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RESEARCH PAPER

The Economic Valuation of Ecosystem Services: Economic Value-Based Management in a Case Study of Protected Areas in Iran

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Abstract

Valuing the ecosystem services can relate the concepts of structure and function to management issues. The absence of a valuation system endangers the ecosystem services, such as regulating services, that cannot be traded in the economic market. Valuing the ecosystem services can facilitate managers' and policy makers' understanding of ecosystem services and their place in decision-making processes. To protect the Protected Areas (PAs), the ecosystem components, opportunities, and threats should first be identified for these ecosystems. In this study, the ecosystem services were evaluated for three services (i.e., forage production, oxygen production, and carbon sequestration), and market pricing methods as well as alternative values were used for valuing these services. The study area was Tang-e Sayad protected area in Iran. The field studies include the implementation of 24 transects and using the plots with 2 m × 2 m dimensions at a distance of 100 m from each other. Based on the results, the value of the protected area for the above three ecosystem services was 4173 USD per hectare per annum, which is a significant amount. Of this amount, 1% is related to the value of forage production, 19% to oxygen release, and 80% to carbon sequestration. These values can be a good guide for planning to focus on carbon sequestration and to reduce grazing pressure in the protected area. It is suggested that valuation processes continue, especially in protected areas, so that they can be used in protection decisions and prioritization of the ecosystem services in policy-making for the PAs.

Article Highlights

- **Valuing the ecosystem services can provide solutions for optimal management in PAs.**
- **The regulation services have much greater economic value than the provisioning ecosystem services.**
- **Carbon sequestration in Tang-e Sayad protected area in Iran has the highest economic value among the studied ecosystem services.**
- **Among the types of carbon sequestration, soil carbon sequestration is higher than all types of sequestration values.**

Keywords Valuing ecosystem services · Forage production · Market price · Carbon sequestration · Oxygen release

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Introduction

Valuing Ecosystem Services in Protected Areas

PAs are the primary tools of humans to limit the effects of human development on the structure of ecosystems and their functions around the world (Guerbois and Fritz 2017). In PAs, plants, animals, soil and water resources, and even the earth's shape are protected. This protection in PAs can lead to biodiversity conservation, human welfare, strengthening local economies, and even mitigating climate change (Tiebel et al. 2021). In recent years, the area of PAs has increased in the world in a way that the terrestrial area of PAs has increased from 14.6% of the Earth's surface in 2016 to 14.9% of the world's land cover in 2018 (UNEP-WCMC 2018). This upward trend is also present in the marine PAs of the world where an annual growth of 8% has been reported (Langle-Flores and Quijas 2020). These statistics show that the level of PAs in the world is increasing due to the importance of preserving ecosystem services for future generations.

Ecosystem services are commonly defined as all benefits that people derive from ecosystems (Langle-Flores and Quijas 2020). They are classified into four categories including provisioning, regulating, supporting, and cultural services (Costanza et al. 2017). Among these services, the regulatory services seem to be more important to future of ecosystems and to improvement of sustainable development. The regulatory services (e.g., water retention, maintenance of soil fertility, carbon sequestration, and oxygen release) can enhance human well-being in PAs (Chen 2021). The regulation ecosystem services affect health and safety components in human life. For this reason, alternative cost methods are effective in valuing these methods (Amirnejad and Ataie Solout 2017; Ninan and Inoue 2013) because these services increase safety and health in human life. Therefore, the economic cost of oxygen production for Tang-e Sayad local area could be calculated if the equivalent value of health loss as an example to reduce oxygen production and respiratory system discomfort is considered. This issue could present the enhancement of human well-being with regard to the regulatory services.

At the same time, the provisioning services (e.g., food, fuel-wood, timber, non-timber products, and grazing in ecosystems) are very important to the people, especially to the local communities of PAs (Guerbois and Fritz 2017). Thus, issues and problems of the ecosystem services require multifaceted research which pursues a combination of social, ecological, cultural, economic, etc. positions.

In view of the global issues of PAs (UNEP-WCMC 2018), research in PAs has great value and can lead to improved management decisions in the field of protection of PAs. Especially, the research on ecosystem services with non-market values will cause managers and policy makers do not be ignored economic effects of these services.

Valuing ecosystem services is very important in PAs, and if we want to make the right decisions about ecosystem services in PAs, we need to investigate their economic valuation processes. This is because it is not possible to valuate many ecosystem services directly in PAs (Ninan and Kontolen 2016). Most ecosystem services (e.g., maintenance of soil fertility, carbon sequestration, etc.) are involved in human well-being intangibly (Iranmanesh et al. 2020). These services become more important in PAs because in these ecosystems, due to conservation issues, the products and provisioning services are reduced, and more attention is paid to other services such as the regulatory and cultural services. Therefore, valuing ecosystem services in non-market systems is necessary so that the position of these services is not ignored or compromised in decision-making processes (Chen 2021).

