Evaluation of provisioning, cultural, and supporting ecosystem services of Khukhmorit soum, Govi-Altai province, Mongolia

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Abstract. In this study, our objective was to determine key ecosystem services of Khukhmorit soum that benefit locals both directly and indirectly, and estimate the value. We identified key services based on Millennium Ecosystem Assessment (MA) categories. Ecosystem services are divided into 4 groups: provisioning, regulating, supporting, and cultural. As we identified, in Khukhmorit soum, provisioning services include forage, timber and wood, and food services, regulating services include carbon sequestration, and supporting services include soil protection services provided by *Caragana microphylla, C.leucophloea*, and *C.korshinskii*. However, in this study, we opt out of regulating services due to a lack of data and technical difficulty. We use the market price method when evaluating provisional services, the Willingness-to-Pay approach for the evaluation of cultural services value and the Replacement Cost method for supporting services evaluation. As a result, the value of provisioning services is 109,608,202,680 MNT, the value of cultural services is 846,762,367 MNT, and the value of supporting services is 8,309,369,894 MNT. In total, the value of direct and indirect ecosystem services is 118,764,334,941 MNT. This study will provide a scientific basis for developing and proposing sustainable policy options for decision-makers and raising public awareness. Furthermore, the results of this study will accelerate the effort made by the local government and local people by highlighting the economic benefit they receive from natural capital.

Keywords: Value of ecosystem services, Market price method, Willingness to pay, Replacement cost method

1 Introduction

Khukhmorit soum is located in the southern part of the Great Mongol Sands and belongs to the desert and desert steppe zone. More than 50% of the soum territory is covered with sands. Therefore, Khukhmorit soum is prone to sand migration and sand storms. Ecosystem services provide biodiversity and valuable natural products such as

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fuel, food, and medicinal plants [1]. In other words, ecosystem services are useful products and services that can be obtained from nature [2]. Ecosystem services are classified into four categories: these include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling [3]. The key ecosystem services identified in the Khukhmorit soum and the evaluation methods are further explained in the method section. In Mongolia, research on the evaluation of ecosystem services is rarely done; especially the evaluation of desert ecosystem services has not been studied sufficiently. [4] estimated the value of ecosystem services of the saxaul forest in their report. By evaluating the ecosystem services of Khukhmorit Soum, we can predict the economic cost due to inaction against desertification. In addition, by estimating the economic benefit from natural capital and promoting the research results to locals, not only do decision-makers and administrations make an effort, but also the willingness of local people to contribute may be increased. Therefore, in this study, we tried to define the direct and indirect ecosystem services, which herders and locals are receiving, and calculate the value.

2 Methods

We used the Millennium Ecosystem Assessment (MA) to identify key ecosystem services of Khukhmorit Soum. We also refer to MA to choose compatible methods for evaluating ecosystem services. Within this study, we assessed the value of key ecosystem services of Khukhmorit soum and provided a scientific basis for decision-makers.

2.1 Provisioning service

Provisioning services are direct products obtained from ecosystems [3]. We identified three key provisioning services: (1) forage, (2) *Psammochloa vilosa* and *Agriophyllum pungens* as the source of food, (3) *Artemisia santalinifolia* for timber and wood, which are direct services that locals use.

Forage. We estimate the amount of forage that will be consumed by the Khukhmorit soum livestock by using the statistical data of the number of livestock and the amount of forage consumed by each livestock in the desert and desert steppe region, calculated in [5].

Source of food: *Psammochloa vilosa* and *Agriophyllum pungens* are used to make traditional flour. The total amount of *Psammochloa vilosa* and *Agriophyllum pungens* collected and sold annually was calculated based on a total of 38 surveys of shopkeepers and locals.

Timber and wood. *Artemisia santalinifolia* is the only source of energy for herders in the area. We used questionnaires from 38 households to determine the amount of wood and wood harvested annually in the soum.

The market price method is often used to evaluate the value of provisioning services because raw materials, which herders receive from natural capital, are often sold in the market [6].

$$V=P*Q \quad (1)$$

V- Value, P- Price, Q- Quantity

2.2 Cultural service

Cultural services are intangible benefits locals obtain from ecosystems, such as aesthetic, spiritual enrichment, recreation, and education [6]. For Khukhmorit soum, aesthetic and recreation are key ecosystem services. To assess the value of cultural service, several approaches are used. The most common approach is the "Travel Cost" method. However, statistical data on tourism were not recorded in Khukhmorit soum, Govi-Altai province, resulting in the use of the Willingness-to-Pay method. This method estimates the value of cultural services by asking locals how much they are willing to pay to protect nature and promote local tourism.

