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Ecosystem Services Valuation of Rig-Ishaqabad Rangeland in Iran: Provisioning and Regulating Services of Rangeland Vegetation Types

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ABSTRACT

One way to better appreciate the value of rangelands with the purpose of developing better policies and make sustainable use of these resources is to determine the monetary valuation of the ecosystem services of these rangelands. Thus, the present study aimed to estimate the economic values of provisioning and regulating services of Rig Ishaqabad Rangeland in Kerman Province, Iran. To this end, samples of the soil and vegetation cover of the region were taken. Following conduction of various experiments, the type and texture of the soil and its content of nitrogen, phosphorus, and potassium nutrients, the soil erosion coefficient, and the amount of carbon absorption for each vegetation type were determined. Then, the monetary values of forage production, carbon absorption, oxygen production, soil production, nutrient absorption, and erosion prevention were estimated using the Revealed Preference Approach. According to the findings, in 2019, the total economic value of the rangeland's services was USD 0.54 million; and the values of provisioning and regulating services were USD 260,102.85 and 283,841.77, respectively. In addition, the economic value of vegetation types of *Artemisia sieberi-Denderostellera lessertii* (Ar si-De Le), *Denderostellera lessertii- Peganum harmala* (De le-Pe ha), *Cousinia congesta* (Co co), *Calligonum polygonoides- Astragalus* sp (Capo-As sp), *Artemisia Sieberi-Peganum harmala* (Ar si-Pe ha) were USD 115,466.42, 159,045.6, 54,815.14, 85,220.66, and 129,396.78, respectively. Based on the results, the De le-Pe ha vegetation type was of the highest value with a value of 49.07 US dollars per hectare. The calculated monetary values can be a useful tool in determining the long-term rental rate of this rangeland and determine the amount of investment to preserve or restore it.

Keywords: Forage production, Gas regulation, Monetary valuation, Rangelands, Revealed preferences.

INTRODUCTION

Rangelands are the largest natural ecosystems on earth, covering 40% of the global surface (Daryanto *et al*., 2019). Over 80% of the rangelands are located in arid and semi-arid regions (Behmanesh *et al*., 2016). In Iran, rangelands constitute 52% of the land and the livelihood of over 916000 rural and tribal households depends on these lands (FRWMOI, 2020). While livestock grazing in rangelands is the most common land-use (Daryanto *et al*., 2019), like other natural ecosystems, they also provide various other services. Generally, natural ecosystems, including rangelands, provide four main services including provisioning, regulating, cultural, and supporting (Baniasadi *et al*., 2020), although most local beneficiaries, ranchers and politicians still

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consider livestock grazing the principal ecosystem service of the rangelands. This one-dimensional view to rangelands has given rise to an overexploitation of rangelands on a global scale. According to the information provided by the Forest, Range and Watershed Management Organization of Iran (FRWMOI), the livestock population of the country is 124 million units, out of which 83 million are dependent on rangelands. However, rangelands in Iran are capable of providing food for 37 million units of livestock for seven months or 24.6 million units in one year. According to these statistics, rangelands in Iran are exploited over 2.2 times more than their permissible capacity (FRWMOI, 2020). The overexploitation of rangelands has led to their destruction and changes in the quantity and quality of providing ecosystem services.

This, however, is not limited to Iranian rangelands since all of the world's natural resources are suffering from the effects of overexploitation. Overgrazing of rangeland, land use change, wrong policies and destructive human activities in many regions of the world have led to rangeland destruction and desertification (Martínez-Valderrama *et al.*, 2018). Some prominent examples include replacing cotton cultivation in rangelands to achieve self-sufficiency in cotton in the Soviet Union, which dried up the Aral Sea and devastated the region (Micklin, 1988) and replacing rangelands with wheat fields, causing wind erosion of sand (Lockeretz, 1978). Also, in Inner Mongolia, China turned "unproductive" rangelands into agricultural production centers (Sheehy, 1992), exposing bare soil to wind erosion. Increased livestock densities and overexploitation of rangelands have also led to pasture degradation in many countries, such as Spain (Ibáñez *et al.*, 2007), Greece (Ibáñez *et al.*, 2014), Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (Mirzabaev *et al.*, 2016).

Due to an increase in humans' economic activities, which exert more pressure on natural resources, a large portion of ecosystem services on the planet, including rangeland ecosystem services, have been depleted or totally destroyed (Sannigrahi *et al.*, 2020). Human activities such as land-use change, changes in vegetation, deforestation and overgrazing of livestock have increased significantly. Among all these factors, depletion of vegetation is one of the most significant factors leading to decreased ecosystem services (Wang *et al.*, 2018; Wang *et al.*, 2019; Zhang *et al.*, 2018; Zhang *et al.*, 2019). Overgrazing alone is a serious factor leading to a decrease in the vegetation of rangelands, which in turn gives rise to the destruction of rangelands' ecosystem services. Such effects necessitate developing policies to support sustainable use of rangelands.

Most ecosystem services are public goods (non-rival and non-excludable) or common pool resources (rival but non-excludable). Therefore, it is not possible to privatize and supply these services in markets (Costanza *et al.*, 2014). Besides, these services have critical importance for the welfare, health, livelihood, and survival of the humankind [Millennium Ecosystem Assessment (MEA), 2005]. However, since such services are free and not paid for, their values are taken for granted. One of the key tools in this regard is identifying various natural services and determining their monetary values. However, this approach has been widely criticized (Schild *et al.*, 2018b). For example, a number of studies have shown that monetary valuation might fail to consider the dynamics of the ecosystem (Polasky and Segerson, 2009; Farley, 2012) or that the type of valuation method adopted by the researcher can change the result of valuation (Martín-López *et al.*, 2014; Schild *et al.*, 2018a).