To incorporate PAs' ecosystem services into decision-making, various steps including combining knowledge about ecosystem services, valuation of ecosystem services, specialization, participation of stakeholders, implementing co-management with stakeholders, and ultimately gaining international cooperation are defined (Langle-Flores and Quijas 2020). Thus, to involve PAs' ecosystem services in decision-making and policy-making systems, it is necessary to first define an appropriate valuation system for PAs' ecosystem services. This system provides a basis for cooperation with stakeholders in PAs and takes advantage of participatory management. Therefore, valuing ecosystem services is necessary in the PAs. In this study, the valuation of some ecosystem services has been done in Tang-e Sayad PA in the west of Iran. This PA is unique due to its habitats and rare species of animal and plant.

Background, Research Aims, and Questions

Local communities' harvesting of PAs include forage produced in the PAs (Soofi et al. 2018) or harvesting some plants to meet local needs (Huynh et al. 2016). Accordingly, in the PAs, some challenges such as the challenge of livestock in the PAs, the challenge of lack of valuation system, the challenge of not recognizing the difference in values between the regulation and provisioning services, and the lack of preference between ecosystem services in decision-making for the PAs are important. In a previous study of the provisioning services, Guerbois and Fritz (2017) found that in PAs, subsistence livelihood is crucial for local communities living in tropical countries. They reported that changing resource availability, human population, honey pot-effect, and buffer capacity of PAs are the main indicators of sustainability of livelihoods of communities related to PAs.

Yeasmin et al. (2021) focused on the sustainable use of the provisioning services in homestead forests in Fatikchhari district, Bangladesh. These forests provide fuel-wood, fruit, vegetables, and timber for locals. The production of these trees plays an important role in the economy of Bangladesh, but at the same time, these forests are responsible for important regulatory services such as carbon sequestration. Most of these studies (i.e., Amirnejad and Ataie Solout 2017; Chen 2021; Ninan and Inoue 2013) are in the field of regulation services in PAs. They have proposed the monetary value of the regulation services and shown their high monetary value in PAs.

In PAs, two groups of issues may show themselves simultaneously. One is the need of the local community to PAs for livestock grazing, and the other is the need of the ecosystem (plants and animals) for protection. Therefore, there can be different values for each of the ecosystem services that depend on these issues. In the proposed solutions to the issue of livestock grazing and the role of local communities in PAs, Guerbois and Fritz (2017) suggested the way to approach the sustainability of PAs according to the role of neighboring communities of PAs. Soofi et al. (2018) described assessing grazing capacity and regulating livestock grazing in protected ecosystems as a management strategy for PAs. Some studies have also provided solutions for systematic analysis of PAs. For instance, Langle-Flores and Quijas (2020) introduced four pathways including social media, emerging technologies, iterative science-policy process, and co-production of ecosystem services to combine socio-ecological systems for the future.

Unlike previous studies (e.g., Guerbois and Fritz 2017; Yeasmin et al. 2021), this study is focused on the integrated valuation of the provisioning and regulatory services. It seems that there is a gap in previous studies in that they simultaneously examined the values of the regulation and provisioning services. In this study, both the value of forage production and the regulatory services such as oxygen release and carbon sequestration are considered. Such a study can differ from related works in the literature in that it compares the values of these services.

Measuring oxygen release using the amount of plant dry matter is a common method in measuring oxygen production in natural ecosystems (Iranmanesh et al. 2020). Measuring oxygen release is usually done using the photosynthesis formula method. During photosynthesis, plants receive energy from the solar source and convert inorganic compounds (i.e., water and carbon dioxide gas) into organic compounds. Equation (1) was used to estimate the economic value of oxygen production in the ecosystem (Yeganeh et al. 2015; Amirnejad and Ataei Solout 2017; Iranmanesh et al. 2020; Rousta et al. 2021).

$$\begin{aligned} 6\mathrm{Co2}(264\mathrm{g}) + 6\mathrm{H2o}(108\mathrm{g}) &\rightarrow 6\mathrm{H12O6}(180\mathrm{g}) \\ &+ 6\mathrm{O2}(193\mathrm{g}) \rightarrow \mathrm{Polysaccharide}(162\mathrm{g}) \end{aligned} \quad (1)$$

According to Eq. (1), in an ecosystem, 264 g of carbon dioxide are deposited simultaneously with the production of 162 g of dry matter. Accordingly, when one ton of dry matter is formed, 1.2 tons of oxygen is released (Based on the sources of Eq. 1).

Iranmanesh et al. (2020) suggest that when discussing carbon storage in ecosystems, it is important to acknowledge that it is divided into two categories: plant biomass and soil carbon. Plant biomass carbon encompasses both aboveground and belowground carbon components. Various methods have been defined in the research literature for measuring carbon, including the measurement of the combustion method in an electric furnace and the measurement of carbon using the Walkley–Black (WB) methods (Iranmanesh et al. 2020) or WB and Loss On Ignition (LOI) methods in soil carbon measurement (Sepahvand et al. 2020). Also, weighing the burned samples and estimating 50% for organic carbon means that half of the ash material is carbon, which is empirically accepted (Yeganeh et al. 2015). Different methods have been proposed for valuing carbon sequestration such as the social cost of carbon (Ganguly et al. 2018). Using the available data on the average cost of absorbing and storing CO2 in an industrial section such as an annual report of trading economics is one of the other valuation methods in carbon sequestration (Amirnejad and Ataei Solout 2017).

