot of things in economy are measured in cash equivalent, and ecosystem services are also measurable. Monetary valuation of ecosystem services does not always mean that ecosystem services must be traded and exchanged on the market. Monetary valuation of ecosystem services may mean possible losses from deterioration of ecology and disturbance of biosphere processes. Such valuations may contribute to the distribution of awareness about the significance of natural components and promote the development of resource-saving technologies and inclusion of nature capital in the valuation of gross domestic product of the countries.

One of the first global monetary valuations of ecosystem services was given in the work of the group of scientists with Robert Kostanza at head in 1997 [12]. In that research, valuation of ecosystem services was calculated for different kinds of lands, giving the following hierarchy (in US dollars of 1994 per 1 ha):

— Wetlands and peat bogs, 14,785;
— Water lands, 8,498;
— Coast line, 4,052;
— Forest, 969;
— Pastures, 244;
Plow land, 92.

That means Kostanza and coauthors give the lowest value to the ecosystem services of agricultural lands. Instead, wetlands and water lands offer the most expensive ecosystem services.

Table 1 shows the information on the scope and functions of different ecosystem services (based on [12] with little changes by coauthors). The table contains a general list of ecosystem goods and services without reference to any particular territory.

Ecosystem services constitute a natural capital and influence directly or indirectly human life and welfare, thus forming a total economic value of different kinds of lands and natural biomes. If the world's average annual GDP is $18 trillion, the average global estimate of ecosystem services amounts to $33 trillion [12].

"Each type of ecosystem provides for a wide range of services (supply, control, support, and culture): clean air, clean water, carbon retention, pollination, tourism potential, etc. Any of the said factors should not be studied separately as the base of natural resources covers different natural production systems. Furthermore, measures developed to preserve and support natural resources and ecosystem services rarely provide for the coverage of different production systems — from forests to fisheries and farms — or recognition of the economic value that the effective use of one ecosystem provides for the adjacent ecosystems." [1]

The interaction between the created, social, human, and natural capital constitutes the general human (humanity) well-being. The economy, including fixed assets, current assets, and human capital, is a composite part of the society that in its turn is a fragment of nature. In this case, ecosystem services constitute a contribution of the natural capital to the human well-being. Yet, since this contribution

[1] See: Retrived from: http://www.fao.org/ecosystem-services-biodiversity/ru/ (date of access: September 5, 2016).

Table 1

Description and functions of ecosystem services

Ecosystem services	Ecosystem functions	Examples
Gaseous regime control	Control over chemical composition of gases in the atmosphere	CO_2 and O_2 balance support, ozone generation, balance of sulfur oxides in the atmosphere
Climate control	Control over temperature, precipitations, and other climate parameters associated with ecosystems at different levels	Control of greenhouse gas emissions, release of dimethyl sulfate affecting cloud formation
Catastrophic phenomena control	Resistance and integration of ecosystem properties for the elimination of consequences of natural cataclysms	Protection from storms and floods, recovery after droughts, and other specific features of vegetation cover of the territories as a way to respond to natural cataclysms
Water-regime control	Water-flow control	Water supply for the purpose of irrigation and for water mills, for power engineering and transport
Preservation of water reserves	Water storage and purification	Water accumulation on the catchlands, in water bodies, and ground waters
Erosion control and fixation of sedimentary rocks	Prevention of soil erosion within a specific ecosystem	Assurance of protection from wind erosion and land loss, from silting of water bodies
Soil formation	Soil-formation processes	Weathering of rocks and accumulation of organic substance
Circulation of fertilizer elements	Accumulation, circulation, transformation, and fixation of fertilizer elements	Nitrogen fixation, circulation of phosphorus, potassium, and other nutrient substances and elements
Waste processing	Involvement of available nutrient elements in the circulation and destruction or removal of toxic organic compounds	Waste processing, reduction of pollution, detoxication
Pollination	Transferring genetic information carriers of flowers	Providing pollinating insects for reproduction of plant populations
Biological control	Dynamic control of populations through trophic chains	Control over the population size of herbivores through the "predator-prey" mechanisms
Refugium	Creating a habitat for rare and/or disappearing species of plants and animals	Breeding grounds, shelters for migrating animals, and endemic habitats
Production of food	A part of gross products allocated for making food products for people	Production of fish, game, agricultural crops, nuts, fruit
Primary production	A part of gross products not intended for making food products	Wood, fuel, fodder production
Preservation of genetic resources	Source of unique biological materials and products	Medicine, products for material science; genes resistant to pesticides, herbicides, weeds, and depredators
Recreation services	Creating opportunities for recreation, entertainment, and health-improving services	Ecotourism, sport fishing, and other outdoor recreation activities
Cultural services	Creating opportunities for noncommercial use	Aesthetic, artistic, educational, spiritual, or scientific values of ecosystems