Despite all the criticism directed at the methods of monetary valuation, it is inevitable to valuate ecosystem services since having a thorough knowledge of their value helps manage them more effectively (Costanza *et al.*, 2014). Nowadays, there is a general consensus that one of the factors contributing to the current dire state of environmental resources is the absence of markets for environmental goods and services (Stapleton and Garrod, 2008). Moreover, optimal allocation of resources requires estimating the true value of ecosystem services and functions and developing mechanisms to appreciate their economic values (Mackenzie *et al*., 2012). In fact, evaluation of ecosystem services is not a goal per se, rather, it is a tool that helps us make effective and proper decisions for logical uses of environmental resources (Bostan *et al*., 2018).

Given the urgency of this matter, the number of studies regarding monetary valuation has risen rapidly over the past decades (Liu *et al*., 2010). The same trend has been true for the valuation of the ecosystem services of rangelands, although fewer studies have been conducted in this field. For instance, Richter *et al*. (2021) provided indicators for evaluating rangeland ecosystem services. This study resulted in a toolbox comprising 85 methods for assessing 29 different ecosystem services indicators for 21 provisioning, regulating, supporting, or cultural ecosystem services. Zakeri *et al*. (2020) conducted a valuation of the function of soil conservation in Northern Iran rangelands. Ning *et al*. (2019) investigated Chinese netizens' willingness to pay for protecting rangeland ecosystem services. The results indicate that there is a significant spatial difference in respondent's WTP. Jahanifar *et al*. (2019) performed an economic analysis of land use changes in forests and rangelands. Bostan *et al*. (2018) determined the economic value of regulating gas in Sheikh Musa Rangeland in Iran. Schild *et al*. (2018b) conducted a meta-analysis on monetary valuation of rangeland ecosystem services. Ahmadpour *et al*. (2016) performed an economic evaluation of rangelands. Each of these studies investigated the valuation of a number of rangeland ecosystem services. Out of the four groups of rangeland ecosystem services, the provisioning services (forage production) and regulating services (regulating gas, water, and soil) are the most important ones leading to the production and support of renewable resources. Moreover, most cases of imbalance between the supply and demand of ecosystem services in a region are related to the regulating and provisioning services (Cardinale *et al*., 2012; Yang *et al*., 2018). Payments for Ecosystem Services (PES) programs have been put forth as potential mechanisms to protect the quality and quantity of ecosystem services while increasing economic viability of livestock operations (Roche *et al*., 2021).

Therefore, the purpose of the present study was to estimate the monetary value of regulating and provisioning ecosystem services of the Rig Ishaqabad Rangeland located in Kerman Province, Iran. To this end, samples of soil and vegetation types were obtained from this rangeland, in 2018. Following that, laboratory experiments were conducted, and finally monetary valuation methods were used to determine the values of ecosystem services. The insights provided by this study can increase the knowledge of policy makers and local beneficiaries and help them in the sustainable management of the rangeland.

MATERIALS AND METHODS

Study Area Description

The Rig Ishaqabad Rangeland is situated in Kerman Province, 10 km away from the city of Sirjan, and covers 12,879 km^2. It is located at the longitude of 55° 08' 18" to 55° 39' 46" and latitude of 29° 22' to 29° 40' 01" and an altitude range of 190-2,000 meters from the sea level. The average annual precipitation during the past 30 years has been 131 mm and the average annual temperature has been 18.4°C. This rangeland is predominantly sheep grazing. The geographical location of the area under study is shown in Figure 1. (Department of Natural Resources and Watershed Management of Kerman Province (DNRWMKP), 2018).

This rangeland features five vegetation types identified based on major plant species. Table 1 presents the vegetation types and the area covered by each type.

Economic Valuation of Environmental Services

Generally, rangeland ecosystems provide four types of environmental services: cultural, regulating, provisioning, and supporting services (Sala *et al*., 2017). The present study valuates the regulating and provisioning services of the Rig Ishaqabad Rangeland. There are two approaches of economic valuation put forth by economists (Ojeda *et al*., 2008; Baniasadi *et al*., 2020): Stated Preferences (SP) and Revealed Preferences (RP). These two approaches differ in data gathering methods and sources. The SP valuation methods estimate consumers' willingness to pay for environmental attributes based on a hypothetical market. The RP methods use actual and substitute markets to estimate the value of environmental goods in the consumers' minds (Ojeda *et al*., 2008). In the present study, the RP approach, including market price, replacement cost, and hedonic pricing was adopted to evaluate the provisioning and regulating services. The datasets generated during the current study are available from the corresponding author on reasonable request.

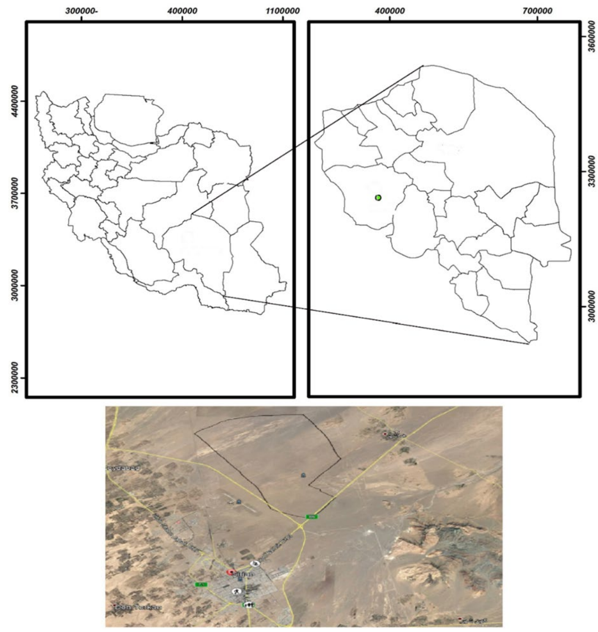

Figure 1. Location of Rig Ishaqabad Rangeland in Kerman Province, Iran.