Most valuation researches have reported the valuation of food (Aulia et al. 2020), wood and agricultural production, rice and corn production (Koko et al. 2021), and food, fuel-wood, and building materials (Yeasmin et al. 2021). Accordingly, there seems to be a need for more research on forage valuation, especially in PAs; in some studies, forage valuation has been considered alongside non-wood products of the ecosystem (e.g., Aryal et al. 2021; Ninan and Kontoleon 2016). In this study, the economic valuing methods have been used in the field of valuing ecosystem services in one of the PAs (Tang-e Sayad PA and its rangeland landscapes) in the west of Iran. To the best of our knowledge, the applications of the issues about livestock grazing and forage valuation in PAs as well as provisioning and regulation services prioritization do not seem to have been investigated with regard to management plans and ecosystem management issues.

There is another gap in these studies. The issue of prioritization and comparison between the values of provisioning and regulation services has been less addressed in policy-making processes. The important point is that if we want to make rational decisions about priorities and preferences in PAs, there is a need to know the economic value of various services in PAs. Recently, several studies have been conducted in the field of ecosystem services valuation (Aryal et al. 2021; Aulia et al. 2020; Sanchez et al. 2021; Saarikoski and Mustajoki 2021; Yeasmin et al. 2021), and they have specially focused on PAs and national parks (Bhat and Sofi 2021; Chen 2021; Langle-Flores and Quijas 2020; Sagoe et al. 2021; Tiebel et al. 2021). However, it seems that no comparison has yet been made between provisioning and regulation services to decide on priorities for the management and policy of PAs. This comparison (between the provisioning and regulation services) report for which PAs more livestock grazing could be allowed for local communities, or for which PAs livestock grazing should be restricted in local communities. Similarly, the issue of valuing ecosystem services can be applied in various decision-making processes. Therefore, in this study, the value of forage production was evaluated as one of the values that is very important for the local community. Also, the values of carbon sequestration and oxygen released were estimated to describe two indicators of regulation ecosystem services in a quantitative and monetary valuation. This study can contribute to the management of PAs by considering the issues of ecosystem services and their valuation, providing forage values, providing values of gas regulation in a PA, and review of values for policy and optimal management of PAs. Accordingly, the aims of the study were (1) valuing of forage (as a provision service in the PA); (2) determining the economic values of some regulation services (e.g., oxygen release and carbon sequestration) to compare the values of the provisioning and regulation services; and (3) providing management solutions to balance PAs and to balance all provisioning and regulation services. In line with these aims, some general questions are raised. First, are services such as forage production visible in the ecosystem in the PA (Tang-e Sayad)? Second, how much is the economic value of livestock grazing in the PA (Tang-e Sayad PA in Iran) for the local communities? Third, is the economic value of livestock grazing (as a service for forage production) higher than the values related to oxygen release or carbon sequestration values in this PA? And fourth, what solutions are provided to coordinate and balance these services in the PA?

Valuing and comparing these services (the provisioning and regulation services) can provide a basis for making right decisions by policy makers and managers of PAs in the above-mentioned ecosystem services. This paper is part of a broader valuation project in Tang-e Sayad PA, Iran.

Materials and Methods

Study Area

As a PA, Tang-e Sayad region is located in Chaharmahal and Bakhtiari province and 15 km from Shahrekord city in the center of the province in the western region of Iran (Jafari et al. 2016; Zarineh et al. 2011). The area of this protected region is 27,000 ha (inside this area, there is a national park with an area of 5400 ha), and the dominant ecosystem is rangeland. In this area, about 26,577 ha are allocated to rangelands, and other areas are mostly rocky with rocky outcrops and agricultural and garden uses (Consulting Engineers for Water Resources Investigation 2002a). Tang-e Sayad area is a high mountainous PA with an average altitude of 2720 m above sea level. This area is located between the geographical coordinates of 50° 58′44/2806″ and 51° 10′25/0896″ east longitude, and 32° 3′6/2886 and 32° 17′7/5516″ north latitude. This area is located in the south part of Shahrekord city (the center of the province) and in the north part of Borujen city in Chaharmahal and Bakhtiari province (Heidari Ghahfarrokhi et al. 2019). Figure 1 shows the geographical location of the study area. In terms of topography, this ecosystem has had many elevations, hills, and highlands. Figure 2 shows an overview of the mountainous location of the PA. Because it is hilly and mountainous with suitable plant species, the PA has provided conditions for wildlife such as *Ovis Orientalis* and predators such as leopards. Plants such as *Astragalus microcephalus* Willd, *A. gossypinus* Fisch, *A.campylanthus* Boiss, *A.susianus* Boiss, *Phlomis olivieri* Benth, *Bromus tomentellus* Boiss, *Stipa hohenackeriana* Trin. & Rupr, *Psathyrostachys fragilis* (Boiss.) Nevski, *Daphne mucronata* Royle, *Gundelia tournefortii* L, *Melica persica* Kunth are found in abundance in the area. The climate of the steppe region is cold, arid, and semi-arid. The average annual rainfall is 329 mm (Moradi Shahgharie and Tahmasbi 2016), and the average annual temperature is 11.5 °C, which indicates the prevalence of a cold climate in the region. The altitude of the region is between 2100 and 3100 m above sea level (Zarineh et al. 2011). In this region, 24 species of mammals such as *Ovis orientalis isphahisa*, *Capra aegagrus, Panthera pardus*, *Felis catus, Canis lupus,* etc., as well as 70 species of birds such as *Dendrocopus* spp. and *Coracias garrulus* have been identified. Moreover, 26 species of reptiles, such as *Macrovipera razii*, have been reported in this area (Jafari et al. 2016).