is not always measurable, it is necessary to develop interdisciplinary studies to duly appreciate the ecosystem services.

In these cases, interrogatory and expert estimates are usually necessary to understand how local population or farmers (or any other party concerned) estimate the significance of ecosystem services of the local biome. In the scientific literature, this method is sometimes called "willingness to pay." Thus, the scientists in their work [13] used to ask the farmers of Indonesia how important it was for them to preserve local ecosystem services, for example, forests and water resources, and whether they were ready to pay a part of their income for the preservation of the ecological state of forests and seeds. The report [14] contains the results of the interview of 300 farmers growing soybeans in the state of Michigan (USA). The authors were interested in how much land the farmers were ready to give for conservation for the purpose of preserving ecosystem services. Then, they calculated a potential product yield from the lands removed from use, converted it into value, and received a monetary valuation of ecosystem services. In the work [15], the rural people of Finland were asked whether they were ready to support the preservation of ecosystems, how much they could pay for that, or what they were ready to do on their own or to create in order to maintain good ecological condition of plow lands and forests. In all these studies, the interview was combined with the monetary valuation methods, and then calculations and statistical analysis were performed to show how different factors (e.g., income or land owned by the farmer) affected the willingness to invest in or to maintain the ecologically clean state of the environment. In this manner, the complex economic evaluation of ecosystem services was performed.

Another method of ecosystem service valuation is the value transfer when the valuation of ecosystems in one part of our planet in respect to any biome may apply to a similar biome in the other part of our planet. There are big databases on monetary valuations of ecosystem services created in different countries (e.g., TEEB database) [16, 17]. We will use some works from this source for the evaluation of wetland ecosystems in Karelia since no works of that kind have been performed for this region until now.

Attempts to evaluate the economic effect and money loss from land degradation have already been made [18]. Recently, there have been some research works where the system of comprehensive environmental and economic benefit of soil protection from degradation is developed [1, 19]. The novelty of this approach consists in using a hidden value of land, which takes into account pecuniary value of ecosystem services, both traded and not traded on the market. These are particular methods for which we may use pecuniary values of ecosystem services received from other studies. It allows us to calculate different scenarios and to analyze economic consequences of fighting against degradation or omission. Such estimates are especially relevant today when we observe strong fluctuations of food prices [20], which results in uncertainty and inaccuracy in calculating the economic (pecuniary) value of ecosystem services [21].

Modern economic studies show that the models of economic behavior have advantages and deficiencies depending on the ratio of income and expenditures of project implementation [22]. If the land use type is changed, we should remember that different types of land use and economic activity produce different environmental impact [23]. That is why there is a need to perform preliminary calculations and to analyze comparison of different kinds of economic and environmental transformation with due regard to benefits and costs not only for business and population but also for the environment in general. The potential economic efficiency of changing the specialization of an enterprise for a ten years' run is shown on the example of one animal husbandry farm in Karelia.

Characteristic of the region

For the purpose of our study, it is important to understand that Karelia is the region with considerable forest landscapes and rich water resources. The industry in the region mainly specializes in woodworking and mining. Agriculture is primarily represented by meat and milk line as well as vegetable and potato complex.

The region is located in the coniferous taiga zone. Wetlands and marshlands make over 30 % of its area and are mainly located in flow-through ravines, closed and effluent depressions, river valleys, and on the terraces of drained lakes and stretches.