Table 1. Area and vegetation cover of Rig Ishaqabad Rangeland types. [a]

Vegetation type	Abbreviation	Area (ha)	Vegetation cover (%)
Artemisia sieberi-Denderostellera lessertii	Ar si-De Le	2850	31
Denderostellera lessertii-Peganum harmala	De le-Pe ha	3241	33
Cousinia congesta	Co co	1428	39
Calligonum polygonoides-Astragalus sp	Ca po-As sp	1795	30
Artemisia Sieberi-Peganum harmala	Ar si-Pe ha	3565	27
Total	-	12879	-

[a] Source: DNRWMKP, 2018.

Revealed Preference Approach

Revealed Preference (RP) approach is based on the observation of individual choices in existing markets that are related to the ecosystem service that is the subject of valuation. In this case, it is said that consumers "reveal" their preferences through their choices. The main methods within this approach are (Ghermandi *et al*., 2011): (a) The travel cost method, (b) The Hedonic Pricing (HP), (c) Market price, and (d) Benefit transfer method.

In revealed preference methods, market imperfections and policy failures can distort the estimated monetary value of ecosystem services. Scientists need high-quality data on each transaction, large data sets, and complex statistical analyses. As a result, revealed preference approaches are expensive and time-consuming. Generally, these methods have the appeal of relying on actual/observed behavior, but their main drawbacks are the inability to estimate non-use values and the dependence of the estimated values on the technical assumptions made on the relationship between the environmental good and the surrogate market good (Kontoleon and Pascual, 2007).

The advantages of this method that led to its application in the present study are: (1) Use of the observed data and the real preferences of consumers; (2) Use of generally accepted and standard economic techniques; and (3) In this study, in order to evaluate the services considered, access to related markets, price, quantity and cost was easily possible.

Market Price Methods

Market price-based approach is one of the direct market valuation approaches. The main advantage of using these approaches is that they use data from actual markets, and thus reflect actual preferences or costs to individuals. Moreover, such data i.e., prices, quantities and costs, exist and thus are relatively easy to obtain (Pascual *et al*., 2012).

Market price-based approaches are most often used to obtain the value of provisioning services (such as rangeland forage), since the commodities produced by provisioning services are often sold on agricultural markets, for instance. In well-functioning markets, preferences and marginal cost of production are reflected in the market price, which implies that these can be taken as accurate information on the value of commodities (Pascual *et al*., 2012). The price of a commodity times the marginal product of the ecosystem service is an indicator of the value of the service, consequently, market prices can also be good indicators of the value of the ecosystem service that is being studied.

Assumptions of Replacement Cost

The Replacement Cost method estimates the costs incurred by replacing ecosystem services with artificial technologies or human-made substitutes (Kumar, 2012). If z (environmental good) and x (market good) are complete substitutes for each other, the value of each change in environmental quality can be estimated using the estimation of changes in demand for x. The methods of replacement cost and defense spending are based on this assumption. Mäler (1974) shows that the final Willingness To Pay for environmental good ($MWTP_z$) can be expressed in the form of a substitution rate between an environmental good and a market good:

$$MWTP_z = -\frac{\partial e(p,z,u)}{\partial z} = -p_i\left(\frac{\partial u(.)/\partial z}{\partial u(.)/\partial x_i}\right) = p_i\left(-MRS_{zx_i}\right) \quad (1)$$

Where, $\partial e(p, z, u)$ is the cost function; the Marginal Rate of Substitution (MRS) is not visible. With the assumption of a utility function, which is weakly separable, and a consumption function of three private goods(x_1, x_2 and x_3), we have:

$$u = \left[u_1(x_1), u_2(x_2), (C.x_3^{-\alpha} + (1 - C)z^{-\alpha})^{-1/\alpha}\right] \quad (2)$$

MRS_{x_3z} is independent of x_1 and x_2, and the Marginal Rate of Substitution is defined as follows:

$$MRS_{x_3z} = \frac{C}{1-C} \times \left(\frac{z}{x_3}\right)^{1/\sigma} \quad (3)$$

In the above equation, σ is the elasticity of substitution and, between x_3 and z, is expressed as follows:

$$\sigma = -\frac{d\left(\frac{x_3}{z}\right)}{\left(\frac{x_3}{z}\right)} \cdot \frac{MRS_{x_3z}}{dMRS} \quad (4)$$

It is assumed that the elasticity of substitution is constant and the Marginal Willingness To Pay is obtained as follows:

$$MWTP_z = P_3 \times \left(-S\left(\frac{z}{x_3}\right)^{1/\sigma}\right) \quad (5)$$

Where:

$$S = \frac{C}{1-C} \quad (6)$$

Where, S is the technical rate of Substitution that can be calculated using the consumption data or the household production function (Freeman, 1993). In the MWTP, it can be observed that information of σ and C are required in order to calculate the MWTP. If x_3 and z are perfect substitutes, the elasticity of substitution between these variables will be infinite, and then, MWTP will be as follows:

$$MWTP_z = P_3 \times S \quad (7)$$

Where, P_3 is the price of x_3.