Methods

This study has been done in three steps including description of ecosystem services, description of socio-ecological subsystems, and valuing of some of the ecosystem services including forage production, oxygen production, and finally carbon sequestration. In this section, it is necessary to present a sampling framework to describe ecosystem services and biomass calculation for valuing the ecosystem services.

Sampling Framework

To value the ecosystem services in this study, three separate work steps including selection of some ecosystem services for valuation, assessment of aboveground biomass in the ecosystem, and valuation process were developed. In the first part, the ecosystem services of the PA were described. One of the key provisioning services for economic valuation is forage production in the ecosystem due to two reasons: (a) the issue of the role of local communities in PAs (Guerbois and Fritz 2017) and (b) considering the importance of livestock grazing for local communities (Bazdar Gandomani et al. 2021). Oxygen release and carbon sequestration, which

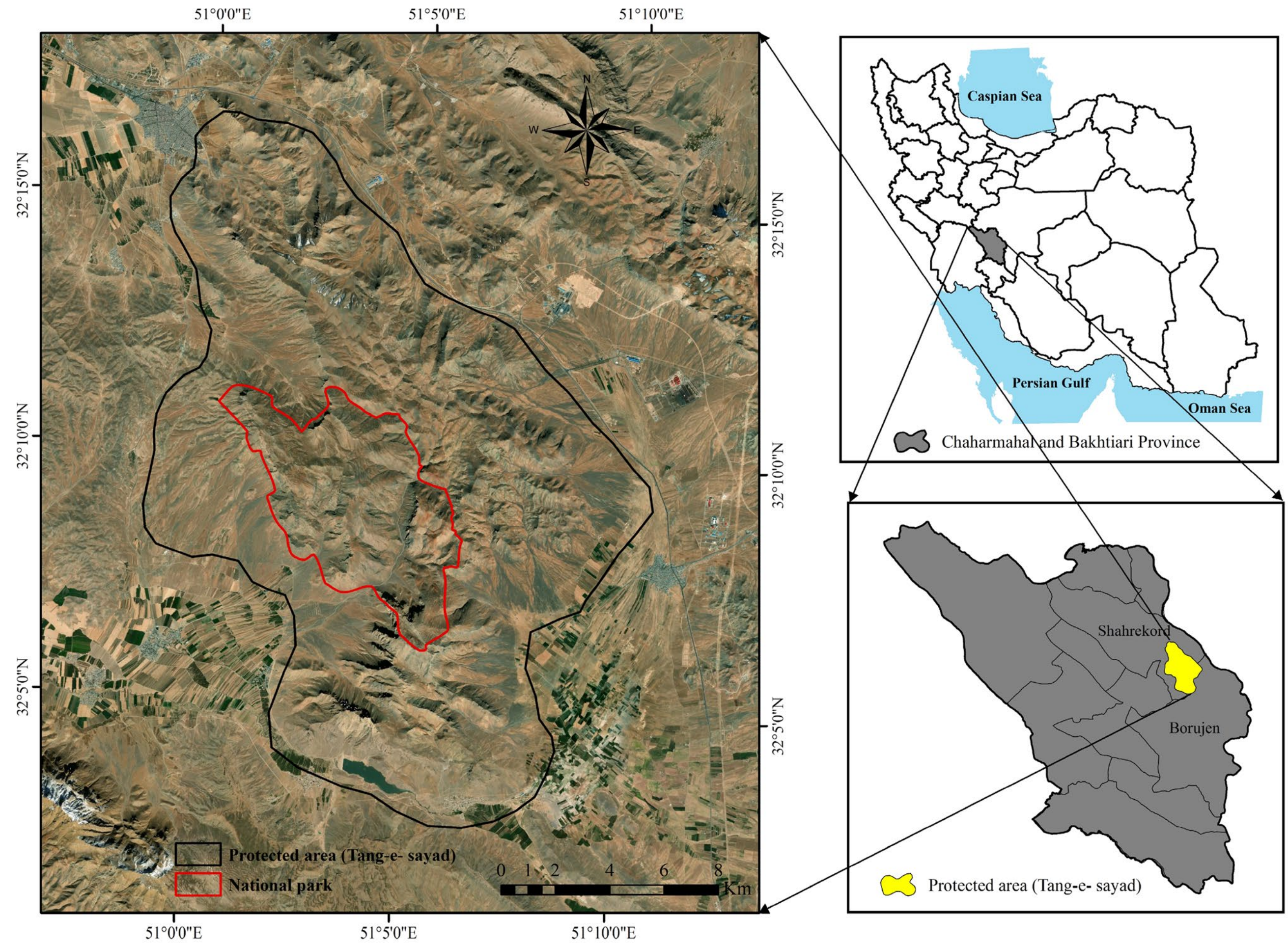

Fig. 1 The geographical location of the study area in Iran

Fig. 2 An outlook of the mountainous location of the PA and wildlife on the landscape ridge. Photograph was taken by the corresponding author, summer of 2021

are significant to prevent climate change (Iranmanesh et al. 2020), were also considered as the two regulatory services for valuation.