The soils of Karelia are formed on the glacial and glaciofluvial deposits of light granulometric composition; the main type of soils is ash grey soil. Glacial deposits (moraines) differ in high stoniness and rockiness. Along with highly acidic reaction of the medium, which is typical of taiga soils, rockiness limits the use of soils in the agriculture [24]. Forest growth properties of soils are satisfactory: spruce and spruce-birch forests grow on sandy loam and loamy soils, and pine forests, mostly on sandy soils. The quaternary history of the territory stipulates its high level of marshiness, which reaches 70 %–75 % at Pribelomorskaya Lowland being one of the most marshy territories in the world. The average area of peaty and peaty gley soils in the Republic is 30 %–40 %. In South Karelia, peaty soils of lowland bogs on the wide glaciolacustrine plains constitute potentially attractive commercial lands, which may be used in the agriculture after performing drainage reclamation.

In this study, we will analyze the possible change in land use type and economic activity of one of the farms[2] in Pryazhinsky national district of the Republic of Karelia. The farm occupies an area of 2,776 ha and mainly specializes in the production of livestock products (cattle milk and meat). Most of the area is used for pastures and haylands, and only 236 ha of the area is used for potato growing. We believe that these lands, taking into account local natural and climatic conditions, could be used for peat harvesting and for the preservation of wetlands.

Model

In our study, we used the method of economic profit valuation (NPV, net present value) from land reclamation [25] with due regard to economic valuation of ecosystem services, including the transfer of the value of individual ecosystem services. In each particular case, we compare some current type of land use with some other type of land use. We evaluate the revenue and different kinds of costs of land use, and finally, the most profitable land use type is considered to be sustainable. Application of such comprehensive approach is stipulated by the possibility to include in the calculations the information on the potential total economic value of ecosystem services on similar territories comparable to this locality. The novelty of this approach consists in using a hidden value of land, which takes into account pecuniary value of ecosystem services, both traded and not traded on the market. These are particular methods for which we may use pecuniary values of ecosystem services received from other studies.

A formula of net income valuation from current land use, including the value of ecosystem services, benefits, and costs for third parties, is as follows:

$$\pi_t = \frac{1}{p^t}\sum_{t=10}\left(PY_t + IV_t + NU_t + b_t - lm_t - c_t - \tau_t\right),$$

where π is the net value; *PY* is the value[3] of current ecosystem services; *IV* is value of indirect use; *NU* is the potential value of what is not produced under the current type of land use; *b* is the third-party benefit (positive externalities); *lm* is the major costs of current land use type support; *c* is other costs; τ is the third-party costs (negative externalities); *p* is the coefficient calculated by the formula $1 + r$; *r* is the discount rate; *t*[4] is the time horizon of project implementation (in our case, 10 years).

Since we assume three kinds of possible land use in farming, we will use three calculation scenarios to compare income and will calculate them using the said formula.

Data in use and obtained results

First, let us characterize the types of land use. Three variants of land use will be calculated: peat harvesting, wetlands, livestock breeding and crop farming (current use). All data was converted into US dollars in prices of 2010 since the data on the current land use of the farm under consideration is available particularly as of that year.

1. The following input data was used for peat harvesting:

— Peat manufacturer's price of $27 per 1 ton (according to the Federal State Statistics Service)

— Net value of $20 (according to the Federal State Statistics Service)

— Area of the site potentially suitable for peat harvesting of 424.4 ha (as reported by the farm)

— Output (average peat yield from 1 ha for 1 year) of 800 tons[5] Therefore, the estimated revenue from peat harvesting is $21,600 from 1 ha, and net value is $16,000 from 1 ha on average for 1 year.

The third-party costs were evaluated using the data on carbon emissions to the atmosphere in the course of peat harvesting. The calculations show that this land use type generates 400 tons of CO_2 emission to the atmosphere in terms of 1 ha. For the purpose of economic valuation of carbon

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[2] We will not mention the name of the farm for confidentiality reasons.

