Monetary valuation of rare plant species in the specially protected natural areas by example of the Samara Region (Russia)

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Abstract. The approaches of assessing the ecosystem services are little implemented in Russia and are being developed recently at the regional level. Earlier, particular components of ecosystem services in the Samara Region have been evaluated. Here, an algorithm for monetary valuation of particular ecosystem services of specially protected natural areas is presented based on the data on rare and endangered plant species using the example of the Red List of the Samara Region. In total, 281 species of vascular plants have been analyzed, taking into account their spatial distribution in 27 municipal districts of the Samara Region. The ecosystem services were evaluated according to the formulas that took into account several parameters: (1) share of the area of specially protected natural areas; (2) number of tree and shrub species; (3) number of herbaceous plant species; (4) cost estimates; (4) expert assessments in the form of correction factors taking into account special value of relict and endemic species. The lower limit of the monetary value of ecosystem services, estimated by the only specially protected plant species, exceeds 50 million rubles. We suggest using this methodology for evaluating the ecosystem services in other territories, which will probably help to ensure the conservation and sustainable use of natural capital and natural ecosystems.

1. Introduction
Protected areas are the most important indicator of the conservation of wildlife, cultural heritage and recreational areas, as well as they are essential for the sustainable development of a region. This reflects the effectiveness of protected areas to prevent the loss of biodiversity and their positive effects on species conservation. Commission of the Fourth World Congress on National Parks and Protected Areas (Caracas, Venezuela, 1992) proposed a standard for the coverage of protected areas. According to this standard, the specially protected natural areas (SPNAs) must occupy at least 10% of the entire area of the region [1].

On the territory of the Samara Region (total area of 53,565 km²), several SPNAs are located, namely, Samarskaya Luka National Park and Buzululsky Bor National Park (approximately half of its area is located in the Samara Region), state landscape reserve, a particularly valuable forest, a resort, a botanical garden, 17 state nature reserves, and 288 natural monuments (13 are of the state significance, 175 are of regional significance, and 11 are key bird nesting areas) [5, 30]. The total coverage of the SPNAs in the Samara Region is 2,054.39 km², or 3.8% of the area. One can easily observe that
the degree of coverage by SPNAs in the Samara Region is almost 3 times lower than the proposed standard.

In the last few decades, leading international organizations such as the UN, the World Bank, the Organization for Economic Co-operation and Development (OECD), the World Wildlife Fund (WWF), and some others have intensified their attempts to evaluate the economic role of a special form of natural resources such as natural capital and ecosystem services. The origin of the modern approach for evaluating the ecosystem services can be traced back to the 1970s (see the detailed historical analysis by Gómez-Baggethun et al. [2]). It begins with the utilitarian definition of the useful functions of ecosystems as services in order to increase public interest in biodiversity conservation [3-5]. In the 1990s, the ecosystem services became the dominant trend in the environmentalism literature [6-7]; an interest in methods for assessing their economic value increased as well [8]. The idea of natural capital promoted the development of methodological tools for assessing and forecasting the changes of the ecosystem services in a certain region in order to achieve its sustainable development.

Nowadays, a wide range of issues related to the ecosystem services are being actively developed both worldwide and in Russian Federation. It is relevant to define particular ecosystem services and to develop the methods for their assessment and monetary valuation. Currently, most ecosystem services are either greatly underestimated or completely free of charge; therefore, their irrational exploitation may lead to the degradation and extinction of ecosystems and the loss of biodiversity. Currently, general methods and approaches are available to determine the value of particular components of the ecosystem services for large territorial units. Unfortunately, such approaches and methods are little implemented for the smaller territories (regional units) and are only being developed. For example, the authors previously estimated certain components of the ecosystem services in the Samara Region using the method suggested by R. Costanza, and the total value of the ecosystem services was accounted as $4.5 billion [9].

Here, we propose an algorithm for estimating some ecosystem services of SPNAs, based on the data on the plant species included in the Red List of the Samara Region. It goes without saying that plants included into the Red List need special protection and the most careful management of the areas of their inhabitance. We assume that evaluation of such plants is one of the measures contributing to the conservation of endangered and rare plant species in the region.

2. Materials and Methods

We analyzed 281 species of vascular plants included in the Red List of the Samara Region. Some species, such as Polypodium vulgare, Polystichum braunii, Asplenium trichomanes, Asplenium septentrionale, Diplazium sibiricum, Anemonoides korsginskii, Peganum harmala, Cladium mariscus, and some others, are found only at one site or small area. Some species are more widespread, so they are presented in several or most of the areas: Fritillaria ruthenica, Iris pseudacorus, Tulipa biebersteiniana, Linum flavum, Linum perenne, Epipactis helleborine, Adonis vernalis, Pulsatilla patens, Populus alba, etc. The number of rare and protected species differs greatly in the municipal districts of the Samara Region (figure 1).

The SPNAs taken into account within this study include the Samarskaya Luka National Park, the I.I. Sprygin Zhiguli State Nature Biosphere Reserve, Buzuluksky Bor National Park (the area belonging to the Samara Region), and the natural monuments.