In the second part, ecosystem resource evaluation was performed to determine the aboveground biomass of the ecosystem. At this stage, by surveying 24 transects (each transect with a length of 1000 m), each of which included 10 plots, the latest vegetation statistics were collected using field observations of rangeland species and their presence in different plots in this area. For maximum compliance with the principles of statistics, the distribution of transects in the study area was based on random sampling. The selected plots on transects were systematically designed with 2 m × 2 m dimensions and at a distance of 100 m from each other. To implement these dimensions, a 2 m × 2 m frame was used during the survey. Sampling was performed using two teams, and a total of five researchers participated in field sampling. Figure 3 shows the steps of taking notes and sampling in the project.

To value forage, it was necessary to cut down some plant species to study the aboveground biomass for the PA. The most accurate way to measure aboveground biomass in forest and rangeland ecosystems is to harvest and cut down ecosystem plants. To measure aboveground biomass, some species should be cut down, and then aboveground biomass could be estimated by weighing them (Amirnejad and Ataei Solout 2017).

The method of cutting rangeland species was designed with the least cut down of the species. For this purpose, cutting of species in each transect was done in only three plots, and to properly distribute the plots, the process of cutting of species was performed in plots 1, 5, and 10 in each transect. Measurement of canopy cover of each plants was done in all plots, and forage production was estimated in only three plots. Therefore, to distribute aboveground biomass in other plots, regression relationships were used between cover and forage production by sampling method to estimate double range production (Arzani et al. 2011). It was essential to cut less plant in the PA and to estimate aboveground biomass with the least degradation (for sampling) in the study area. Harvesting all the bush and shrub plants is hard, time-consuming, and expensive, and it can be destructive in protected areas. For this purpose, the Adelaide method was used to calculate the aerial biomass of plants. Based on the Adelaide method, only part of the plants was cut down to reduce cuttings from the plants. For example, in some large species, only one-fiftieth, and in some species, one-eighth or one-tenth of plants was cut to estimate aboveground biomass with minimal damage to plants. After calculating the dry weight of the plants, the weight was multiplied by 50 (or 8 or 10) (Arzani and Abedi 2015).

To measure the carbon of the soil in the PA, a soil sample was taken with the weight of one kg from the center of the sample plot. These soil samples were taken from a depth of 0 to 30 cm according to the protocols of the soil-related source (Heuvelink et al. 2020). Finally, samples of soil were transferred to the soil and water laboratory of Chaharmahal and Bakhtiari agricultural and natural resources research and education center, Iran to calculate the soil organic carbon.

Sampling was done to calculate the value of aboveground biomass in August 2021. To calculate the dry weight, after field sampling of ecosystem plants, the sampled plants were kept in the herbarium of Chaharmahal and Bakhtiari agricultural and natural resources research and education center, Iran for two months to dry naturally. After repeated measurements, when the weight of the dried plants remained

Fig. 3 Taking notes and sampling process in the project

constant, the process of measuring was performed for the dry weight of plants using a digital scale.

Identifying Ecosystem Services

In the first step, the ecosystem services of the PA were described through extensive observation of the landscapes. Extensive observation by the expert team (a team of five experts for field observation in Chaharmahal and Bakhtiari agricultural and natural resources research and education center) was the main source for data collection in this step. Although these surveys could be the only way to describe the PA ecosystem services, some complementary methods were used to complete the ecosystem services of the PA. The other methods used in this study include preparing an open quality-based questionnaire to collect information from some experts who were fully acquainted with the PA and finally reviewing the documents in the department of environment of Chaharmahal and Bakhtiari province (Consulting Engineers for Water Resources Investigation 2002a, b, c) as well as papers related to Tang-e Sayad region. This study did not rely on the number of questionnaires and reviewing the documents, but it aimed at saturating information on the subject of ecosystem services and related subsystems similar to the snowball sampling method to complete the field survey observations. Field observations of the PA, documentary study, and questionnaire design have been done in the summer of 2021.

In the field of ecosystem services, Costanza et al. (1997) classified the ecosystem services into 17 categories based on their ecosystem functions in the form of Table 1. Various institutions and programs around the world study the subject of ecosystem services and their various issues. These institutions and programs include Millennium Ecosystem Assessment (MEA), Economics of Ecosystems and Biodiversity (TEEB), Ecosystem Services Partnership (ESP), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), etc. (Costanza et al. 2017). Each institution has a list of ecosystem services for different ecosystems. Earlier in 1977, a simple but practical set of ecosystem services was introduced by Costanza et al. (1997) (Table 1). In this study, a combination of the above models was used to develop the ecosystem services in Tang-e Sayad PA in the western Iran.