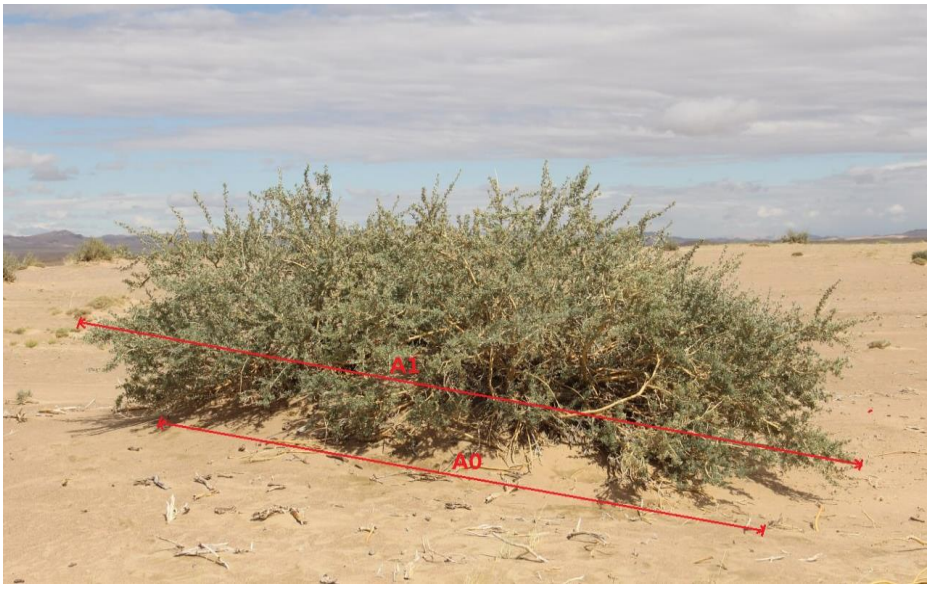
2.3 Regulating Service

Regulating services are obtained from the regulation of ecosystem processes, such as air quality regulation, climate regulation, water regulation, erosion regulation, water purification, pollination, etc. [3]. Within this study, we evaluated the value of ecosystem services, except regulating services. For regulating services, we intended to evaluate the value of carbon sequestration of *Artemisia santalinifolia*, which is the source of energy for herders. However, this type of research was rarely done in Mongolia and due to the lack of data and equipment, we exempted it from the calculation of the value of ecosystem services.

2.4 Supporting service

Supporting services are the foundation of other ecosystem services. In other words, supporting services are necessary for other services to be consistent and productable. The impact of supporting services appears in the long term; however, the impact of other services are relatively direct and short term [3]. In this study, we assessed the value of the soil protection service and identified the dominant vegetation that fixes the sand based on observations. *Caragana microphylla, C.leucophloea,* and *C.korshinskii* are one of the dominant plant species in the semi-arid and arid ecosystem of Khukhmorit soum. For *Caragana microphylla, C.leucophloea,* and *C.korshinskii*, we assessed the value of the accumulated sands using the market price of fertiliser. *Caragana microphylla, C.leucophloea,* and *C.korshinskii* support soil conservation, reduce sand migration, and enrich soil organic matter; the values of supporting services are estimated using the replacement cost method. For example, the value of underground water can be estimated as equal to the value of water from other sources [7]. In the course of field research measurements, the amount of sand accumulated by

Caragana microphylla, C.leucophloea, and *C.korshinskii* was calculated in two categories: height below 150 cm and between 150 and 350 cm. The distribution of 150-350 cm tall *Caragana microphylla, C.leucophloea,* and *C.korshinskii* covers an area of 3,543.5 hectares from the distribution map of plant typology. The distribution of *Caragana microphylla, C.leucophloea,* and *C.korshinskii* with a height of up to 150 cm covers an area of 94,921 hectares (Table 3). For accumulated sand, the useful content replaceable by fertiliser was determined based on laboratory analysis. The useful content of soil replaceable by fertiliser refers to K_2O, Ca, and Mg, which are nutrients that support soil fertility. Biometric and sand accumulation measurements of 89 individual *Caragana microphylla, C.leucophloea and C.korshinskii* are taken according to the picture below (Fig. 1).