Provisioning Services: Forage Production

The Replacement Cost and Hedonic Pricing Approaches were used to valuate the forage production service. The replacement scenarios for valuation need to be a near perfect substitution for services (De Lange *et al*., 2013). To valuate the rangeland forage through the replacement cost approach, the equivalent nutritional content needs to be substituted or supplemented by other kinds of forage (Nábrádi, 2007). This means other marketable forage can replace the rangeland forage through their inner content. In this approach, the price is a function of the content of Total Digestible Nutrients (TDN) (Hedonic pricing method):

$$P_i = f(\%TDN_i) + \varepsilon_i \quad (8)$$

Where, P_i is the Price of the i^{th} feedstuff; $\%TDN_i$ is the TDN percentage of the i^{th} feedstuff and ε_i is the error term (Almas *et al*., 2013). The ranchers in the area use wheat straw, wheat bran, maize, and barley as a substitute for rangeland forage in the livestock's diet. The absence of intercept in the equation indicates that if TDN is zero, the price of forage is zero, and thus forage is of no economic value (Almas *et al*., 2013).

Total Digestible Nutrients (TDN)

Each 4.4 Mcal of Digestible Energy (DE) is equal to a kilogram of TDN. DE is calculated through its relation with Metabolizable Energy (ME) (National Research Council, 1985):

$$ME = DE \times 0.82 \quad (9)$$

ME is calculated through Equation (3) (Standing Committee on Agriculture, 1990):

$$ME = (0.17DMD\%) - 2 \quad (10)$$

Dry Matter Digestibility (DMD) is calculated through the formula developed by Oddy *et al*. (1983) (Equation 4):

$$DMD = 83.56 - (0.824ADF) + (2.626N) \quad (11)$$

Acid Detergent Fiber (ADF) was determined by Fibertec System 1010 Heat Extractor (Switzerland) and nitrogen content was determined using the Kjeldahl method.

Forage Production and Available Forage

To estimate forage production in 2018, sampling plots were used. The sample plots (4 m^2) were located in random transects (150 meters). To determine available forage in rangeland, the Proper Use Factor (PUF) for different types was calculated based on Range Condition (RC), Range Trend (RT), and Soil Erosion sensitivity (SE) (Table 3). Soil erosion sensitivity was determined through the Erosion Potential Method

(EPM), range condition was determined using the four-factor method, and range trend was determined using the survey balance method (Amiri *et al*., 2014; Amiri and Mohamed Sharif, 2012; Arzani *et al*., 2008).

Regulating Services

Gas Regulation

First, the amounts of absorbed CO_2 and released oxygen in the rangeland ecosystem were determined. Next, the economic value of absorbed CO_2 was estimated using the shadow price of carbon estimated by the World Bank (2017) and the economic value of oxygen release was estimated using the replacement cost method. This method calculates the economic value based on the easily available data without the need for hydrological modeling (Barth and Döll, 2016). The economic values of these services were calculated through the following equation:

$$V_e = G_e \times P_c \qquad (12)$$

Where, V_e is the economic Value (USD), G_e is the total amount of absorbed CO_2 or released oxygen (ton) and P_c is the cost of released oxygen or absorbed CO_2 (USD ton^{-1}). The average cost of absorbed CO_2 based on the average shadow price of CO_2 was set to USD 57.5 (World Bank, 2017) and the average released oxygen was set to 4.64 USD t^{-1} based on the cost of oxygen production in the industry.

Amount of Carbon Sequestration and Absorbed CO_2

To determine the dry weight and percentage of humidity, the samples were dried in the oven for 72 hours at 70°C. To determine the carbon sequestration conversion coefficient, the dried samples were powdered in an electric mill and 10 grams of the dried sample was burned at 500-600°C for four hours. Based on the fact that the weight ratio of CO_2 to carbon is 3.67, the amount of absorbed CO_2 was determined.

Amount of Released Oxygen

In order to estimate the amount of oxygen supply, the photosynthesis and respiration formula was applied as follows (Guo *et al*., 2001; Xue and Tisdell, 2001; Bostan *et al*., 2018):

$$CO_2(264g) + H_2O(108g) \rightarrow C_6H_{12}O_6(180g) + O_2(193g) \rightarrow \text{Amylase}(162g) \qquad (13)$$

In the production of 162 g of dry matter, 193 g of oxygen is released. In other words, in the production of 1 g of dry matter, 1.19 g of oxygen is released.

Soil Regulation

Soil regulation service was evaluated through the valuation of soil production, material absorption, and preventing soil erosion services. First, samples of the soil were collected and the soil texture was determined through the hydrometer method at 20°C. Next, in order to evaluate the quality of the rangeland soil, major nutrients of the soil were measured focusing on Nitrogen (N), Phosphorus (P), and potassium (K). The total amount of nitrogen was measured through the Kjeldahl method (Zha *et al*., 2018) which consists of three stages: mineralization (change of organic nitrogen to mineral nitrogen), distillation, and titration (Hesse, 1971). The amount of phosphorus in the soil was measured by applying the Olsen method (Olsen and Sommers, 1982). The amount of potassium in the soil was measured using the flame photometer device and extraction from ammonium acetate (Jackson, 1969). Following the identification of the soil elements, the soil quality value was calculated using the market price method.