[3] Hereinafter, the value shall mean the ask price, or the selling price.

[4] A time component is necessary since the cost structure may change in different years. It may happen that in future we will be able to simulate change in the cost structure with time, for example, when in the first years of project implementation the value of indirect use and other costs is high, and when benefits for the third parties are accumulated when the project has been already running for several years.

[5] Calculated based on information taken from http://ru-ecology.info/term/3433/ (date of access: September 5, 2016).

emissions, we used the value of $7 per 1 tons of gas released[6]. Therefore, third-party costs amount to $2,800 per 1 ha.

For the purpose of calculating the efficiency of using this type of lands, we will also use a potential value of what is not produced here but what could have been produced if these lands had been used for mixed livestock breeding and crop farming; we estimate it at $1,994 per 1 ha (based on the averaged data of the Federal State Statistics Service for Karelia).

2. The following data was used to evaluate the scenario of land conversion into wetlands:

For the purpose of economic valuation of the current use of wetlands, we used data on picking up berries in Karelia. Based on the data of [26, 27], it is possible to pick up about 2 tons of berries from 1 ha of wetlands on average for a year. The average annual value of berries on the markets of Karelia in 2010 was about $4,934 per 1 ton[7]. Therefore, the value of berries picked up from 1 ha may be $9.819.

A potential value of what is not currently produced at the farm but could have been produced was measured using the method of ecosystem service-value transfer. In our opinion, the wetland ecosystems of Karelia may be compared by some parameters with other points on the Earth and with the following types of ecosystem services: recreation services on the wetlands in Denmark [28], wetland tourism in Austria [29]. This data was converted into the prices of 2010, and thus we received $956 from 1 ha.

For the purpose of calculating positive externalities of wetlands, we used the following types of ecosystem services in the similar territories:

— Protection from floods in Canada ($691 from 1 ha) [30];

— Water purification in Denmark ($522 from 1 ha) [28];

— Preservation of biodiversity in Denmark ($261 from 1 ha) [28].

Therefore, positive externalities for wetlands in Karelia may amount to $1,474 from 1 ha per year. In this case, application of the value transfer method is not in conflict with the mathematical logic, and we may formally use ordinary summing up. If we knew how wetlands in Karelia would be used in future, we could give weighted estimates, but by now we have no information and necessary development scenarios for that.

The last kind of costs is third-party costs. In our case, they will not be emissions but the absorption of carbon amounting to 0.68 ton from 1 ha per year [31]. Taking into account the value of $7 per 1 ton of sequestered carbon, we get $4.8 from 1 ha per year (we put the minus sign here in the formulas below because it is de facto a potential benefit for third parties).

3. Data on the current use of the farm lands for livestock breeding and crop farming was from the reports of the farm for 2010 and from the data of the Federal State Statistics Service for Karelia.

There is 2,540 ha of land used in the farm for cattle breeding (including the areas of pastures and haylands). 236 ha is used for crop farming, particularly for potato growing. In 2010, the revenue from livestock breeding (sale of meat and milk) amounted to $1,803 from 1 ha, while the costs amounted to $1,597 from 1 ha (as reported by the farm). In crop farming, the revenue for the same year was $4,044 from 1 ha vs. $2,696 of costs from 1 ha. Therefore, we get the revenue of $1,994 from 1 ha vs. $1,690 of costs from 1 ha from current land use in general for the farm, taking into account average weighted estimates.

Third-party costs include carbon emissions, which we estimate at 15.4 tons per year under the given type of land use and based on the experiments and observations. Taking into account sequestered carbon at $7 per 1 ton, we get the estimated externalities in the amount of $108 from 1 ha.

Table 2 shows income calculations based on formula 1 with the input data and results for all three scenarios.

The calculation results show that conservation of lands for wetlands turns out to be the most profitable activity. Here, we see the biggest profit and the least costs. That is because we may pick up berries there, which are highly appreciated on the market. The costs of land conservation are minimal.