Although most of the selected services (Table 1) were consistent with the model of Costanza et al. (1997), some services of other institutions and programs were also considered. From these services, maintaining soil fertility from TEEB (2010), medicinal resources from TEEB (2010), mediation of waste, toxics, and other nuisances from CICES (Common International Classification of Ecosystem Services) version 5.1 (Haines-Young and Potschin 2018), recreation and ecotourism from MEA (2005), and water from TEEB (2010) & CICES V5.1 could be mentioned. Some services were also removed from the list. For example, in setting up ecosystem services in this PA, because ‘raw material’ was not significant, when compared to other ecosystem services in the PA, it was removed from the list of these ecosystem services. The description of the ecosystem services in Tang-e Sayad PA is based on the models mentioned in the method section, as described in Table 5.

Forage Valuation

For economic valuing of forage, the plants were classified into three categories based on plant palatability: class 1, class 2, and class 3. Class 1 has priority in terms of plant palatability, class 3 has the least importance in terms of plants palatability, and class 2’s importance lies in between. The amount of available forage was considered 60% of plant biomass for class 1, 50% for class 2, and 35% for class 3 (Fayyaz et al. 2015). The areas of stands of

Table 1 Ecosystem services based on their ecosystem functions

Ecosystem services	Ecosystem functions	Ecosystem services	Ecosystem functions
Gas regulation	Regulation of atmospheric composition	Pollination	Movement of floral gametes
Climate regulation	Regulation of global temperature	Biological control	Trophic-dynamic regulations of populations
Disturbance regulation	Capacitance, damping, etc	Refugia	Habitat for residents
Water regulation	Regulation of hydrological flows	Food production	That a portion of gross primary production is extractable
Water supply	Retention of water	Raw materials	A portion of gross primary production
Erosion control and sediment retention	Retention of soil within an ecosystem	Genetic resources	Sources of unique biological materials
Soil formation	Soil formation processes	Recreation	Providing opportunities for recreational activities
Nutrient cycling	Storage of nutrients	Cultural	Providing opportunities for non-commercial uses
Waste treatment	Recovery of mobile nutrients and removal or breakdown of the excess		

Costanza et al. (1997)

rangeland species types were determined using Arc GIS 10.8 software to determine the value of species in all areas of the ecosystem. Finally, the area of the plant species was determined according to distribution area of the rangeland species on the vegetation map of the region and the expert opinions in research team.

In the third part, the market value of forage for different classes was determined by the market price method (Yeasmin et al. 2021) to evaluate the forage of the ecosystem by determining the purchase and sale price of forage in Chaharmahal and Bakhtiari province. The selection criteria to value forage was as follows: (A) for class 1 of plant palatability, the daily price of alfalfa, (B) for class 2 of plant palatability, the daily price of lentil forage, and (C) for the third class of plants palatability, the daily price of wheat and barley forage (Fayyaz et al. 2015). Finally, the exchange of money was used from the currency in Iran (IRR) into the US dollar currency on 28 March 2022 to make the numbers of forage monetary values meaningful for international readers. To adjust prices in different years, the time value of money in Eq. (2) was used along with the source (Oskounejad 2020).

$$V_t = V_0(1 + i)^t \tag{2}$$

In Eq. (2), "V_t" is the value for money at the time "t", "V_0" is the value for base money, "i" is the interest rate, and "t" is the duration of time change.

Oxygen Release Valuation

Based on Eq. (1), the production of the total aboveground biomass multiplied in number of 1.2 to calculate the oxygen release in the ecosystem. To value the oxygen release in the ecosystem, the alternative valuation method was used (Ninan and Kontoleon 2016). In estimating the replacement cost for oxygen release in the ecosystem, the market price of oxygen production using industrial method (using air compression in capsules for this process) replaced the cost of oxygen release. In previous research (Amirnejad and Ataei Solout 2017), the market price of industrial oxygen was estimated at 14,000 currencies of Iran, based on the submission time of the article in 2016. The conversion of these currencies was used for the end of 28 March 2022 to calculate the daily prices for the PA. The currencies were converted into USD based on the exchange rate of the Iranian Rials to the dollar in 28 March 2022, so that they could be understood by the international readers of the paper.

Valuation of Carbon Sequestration

Valuation of Soil Carbon Sequestration The first section of carbon sequestration is soil carbon sequestration. To value soil carbon sequestration, three soil samples were taken at a depth of 0–30 cm in the three plots (Plots 1, 5, and 10) in each transect (total of 72 soil samples). The soils were transferred to the soil and water laboratory of the agricultural and natural resources research and education center of Chaharmahal and Bakhtiari province to be calculated in terms of soil carbon. The laboratory analyses related to ecosystem soil were performed in early autumn 2021. Finally, the amount of carbon sequestration was calculated based on Eq. 3 (Heuvelink et al. 2020).

$$\begin{aligned} \mathrm{SOC_{stock}}\left(\mathrm{kg\ C\ m^{-2}}\right) &= \mathrm{SOC_{concentration}}\left(\mathrm{g\ kg^{-1}}\right) \\ &* \mathrm{BD\ g}\left(\mathrm{cm^{-3}}\right) * 1 - \mathrm{CRF} * 0/3(\mathrm{m}) \end{aligned} \tag{3}$$

In Eq. (3), SOC refers to soil organic carbon, BD is bulk density, and CRF is the ration of coarse fragments. All variables in Eq. 3 belong to depth of soil to a pan 0–30 cm (Heuvelink et al. 2020).