To valuate the benefits of the soil production service of the rangeland, the amount of soil production was calculated based on the volume and weight of the annual produced soil. Next, taking into account the weight of the area's soil, the amount of produced soil in each vegetation type was determined in tons. After that, using the nutrient cost replacement method, the economic value of the soil production service was determined.

The economic value of material absorption is calculated using the amount of nitrogen and phosphorus released by each sheep and taking into account the average monthly grazing capacity per hectare. The economic value of the absorption of these materials by the rangeland ecosystem was calculated through the following equation:

$$\mathrm{VMA} = \mathrm{AUM} \times \mathrm{S} \times \mathrm{D_f} \times \mathrm{K} \times \mathrm{P_f} \quad (14)$$

Where, VMA is the Value of Material Absorption in the rangeland, AUM is the Average animal Unit per Month in the rangeland, S is the area of the rangeland, D_f is the Dung released by each livestock in tons, K is the ratio of livestock staying on rangeland, which is the ratio of grazing months to all months of the year, P_f is the market Price of the chemical fertilizer, which is equivalent to the dung released by livestock.

RESULTS

Economic Valuation of Forage Production

Following the calculation of ME and DE, the TDN contents of different rangeland types were measured. Table 2 shows ME, DE, and TDN calculated for the major plant species.

The relationship between TDN and the prices of different types of forage was calculated according to Equation (1) (Figure 2). Based on TDN= 0.42, the average price for a kilogram of forage (dry) was calculated as 87,975 Rials (USD 0.82).

After the average price of one kilogram of forage was determined, proper use factor for different types was determined based on RC, RT, and SE. Then, the available forage for different types of rangelands was calculated by multiplying the proper use factor by forage production. Finally, the product of forage price multiplied by the amount of available forage in each vegetation type of rangeland was used to determine the economic value of forage (Table 3). The total economic value of rangeland forage was USD 260,102.85 a year and USD 20.20 per hectare.

Economic Valuation of Regulation Services

Gas Regulation Service

After the plant samples were dried, the total dry material produced per year for different vegetation types was determined. Based on the amount of organic carbon, the total amount of absorbed carbon was

Table 2. ME, DE, and TDN for the major plant species.

Species	N (%)	ME (Mcal kg^{-1})	DE (Mcal kg^{-1})	TDN (g kg^{-1})
Artemisia Siebere	48.9	1.69	2.06	0.47
Kochia Scoparia	46.9	1.55	1.89	0.45
Denderostellera Lessertii	48.3	1.50	1.83	0.42
Echinops Lalesarensis	45	1.43	1.74	0.39
Allagi Mannifera	52.8	1.36	1.66	0.38
Peganum Harmala	46	1.28	1.56	0.35
Cousinia Congesta	53.1	1.47	1.79	0.41
Calligonum Polygonoides	52	1.58	1.92	0.44
Astragalus Sp	44.3	1.65	2.01	0.46

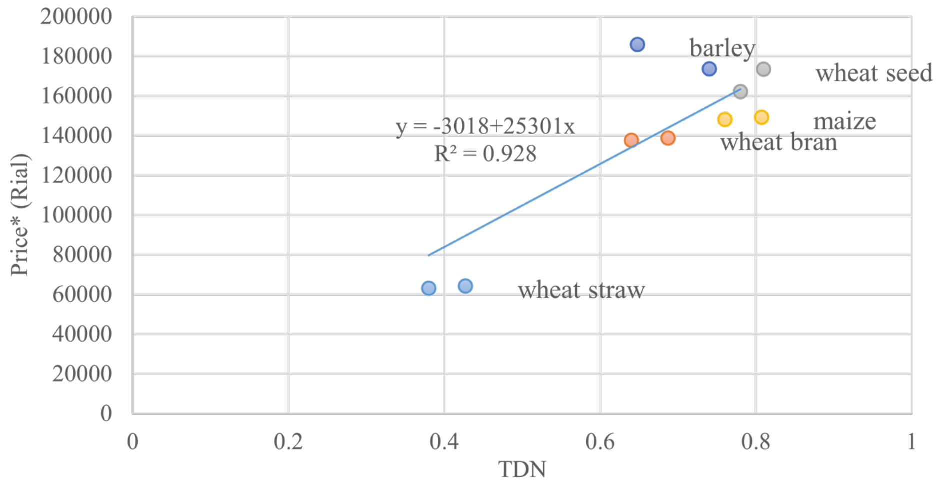

Figure 2. The relationship between price and TDN. * Rial is the currency of Iran. Each US dollar (USD) in 2019 was 107,830 Rials on average.

Table 3. Economic value of forage for different rangeland vegetation types.

Vegetation type	PUF [a]	Forage production (t yr^{-1})	Available forage (Ton)	The economic value of forage (USD)
Ar si-De Le	20	319.2	63.84	52084.95
De le-Pe ha	25	405.13	101.28	82632.11
Co co	25	132.80	33.20	27087.64
Ca po-As sp	20	245.92	49.18	40126.77
Ar si-Pe ha	20	356.50	71.30	58171.38
Total	-	1459.54	318.81	260102.85

[a] Data source: DNRWMKP (2018)

Table 4. Annual amount of carbon and CO_2 absorption and oxygen production in different types of rangelands.