The comparative benefit of wetlands will amount to $1,205 from 1 ha. That means that the use of lands for wetlands will give a more significant effect (mainly due to picking up berries and because of the absence of externalities) than the use of lands for peat harvesting.

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6 See http://www.wri.org/sites/default/files/carbonpricing_april_2015.pdf 42–44 (date of access: September 5, 2016).

7 Calculated based on information from the websites http://vesti.karelia.ru/social/gorbatyj_biznes_kak_zarabotat_na_sbore_yagod_v_karelii/ (date of access: September 5, 2016) and http://agrobazar.ru/berries/wholesale/all/respublika_kareliya_rossiya/?sort=date_asc (date of access: September 5, 2016).

Though peat harvesting is a profitable business, it incurs high costs and inflicts harm to the environment because of carbon emissions.

Income gained from peat harvesting appears to be higher than income gained from the current use (livestock breeding and crop farming). Therefore, comparative benefit from peat harvesting against current land use will make $743 from 1 ha.

Current specialization of the farm is the least profitable. In our opinion, the management of the farm may consider the possibility to extend the areas used to grow potato and vegetables. It is the most profitable activity, and its products are highly demanded on the market.

Table 2

Comparative analysis of income and expenditures from different land use scenarios (in the comparable prices of 2010, US dollars per 1 ha on average for 1 year)

Indicator	Wetland	Peat harvesting	Livestock breeding and crop farming
Net income	1,979	774	32
Cost of current ecosystem services	9,819	21,600	1,994
Cost of indirect use	0	0	0
Potential value of what is not produced here at the moment	956	1,994	0
Third-party benefit (positive externalities)	1,474	0	0
Major costs of current use support	0	16,000	1,690
Other expenditures	0	0	0
Third-party costs (negative externalities)	-5	2,800	108
Coefficient	1	1.2	1.2
Discount rate	0.2	0.2	0.2
Time horizon of project implementation	10	10	10

Source: authors' calculations.

Note: Some cells of the table contain (0). That is not because of our estimates but rather because of the absence of necessary data and information in order to make any estimates.

Practical application of this method of the consequences of land use change with regard to the potential value of ecosystem services may be as follows:

— Providing the scientific community and regional management bodies with the instruments for assessment and valuation of the benefits from ecosystem services;

— Distributing information on the alternative ways of using different nature zones;

— Extending the opportunities of ecosystems for a more successful preservation and recovery of ecosystem services by responsible subjects and users;

— Strengthening the management of local territories, including acknowledgment of rights of local people and their life style.

We would like to note that our estimate does not mean mandatory preservation of all pastures and plow lands of Karelia for wetlands. Our aim is to start discussing estimates of ecosystem services in Russia and to show the potential and significance of local ecosystems. Besides, it is important for us to emphasize the need to develop sustainable farming and to use resource-saving technologies in the agriculture that would not only bring favor for people but also support the stability of the environment.

Conclusion

A change in the type of land use and in the type of economic activity often results in unexpected effects for local ecosystems. There is a need to perform preliminary calculations and analyze comparison of different kinds of economic and environmental transformation with due regard to benefits and costs not only for business and population but also for the environment in general. The potential economic efficiency of changing the specialization of an enterprise for a ten years' prospect is shown on the example of one animal husbandry farm in Karelia. Among other land use types, we chose peat mining and wetland conservation. Complex calculations were performed for each of the types with due regard to different costs and benefits.

Translation

In our research, we used the method for evaluating the consequences of changing the land use type taking into account the cost of ecosystem services. Pecuniary values of ecosystem services are given with respect to foreign analogs and local realities. Our results show that wetland conservation is the most beneficial for the society and the environment because of being used for picking berries, which are highly appreciated on the market, and due to low costs for third parties since wetlands perform regulative and cleaning functions of local ecosystems. In contrast, peat mining is a profitable business, but it pollutes the environment because of carbon emissions into the atmosphere. The current use of lands for animal husbandry is also not an optimal solution because of low profitability of the farm. The results of the research may be used for the elaboration of recommendations to improve the regional policy of agriculture and nature management economy to retain the ecological balance between human activities and the environment.

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