Valuation of Other Carbon Sequestration Forms Carbon sequestration consists of three parts including carbon sequestration by soil, by aboveground biomass, and by belowground biomass (Yu et al. 2020). To estimate carbon sequestration in the regulatory services of the PA, it is necessary to estimate the total biomass (i.e., total aboveground and belowground biomass) (Islam et al. 2020; Ninan and Kontoleon 2016). The Eqs. (4) and (5) were used to estimate the carbon sequestration resulting from the ecosystem functions of the PA.

$$\text{Carbon sequestration} = Y \times 50\%;\ \text{where, } Y = Y_1 + Y_2 = \text{ total biomass} \tag{4}$$

$$\text{where } Y_2 = Y_1 \times 70\% \tag{5}$$

In Eq. 4, Y_1 is aboveground biomass and Y_2 is belowground biomass. In the field of root sampling and estimation of belowground biomass, due to the protection of the area and severe damage due to root sampling, the previous calculations were used in the field of belowground biomass in semi-steppe areas of the Central Zagros region and in the adjacent province (i.e., Isfahan province) (Naghipour and Farrokhnia 2017). The Eqs. (4) and (5) are based on the article of Islam et al. (2020) in the field of forest ecosystem, but in this study 70% was used instead of 15% in Eq. (5). In forest trees, due to the heavy biomass of tree trunks, the ratio of belowground to aboveground biomass is estimated at 15% (Islam et al. 2020). In terms of belowground biomass rates in rangeland ecosystems, the same ratio cannot be used in forest trees.

Belowground biomass to aboveground biomass ratio is more in rangeland plants compared to forest ecosystems. Hence, by aggregating the views of the analytical team on the issue of valuation in the PA and the quantification of sizes obtained in previous research on belowground biomass in one of the areas in Iran (Naghipour and Farrokhnia 2017), the coefficient of 70% estimated for the study area. The cost of industrial carbon sequestration (Amirnejad and Ataei Solout 2017) was used as an alternative cost to valuate carbon sequestration. The industrial carbon sequestration statistics in previous years were calculated based on the inflation rate for the year 2021 (global inflation rate was 3.29). In the above calculations (Eq. 4 and 5), carbon sequestration was calculated for aboveground and belowground biomass.

Results

Ecosystem Services in the PA

The initial finding of this study was a checklist of the ecosystem services for a PA in the western Iran. Table 2 describes the list of the ecosystem services in Tang-e Sayad PA in the western Iran. In this study, some ecosystem services were removed from the list of the ecosystem services, unlike the list of the ecosystem services provided by MEA (2005), TEEB (2010), and Costanza et al. (2017); this was due to the nature of the PA.

Kolahi et al. (2012) have reported that systems of PAs in Iran lack manpower, equipment, financial resources, national biodiversity indicators, and objective monitoring processes. Furthermore, limited public participation and public engagement with PAs are other key issues for these areas. Due to the issues related to decline of plants in rangeland species, the results of this study is in line with that of Kolahi et al. (2012). Ayivor et al. (2020) reported the role of local perceptions and all stakeholders in effective management in PAs in Ghana. Similar to Kolahi et al. (2012) and Ayivor et al. (2020), description of the ecosystem services in this study shows the role of local communities, grazing in the ecosystem (in provisioning services), or stakeholder-related issues (in regulating habitat and cultural services as well) (Table 1).

Forage Valuation

The forage calculation is presented in Annex A_1–A_3 based on the results of field sampling in different classes of plant palatability. Table 3 shows the monetary value of forage in different classes of plant palatability and total monetary value of forage of all plants, and Fig. 5 shows the distribution of the monetary value of forage in different classes of plant palatability. The results of Table 3 show that Tang-e Sayad PA has a monetary value of about $760,794 in terms of forage value per year. Table 4 shows the aboveground biomass in different classes of plant palatability and total aboveground biomass of all plants. The results of Fig. 4 show that most values of the plants in the PA are in the 3rd plant palatability class. In other words, they are not in a good plant palatability condition, especially since the percentage of the values of the 1st plant palatability class is very limited.

Oxygen Release Valuation

To value oxygen release, it is first necessary to estimate the amount of it. Table 5 shows the oxygen release in the PA based on calculations and matching of Eq. (1) with the results of total aboveground biomass of all plants. After estimating the oxygen release, using the replacement cost method of industrial oxygen in factories, and the market price of industrial oxygen that was explained in section "Identifying Ecosystem Services", the value of oxygen release in the PA was determined. Also, in this Table (Table 5), the valuation of oxygen production is presented along with its calculations in ton per ha and ton per total area.