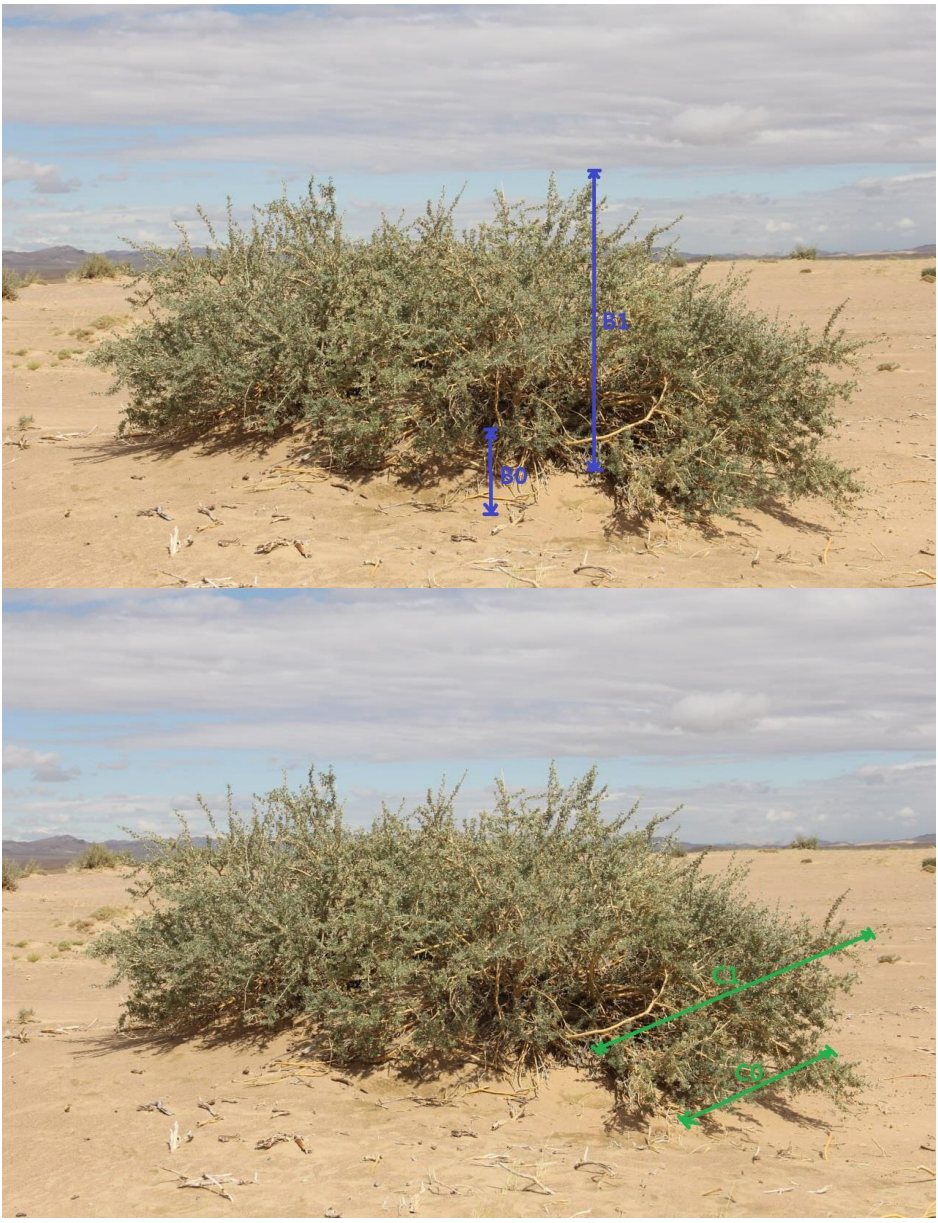


Fig. 1. Biometric and sand accumulation measurements of *Caragana microphylla, C.leucophloea,* and *C.korshinskii.* A0 indicates length of sand accumulation of one individual shrub, A1 indicates the length of shrub, B0 indicates the height of sand accumulation of one indivudual shrub, B1 indicates height of shrub, C0 indicates width of sand accumulation, C1 indicates width of shrub

Length of sand accumulation,

$$SA_{Length}=\frac{y\times Lcar.avg}{\Sigma_1^y\left(\frac{A1i}{A0i}\right)} \quad (2)$$

SA_{Length}- *Average length of sand accumulation of an individual shrub*
A0- Length of sand accumulation
A1-Length of an individual shrub
$L_{car.avg}$-*Average length of shrubs based on biometric measurements*
y −*Number of measurements performed*