Type	Anuual production of dry matter (Ton)	Total annual absorbed carbon (Ton)	Total absorbed CO_2 (Ton)	Absorbed carbon (ton ha^{-1})	Absorbed CO_2 (t ha^{-1})	Annual oxygen production (Ton)	Produced oxygen (t ha^{-1})
Ar si-De Le	478.80	226.95	832.91	0.08	0.29	569.77	0.20
De le-Pe ha	607.69	282.17	1035.56	0.09	0.32	723.15	0.22
Co co	199.21	97.71	358.60	0.07	0.25	237.06	0.17
Capo-As sp	368.87	167.47	614.61	0.09	0.34	438.96	0.24
Ar si-Pe ha	534.75	249.37	915.19	0.07	0.26	636.35	0.18
Total	2189.32	1023.67	3756.87	0.40	1.46	2605.29	1.01

determined; and based on the weight ratio of CO_2 to carbon (3.67), the amount of absorbed CO_2 was calculated. Based on the fact that in producing 1 g of dry matter 1.19 g of oxygen is released, the supply of oxygen for different types of rangelands was calculated. Table 4 shows the amount of absorbed CO_2 and released oxygen in the rangeland ecosystem.

According to Table 4, the total amounts of carbon absorbed and oxygen produced in the rangeland were 1,023.67 and 2,605.29 tons per year, respectively. As shown by Equation (5), the annual economic values of CO_2 absorption and oxygen production services of the rangeland were USD 216,020.21 and 12,080.5, respectively (Table 5). Therefore, the economic value of the rangeland's gas regulating service was calculated as USD 228,100.71 per year and USD 17.71 per hectare.

Soil Production Service

Considering the presence of five vegetation types in the rangeland and differences in the soil production for each type, the amount of produced soil by each type in a year and their respective economic values (considering the value of nutrients N, P, and K present in the soil) are presented in Table 6.

Material Absorption Service of Soil

The Average animal Unit per Month (AUM) for Ar si-De Le, De le- Pe ha, De le-Pe ha, Capo-As sp, and Ar si-Pe ha is 0.8, 0.89, 0.66, 0.98, and 0.72, respectively (DNRWMKP, 2018). Based on this, the total animal units were calculated for each type of the rangeland.

According to the studies conducted in Iran, the average yearly amounts of released nitrogen and phosphorus for each unit of sheep and goat are 6.2 N and 2.8 P_2O_2 kg (Alipour *et al*., 2015). Since the grazing period lasts for three months, the total amounts of the above-mentioned elements released by the animals in the rangeland (the

Table 5. Economic value of rangeland's gas regulating service.

Species	Annual economic value of absorbed CO_2 (USD)	Annual economic value of produced oxygen (USD)	Economic value of gas regulation (USD)	Economic value of gas regulation per hectare (USD)
Ar si-De Le	47892.38	2642.03	50534.41	17.73
De le-Pe ha	59544.83	3353.15	62897.98	19.41
Co co	20619.37	1099.23	21718.60	15.21
Capo-As sp	35339.96	2035.43	37375.39	20.82
Ar si-Pe ha	52623.67	2950.76	55574.43	15.59
Total	216020.21	12080.5	228100.71	–

Table 6. Economic value of soil production service in the rangeland ecosystem.

Species	Weight of produced soil (ton)	Amount of major nutrients in produced soil (ton)			Annual economic value of soil production services (USD)
		N	P	K	
Ar si-De Le	3534	4.24	10.60	42.41	8298.43
De le-Pe ha	3370.64	4.04	10.11	40.45	7914.49
Co co	1713.60	2.05	5.14	20.56	4022.53
Capo-As sp	1866.80	2.21	5.60	22.40	4380.13
Ar si-Pe ha	4420.60	5.30	13.26	53.05	10380.04
Total	14905.64	17.89	44.72	178.87	34995.64

number of animals multiplied by the amounts of released nitrogen and phosphorus) were calculated. Using the cost replacement method and employing the equivalent value of marketable fertilizers, the total and per hectare values of the material absorption service of Rig Ishaqabad Rangeland were calculated. The results are presented in Table 7.

Soil Erosion Prevention Service

The average amount of erosion on Iranian rangelands is 0.09 t ha^{-1} per year. Erosion, especially wind erosion in the hot and dry areas, is highest in areas without vegetation. In Iran, maximum erosion for areas without vegetation is 0.27 t ha^{-1} per year (Baniasadi, 2017). The difference in soil erosion of rangeland and without vegetation lands is 0.18 ton ha^{-1} per year. The total amount of soil preserved from erosion and its respective economic value are presented in Table 8, according to the rangeland soil type and the density of each soil type.

According to the calculations, every year, 2,318.22 tons of soil are conserved from erosion due to the vegetation of this rangeland. The value of this amount of conserved soil is USD 5443.4.

DISCUSSION

In addition to producing forage, rangelands have many environmental and social benefits, most of which are not marketable. Therefore, quantifying their values is of utmost importance in regulating the process of their conservation and preventing their destruction (Li *et al*., 2006). This study measured the economic values of the provisioning and regulating services of the Rig Ishaqabad Rangeland in Kerman Province, Iran. Of provisioning services,

Table 7. Total and per hectare values of material absorption service for each vegetation type.

Species	Economic value of nutrients absorption service in hectare			Total economic value of nutrients absorption service		
	N (kg)	P (kg)	Economic value (USD ha^{-1})	N (Ton)	P (Ton)	Total economic value (USD)
Ar si-De Le	9548	2688	1173.44	27.21	7.66	3344.06
De le-Pe ha	10622.15	2290.40	1253.52	34.43	9.69	4231.20
Co co	7877.10	2217.60	968.09	11.25	3.17	1382.82
Capo-As sp	11696.30	3292.80	1437.46	20.99	5.91	2579.71
Ar si-Pe ha	8593.20	2419.20	1056.10	30.63	8.62	3764.17
Total	48336.75	13608	5888.61	124.52	35.05	15301.96

Table 8. Economic value of soil erosion prevention service of rangeland ecosystem.