The rates for calculating the amount of damage of one hectare of herbaceous plants (Tm, 450,000 rubles) and of one ha of trees and shrubs (Tr, 750,000 rubles) were used for calculation the negative effect. The rates corresponded to the Order of the Ministry of Natural Resources and Ecology of Russia No. 658 of August 1, 2011 on the Endorsement of Charges for Calculation of Damage Incurred on the Objects of Flora Included in the Red List of the Russian Federation and Their Habitat Because of Violation of the Legislation in the Area of Protection of the Environment and Use of Natural Resources.
Figure 1. Number of the rare plant species included into the Red List of the Samara Region, Russia, by municipal districts [10]

The number of rare and endangered species of vascular plants (herbaceous plants, trees, and shrubs), including relict and endemic species, was assessed in accordance to the Red List of the Samara Region. The municipal districts of the Samara Region were classified using the R package (K-means cluster analysis and Ward's method) according to the obtained values.

The municipal districts formed three large clusters (figure 2). The cluster no. 1 comprises the districts where federal SPNAs are located (I.I. Sprygin Zhiguli State Nature Biosphere Reserve and Samarskaya Luka National Park). This cluster is characterized by a high level of diversity of rare species of vascular plants, including relict and endemic species, and, therefore, by the greatest economic value of the territory. The cluster no. 2 combines a large group of districts characterized by an average degree of floristic diversity of rare species. The areas belonging to the third cluster are characterized by significantly lower diversity of rare species of vascular plants (including relict and endemic species) comparing to that of the first and second clusters, which is due to high anthropogenic transformation of their territories.
K-means Cluster Analysis

Ward’s Method

Figure 2. Classification of municipal districts of Samara region by rare species of vascular plants (municipal districts: 1 - Alekseevsky, 2 - Bezenchuksky, 3 - Bogatovsky, 4 - Bolshegovskiy, 5 - Bolshegovinskiny, 6 - Borsky, 7 - Volzhsky, 8 - Elkhovsky, 9 - Isakinsky, 10 - Kamyshlinsky, 11 - Kamskynsky, 12 - Bolshieglushitsky, 13 - Bolshechernisky, 14 - Klyavlinsky, 15 - Koshkinsky, 16 - Krasnoarmeyskky, 17 - Krasnoyarskky, 18 - Neftegorovsky, 19 - Pestravsky, 20 - Privolzhsky, 21 - Sergievsky, 22 - Stavropolsky, 23 - Syzransky, 24 - Shigonsky, 25 - Khvorostyansky, 26 - Chelnovo-Vershinsky, 27 - Shentalinsky, 28 - Shigonsky).

3. Results and Discussion

The total monetary value of the Red List plants in the municipal districts of the Samara Region was calculated by the equation (1):

\[ O_{Ci} = S_i (N_{Ti} T_T + N_{Nm} T_M) \]  

where \( O_{Ci} \) is the total monetary value of the plants included into the Red List of the \( i \)-th region; \( S_i \), the share of the protected areas; \( N_{Ti} \), the number of tree and shrub species in the \( i \)-th region; \( N_{Nm} \), the number of herbaceous plant species in the \( i \)-th region; \( T_M \) and \( T_T \), monetary value of the herbaceous and tree/shrub species, respectively.

When determining \( S_i \) for the Samara Region, several SPNAs were considered, namely, Samarskaya Luka National Park, I.I. Sprygin Zhiguli State Nature Biosphere Reserve, Buzuluksky Bor National Park (the territory of the Samara Region), and the natural monuments. For monetary valuation, the rates to calculate the amount of damage of one ha of herbaceous plants \( (T_M) \) and one ha of trees and shrubs \( (T_T) \) were considered. The monetary value of rare and endangered species included in the Red List of the Samara Region, taking into account their significance, was calculated by the equation (2):

\[ N = \sum_{j=1}^{N_r} K_{pj} = N_{Ti} + N_{Nm} = \sum_{j=1}^{N_{T'}} K_{pj}' + \sum_{j=1}^{N_{T''}} K_{pj}'', \]

where \( N_r \) is the number of rare species in the \( i \)-th municipal district of the Samara Region; \( K_{pj}'', \) coefficient depends on the species status as: rare – 1.0; relict – 1.1; endemic – 1.2.

The calculation results (figure 3) show that the largest number of plant species listed in the Red Book are observed for the Stavropolsky, Volzhsky, and Borsky districts, as well as for the Shigonsky, Syzransky, and Krasnoyarsky districts, where the protected areas cover a significant part of the
territory. These areas are the most "expensive" in terms of the ecosystem services. The lower limit of the monetary value of rare plant species in these districts exceeds 50 million rubles.

Figure 3. Monetary value of rare plant species in the specially protected natural areas in the municipal districts of the Samara Region. Colour scale: 1 - up to 100.0 thousand roubles; 2 - 100.1 – 500.0; 3 - 500.1 – 2000.0; 4 - 2000.1 – 5000.0; 5 – 5000.1 thousand roubles and more)

4. Conclusion
Earlier, we have evaluated all ecosystem services of the Samara Region at 205.038 billion rubles [9, 10]. Therefore, the monetary value of rare plant species in the SPNAs of this region is about 0.04%.

We argue that this share does not correspond to the importance of plants discussed above and this value does not ensure the conservation of the biodiversity of ecosystems in general and the conservation of plants included into the Red List of the Samara Region. We recommend a significant change (increase) in the value of these plants. The increase in the value will ensure the conservation of rare, endangered, and relict plant species, which, in turn, will ensure altogether the ecosystem protection in general and its sustainable development.

We believe that the proposed methodology can be used for the monetary valuation of rare plant species in other administrative units of the Russian Federation. Eventually, this will promote ensuring the conservation of natural capital and natural ecosystems.

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