Width of sand accumulation,

$$SA_{Width}=\frac{y\times Wcar.avg}{\Sigma_1^y\left(\frac{C1i}{C0i}\right)} \quad (3)$$

SA_{width}-*Average width of sand accumulation of one individual shrub*
C0-Width of sand accumulation
C1-width of an individual shrub
$W_{car.avg}$-*Average width of shrubs based on biometric measurements*
y −*Number of measurements performed*

Height of sand accumulation is calculated as an average of 89 measurements. When measuring the amount of sand accumulated by *Caragana microphylla* and *C.leucophloea and C.korshinskii*, the average amount of sand accumulated per individual shrub was calculated for each height category, assuming that the accumulated sand is equal to half of the ellipsoid.

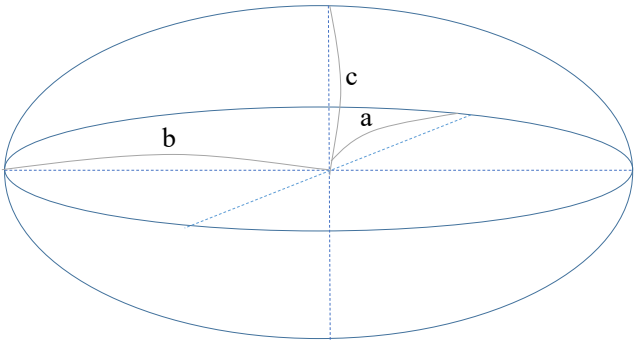


Fig. 2. Ellipsoid

The total value of the key ecosystem services of the Khukhmorit soum is calculated by the sum of each value of services.

$$ESV=\Sigma ES_i \quad (5)$$

where, ES_i is value of each ecosystem services, MNT/year.

3 Results

3.1 Provisioning Services

Forage. One of the direct services provided by the ecosystem is grass and forage services for grazing livestock. In 2021, a total of 184,633 livestock have been counted in the area. The amount of grass that an animal can eat per day from pastures in the desert and steppe regions is between 1.1-1.5 kg for goats and sheep and 6.6-9.9 kg for camels, horses, and cows [5]. Using this estimate, the value of the forage services provided by the Khukhmorit soum pasture is estimated at 105,254,842,680 MNT using the market price method.

Table 1. The amount of forage consumed by single livestock in the desert and the desert steppe zone. (dry matter, kg) [5]

The amount of forage consumed by single livestock in the desert and the desert steppe zone. (dry matter, kg)					
Type of livestock	Camel	Cow	Horse	Sheep	Goat
Summer-Autumn	8.5	9	9.9	1.5	1.5
Winter-Spring	6.3	6.6	7.3	1.1	1.1

Table 2. Value of the forage services provided by the Khukhmorit soum pasture

Name of the soum	The amount of forage consumed, ton *(used the statistical data on the number of livestock recorded in 2021*	The Value of Forage Services, MNT
Khukhmorit	146,187	105,254,842,680

***Psammochloa vilosa* and *Agriophyllum pungens* as a source of food.** One of the ecosystem services that improves the livelihood of local people to some extent is the service of *Psammochloa vilosa* and *Agriophyllum pungens,* which are used to make traditional flour. As a result of the questionnaire, locals collect an average of 103.55 kg of *Psammochloa vilosa* and *Agriophyllum pungens* annually per household for sale and consumption. Using the market price method, the value of services provided by *Psammochloa vilosa* and *Agriophyllum pungens* is equivalent to a total of 2,075,142,000 MNT (Table 2).

Wood and timber: It is common for locals to burn the dung of livestock, especially rural herders. During the questionnaire, residents of the soum centre often use coal and dung, while herders in the countryside use dung and *Artemisia santalinifolia* as fuel. As a result of the questionnaire, a household collects and burns an average of 388 kg of *Artemisia santalinifolia* per year, and a total of 561 rural households are estimated to benefit from wood and wood services worth 4,353,360,000 MNT. The total value of the provisioning services is 109,608,202,680 MNT.

3.2 Cultural services

The Willingness-to-Pay method is used to calculate cultural services, and this method is based on an open questionnaire of 38 local people about how much money they are willing to pay to protect nature and preserve the landscapes. A household in Khukhmorit soum can pay an average of 1,267,608 MNT per year, and the value of cultural services is 846,762,367 MNT.