Species	Area of each species (ha)	Soil texture	Reduction in soil erosion (ton)	Amount of major nutrients in the soil (ton)			Economic value of the preventing soil erosion service (USD)
				N	P	K	
Ar si-De Le	2850	Sandy	513	0.62	1.54	6.16	1204.57
De le-Pe ha	3241	Loam-Sandy	583.38	0.70	1.75	7.00	1369.82
Co co	1428	Sandy-Loam	257.04	0.31	0.77	3.08	603.55
Capo-As sp	1795	Loam-Sandy	323.1	0.39	0.97	3.88	758.66
Ar si-Pe ha	3565	Sandy	641.7	0.77	1.92	7.70	1506.76
Total	12879	–	2318.22	2.78	6.95	27.82	5443.37

forage production and of regulating services, gas regulation service (absorbed CO_2 and released oxygen), and soil regulation (soil production, preventing soil erosion, and nutrients absorption) were investigated and valuated as a number of the rangeland's environmental services. Five major species were identified in this rangeland and the provisioning and regulating services of each vegetation type were determined, as summarized in Table 9.

The results revealed that among the various services of the rangeland, forage production had the highest economic value (USD 260,102.85). The value of this service is higher than those found by other studies conducted on other Iranian rangelands by Hosseini *et al*. (2018) and Yeganeh (2014). The reason behind this is an increase in the price of all kinds of forage in Iran. Gas regulation is one of the most important services of natural ecosystems, especially rangelands. In this study, the gas regulating service was the second most valuable service after forage production (USD 228,100.80). The present study found that in each hectare of the Rig Ishaqabad Rangeland, an annual average of 1.46 tons of CO_2 is absorbed and a total of 1,023.7 tons of carbon is absorbed per year. Also, in each hectare of the rangeland, an annual average of 1.01 tons of oxygen, and a total of 2,605.3 tons in the whole rangeland are produced. The results of other studies conducted on Iranian rangelands confirm the results of this study regarding annual oxygen production and CO_2 absorption.

According to Yeganeh *et al*. (2015), the studied Semi-Steppe rangelands sequestrate about 1.9 tons of CO_2 per year ha^{-1} and produce 1.5 tons of oxygen per year ha^{-1}. The overall value of gas regulation function was estimated about 379,780 USD per year (This figure is based on the exchange rate of the study year; based on exchange rate in our study, that figure would be 121513 USD). Bostan *et al*. (2018) estimated the economic value of gas regulation function of Sheikh Musa ecosystem in Iran as 318,364 USD per year and 30.3 USD per ha. The difference in value calculated in different rangelands is due to differences in the type of rangeland vegetation, valuation method and rangeland area. Exchange rate fluctuations also affect the value of rangeland services in US dollars, while the amounts are closer to the Iranian currency.

Among various services, soil regulation in the Rig Ishaqabad Rangeland is of the lowest economic value (USD 55,740.97). The results of soil regulation service evaluation are in line with the results of the study of Costanza *et al*. (2014), Yeganeh *et al*. (2015) and Bostan *et al*. (2019). Despite

Table 9. Annual economic values of the Rig Ishaqabad Rangeland services (USD).

Services	Major vegetation type					Total
	Ar si-De Le	De le-Pe ha	Co co	Capo-As sp	Ar si-Pe ha	
Provisioning service						
Forage production	52084.95	82632.11	27087.64	40126.77	58171.38	260102.85
Regulating services						
Absorbed CO_2	47892.38	59544.83	20619.37	35339.96	52623.67	216020.2
Produced oxygen	2642.029	3353.148	1099.23	2035.426	2950.756	12080.59
Total gas regulation	50534.41	62897.98	21718.6	37375.39	55574.43	228100.80
Soil production	8298.43	7914.49	4022.53	4380.13	10380.04	34995.64
Nutrients absorption	3344.06	4231.2	1382.82	2579.71	3764.17	15301.96
Preventing soil erosion	1204.57	1369.82	603.55	758.66	1506.76	5443.37
Total soil regulation	12847.06	13515.51	6008.90	7718.50	15650.97	55740.97
Total monetary valuation	115466.42	159045.6	54815.14	85220.66	129396.78	543944.62

the lowest value of this service, it is of particular importance. Soil erosion leads to the destruction of valuable soil resources, which take years to form again. Soil, together with water resources, preserve rangelands and their vegetation in the long term and other rangeland ecosystem services are in one way or another dependent on these resources. The Rig Ishaqabad Rangeland ecosystem preserves an average 2,318.22 tons of soil annually and prevents soil erosion. This service allows policy makers in the natural resources and agricultural sector to develop appropriate policies and plans in order to make sustainable use of the rangeland (as a renewable natural resource).

Based on the results of this study, in 2019, the total economic value of the rangeland's ecosystem services was USD 0.54 million and the economic values of the vegetation types Ar si-De Le, De le-Pe ha, Co co, Capo-As sp, and Ar si-Pe ha were USD 115,466.42, 159,045.6, 54,815.14, 85,220.66, and 129,396.78, respectively. The economic value of each hectare of the rangeland was USD 42.23 and the values of provisioning and regulating services were calculated as USD 260,102.85 and 283,841.77, respectively. The DE le- Pe ha vegetation type was of highest economic value, although it ranked second in terms of area. This vegetation type provides USD 49.07 value of provisioning and regulating service per hectare, which is the highest value for all vegetation types in this rangeland. As a result, given the compatibility of this vegetation with the climate of the region, it can increase in area under cultivation in this rangeland in other similar ones. The results of this study are different from other studies conducted in Iran, in that the value of provisioning and regulating services has been estimated separately by the type of vegetation. In other studies, however, the conservation, provisioning and regulating values have been estimated for the entire rangeland, regardless of the type of vegetation. Therefore, this innovation can be considered in future studies to evaluate other rangelands in other areas.