3.3 Supporting Services

The amount of sand accumulation of one individual shrub (*Caragana microphylla, C.leucophloea,* and *C.korshinskii*) with a height of up to 150 cm is 0.25 m^3, and the amount of sand accumulation for one individual shrub (*Caragana microphylla, C.leucophloea* and *C.korshinskii*) with a height of 150-350 cm is equal to 3.9 m^3 on average (Table 3). Based on this calculation, the sand accumulated in the area spread by *Caragana microphylla, C.leucophloea,* and *C.korshinskii* is 36,675,048.83 tons, of which the useful content that can replace fertilizer is 7,419.08 tons (Table 3). The useful content replaceable by fertilizer is calculated based on laboratory analysis of topsoil samples.

Table 3. The value of supporting services

Name of the soum	Khukhmorit
The area covered by *Caragana microphylla, C.leucophloea*, and *C.korshinskii* with height up to 150 cm, hectares.	94,921
Volume of sands accumulated per individual, m^3	0.25
The amount of sand accumulation, ton	30,018,249.5
The area covered by *Caragana microphylla*, *C.leucophloea*, and *C.korshinskii* with height between 150 and 350 cm, hectares	3,543.5
Volume of sands accumulated per individual, m^3	3.9
The amount of sand accumulation, ton	6,656,799
Total amount of sand accumulation, tons	36,675,048.83

The soil replaceable by fertiliser content is calculated as 7,419.08 tons. Using the market price of fertilizers, the value of soil protection services is 8.3 billion MNT.

Table 4. The useful content of the sand accumulated by *Caragana microphylla, C.leucophloea and C.korshinskii* and the value of the soil protection service

Name of the soum	Khukhmorit
K2O, ton	3,103
Ca, ton	2,701.8
Mg, ton	1,613.98
Content of the accumulated sands that can be replaced by fertilizer, ton	7,419.08

The Value of Soil Protection Service (billion MNT)	8.3

The value of provisioning services for Khukhmorit soum is 109,608,202,680 MNT, the value of cultural services is 846,762,367 MNT, the value of supporting services (soil protection services) is 8,309,369,894 MNT, and the total value of provisioning, cultural, and supporting services is 118,764,334,941 MNT per year (Table 5).

Table 5. The Value of Provisioning, Cultural, and Supporting Services of Khukhmorit Soum

Name of the soum	Khukhmorit
Provisioning, MNT	109,608,202,680
Cultural, MNT	846,762,367
Supporting, MNT	8,309,369,894
Total, MNT	118,764,334,941

4 Discussion and Conclusions

The purpose of this study is to raise public awareness and provide a scientific basis for decision-makers in terms of developing and proposing sustainable policy options and to accelerate the efforts of both local government and residents. Although ecosystem services are divided into 4 subcategories and each category includes various ecosystem services, key services provided by the Khukhmorit soum ecosystem are identified based on observation and Millennium Ecosystem Assessment (MA). For provisional services, we evaluated the value of timber and wood (*Artemisia santalinifolia*), forage, and food services (*Psammochloa vilosa* and *Agriophyllum pungens*). For cultural services, the value of recreation and aesthetic services is estimated. Furthermore, the value of shrub sand fixing services (*Caragana microphylla, C.leucophloea* and *C.korshinskii*) is calculated as a type of supporting service. The total value of these key ecosystem services is estimated to be 118,764,334,941 MNT per year (Table 5). The value of key ecosystem services per capita for Khukhmorit soum is 50,971,818 MNT annually. The value of direct services such as timber and wood (*Artemisia santalinifolia*), forage, and food services (*Psammochloa vilosa* and *Agriophyllum pungens*) per capita for Khukhmorit soum is 47,042,147 MNT annually. The value of indirect services, cultural (aesthetic and recreation) and supporting (soil conservation) services per capita is estimated at 3,929,670 MNT per year. We introduced our research results to local government and residents, giving lectures and having discussions in October 2022. This type of research has not been conducted in semi-arid and arid regions of Mongolia and is one of the first studies, so there are numerous things to improve. For example, despite the need to demonstrate the value of carbon sequestration of *Artemisia santalinifolia* in regulating services, the lack of statistical databases, techniques, technologies, tools and equipment is a major obstacle. Although attempts have been made, we could not estimate the carbon sequestration of *Artemisia santalinifolia*. Therefore, the regulation service is exempted from this study. Furthermore, it can be further investigated to see whether the cost of preventing desertification is greater than

the cost of combating desertification based on this study. In this way, decision makers can adopt rational and scientifically based decisions and budgets.

5 Acknowledgements

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