CONCLUSIONS

The present study applied a combination of laboratory experiments and economic valuation approaches to determine the monetary values of the ecosystem services and vegetation of the Rig Ishaqabad Rangeland in Kerman Province, Iran.

Given the importance of the provisioning and regulating services of rangelands for the well-being and livelihood of the residents of the region, the monetary values of these services were determined. The monetary values of cultural and supporting services were not determined since soil and vegetation sampling, conducting tests to specify the physical features of the soil including soil type, texture, and nutrients, specifying the vegetation type, the presence of different vegetation types in the rangeland, determining the amount of absorbed carbon, and the nutritional value of each vegetation type produced a heavy workload. Thus, in order to complete the information on the values of this rangeland's environmental services, it is recommended that future researches address these services as their future point of focus. The calculations did not address the values of all environmental services of the Rig Ishaqabad Rangeland, namely, preserving plant and animal diversity, habitat, recreational, tourism, heritage, scientific and cultural services. These services are mainly valuated through the stated preference approach, which could be addressed in future studies.

Although the monetary values determined in this study do not reflect the values of all environmental services of this rangeland, they are considerable and show the remarkable role of these services in the well-being of rural and tribal communities formed around this rangeland. Ranchers and beneficiaries of the rangeland understand the value of forage production service because they use forage to raise sheep and produce meat. However, they do not grasp the value of regulating services, which are of considerable value. This lack of understanding has led to an overexploitation of the rangeland. If this trend continues, the rangeland will be inevitably destroyed, leading in turn to the destruction of ecosystem services including forage production, which directly affects the livelihood of the region inhabitants. As a result, the findings of this study provide insights for the inhabitants of the region regarding the role of true value of the rangeland's vital regulating and provisioning services. They also have clear implications for policy makers concerning effective management and developing policies suitable for sustainable exploitation of this rangeland. The values determined in the study can clarify the amount of investment to preserve or restore the rangeland. Since the Iranian government has been required to specify the economic value of environmental resources, reform national accounts and calculate green GDP in the Iranian economic development plans, it is recommended that the values of the environmental services calculated in this study and other studies of the kind be used in preparing national accounts. Reforming national accounts and considering the values of ecosystem services ensures that the role of these services are taken into account in macro-planning and allocating budgets to preserve these environmental resources. In addition, the monetary values calculated in this study can be applied as the long-term rental rate in leasing the rangeland to the private sector.

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ارزشگزاری خدمات اکوسیستمی مرتع ریگ اسحاق آباد در ایران: خدمات تأمینی و تنظیمی تیپ‌های گیاهی مرتعی

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چکیده

یکی از راه‌های درک بهتر ارزش مراتع جهت سیاست‌گذاری‌های مناسب و استفاده پایدار از این منابع، ارزشگذاری اقتصادی خدمات اکوسیستمی آن‌ها می‌باشد. بنابراین مطالعه حاضر، با هدف برآورد ارزش اقتصادی خدمات تأمینی و تنظیمی مرتع ریگ اسحاق آباد در استان کرمان انجام شده است. بدین منظور، از خاک و پوشش گیاهی منطقه، نمونه برداری شد. پس از انجام آزمایشات مختلف، نوع و بافت خاک، مقدار مواد مغذی نیتروژن، فسفر و پتاس در خاک، ضریب فرسایش خاک، انواع تیپ‌ها و گونه‌های گیاهی و میزان جذب کربن هر تیپ گیاهی تعیین شد. سپس ارزش اقتصادی کارکردهای تولید علوفه، جذب کربن، تولید اکسیژن، تولید خاک، جذب مواد مغذی و جلوگیری از فرسایش خاک با استفاده از رویکرد ترجیحات آشکار شده برآورد شد. نتایج نشان داد که ارزش اقتصادی کل خدمات اکوسیستمی مرتع ۰/۵۴ میلیون دلار و ارزش خدمات تأمینی و تنظیمی به‌ترتیب ۲۶۰۱۰۲/۸۵ و ۲۸۳۸۴۱/۷۷ ۷ دلار در سال ۱۳۹۸ بوده است. همچنین ارزش اقتصادی تیپ‌های گیاهی Ar si-De Le، De le- Pe ha، Co co، Capo- As sp و Ar si- Pe ha به‌ترتیب ۴۲/ ۱۱۵۴۶۶، ۱۵۹۰۴۵/۶۰، ۵۴۸۱۵/۱۴، ۸۵۲۲۰/۶۶ و ۱۲۹۳۹۶/۷۸ دلار می‌باشد. با توجه به نتایج، تیپ گیاهی De le- Pe ha با ارزش ۴۹/۰۷ دلار در هر هکتار، با ارزش‌ترین تیپ گیاهی مرتع است. ارزش‌های پولی محاسبه شده می‌تواند راهنمای مناسبی برای تعیین نرخ اجاره بلندمدت این مرتع باشد و میزان سرمایه‌گذاری برای حفظ یا احیای آن را مشخص نماید.