Carbon Sequestration Valuation

Carbon of Soil

It is necessary to estimate the amount of carbon sequestration for carbon sequestration valuation. In this part, it is essential to first analyze the calculations related to a laboratory data of soil carbon. Table 6 shows the soil organic carbon in the PA based on calculations of Eq. (3). In Table 6, the calculations are reached from the unit of ton per hectare to the unit of ton when 27,000 ha (as the area level) is considered. To obtain the results of Table 6, the results of the tests related to the soils of the PA were used. A detailed description of the carbon content (percentage of carbon) in different plots based on the results of soil laboratory is provided as an Annex B.

Other Carbon Sequestration Forms

After analyzing the data related to soil laboratory in the field of carbon sequestration, valuation of carbon sequestration is possible in all sections. These sections are C_1 (carbon from aboveground biomass), C_2 (carbon from belowground biomass), and C_3 (organic carbon from soil), based on the method section in Eqs. 4 and 5. Table 7 shows the economic value of carbon sequestration in different sections. To show the results of this section more prominently, Fig. 5 can clearly show the percentage of each of these sections in terms of economic value. This representation based on percentage is significant to showing the prominent role of

Table 2 Description of ecosystem services in Tang-e Sayad PA in the western Iran

Ecosystem services	Description in Tang-e Sayad PA
Food production	Forage production is important for the livestock of the local community, especially for services of *Bromus tomentellus* Boiss., *Astragalus effusus* Bunge, *Melica persica* Kunth, *Stipa hoheneackeriana* Trin. & Rupr., and *Gundelia tournefortii* L. which are very important for grazing. It is also important to provide forage for wildlife herbivorous species in this ecosystem.
Water	The ecosystem of the PA is important for supplying water; however, the seasonal springs of the PA have dried up.
Genetic resources	Some plant species, such as *Cousinai tenuiramula* Rech.f., *Astragalus campylanthus* Boiss., *Astragalus murinus* Boiss., *Astragalus susianus* Boiss., and *Salvia hydrangea* DC. ex Benth., and some animal species, such as *Ovis orientalis isphahisa* and *Capra aegagrus*, are very important in the PA in terms of genetic resources. This is due to the fact that these species are among the native and dominant species in the study area.
Medicinal resources	Production of medicinal plants such as *Thymus daenensis* Čelak., *Satureja bachtiarica* Bunge, *Stachys lavandulifolia* Vahl, *Gundelia tournefortii* L., and *Ziziphora tenuior* L. offers excellent services in this regard.
Gas regulation	Oxygen production and carbon fixation are very important, especially considering the factories around the ecosystem of the region.
Climate regulation	Climate change prevention and annual heating are important, given the vast ecosystem level of the PA and the annual temperature rise
Disturbance regulation	Due to the hilly, high altitude and the rocky nature of many areas, ecosystem services are very important in preventing floods.
Water regulation	Water regulation, especially in the field of drought prevention, has considerable importance. In this context, some rangeland species such as *Astragalus rhodosemius* Boiss. & Hausskn., *Melica persica* Kunth, *Acantholimon erinaceum* (Jaub. & Spach) Lincz., *Scariola orientalis* (Boiss.) Soják, and A*stragalus myriacanthus* Boiss. have declined with different intensities.
Waste treatment	Mediation of nuisances is especially important in the case of production units in the neighborhood of the PA.
Erosion control	Different plant densities in the ecosystem of the PA and biodiversity of different species in the region play an important role in soil bioengineering, soil strength, and preventing erosion control.
Maintaining soil fertility	In Tang-e Sayad PA, the increase in the fertility of the region's soil is very important for the growth of plants.
Pollination	Plant species reproduction, seeding, and pollination play an important role in habitat regulation.
Biological control	Some plant species like *Astragalus* spp., *Phlomis olivieri* Benth., *Phlomis persica* Boiss., *Ziziphora clinopodioides* Lam., etc. in Tang-e Sayad PA are used for biological regulation and control of pests and diseases of other species.
Nutrient cycling	The ecosystem of the PA provides important services for the initial production of biomass and the provision of nutrient cycles.
Refugia	Due to the wide surface of the canopy crown cover, compared to other species, *Astragalus* spp., *Acantholimon* spp., *Daphne mucronata* Royle, and *Acanthophyllum microcephalum* Boiss. can act as a nurse for other species.
Recreation and ecotourism	The PA's ecosystem can also offer services for ecotourism and outdoor activities.
Other cultural outputs	The ecosystem also offers services in other cultural outputs including esthetics, spiritual services, education, and science.

Research findings

Table 3 The monetary value of forage in different classes of plant palatability and total monetary value of forage of all plants

Monetary values and currencies	Class 1	Class 2	Class 3	Total monetary value of forage of all plants
Iranian Rial (IRR)	111,018,671,880	114,007,749,531	64,332,459,570	289,358,880,980
USD ($)	388,123	398,572	224,907	1,011,603

Research findings

C_3 (organic carbon from the soil) in the economic value of carbon sequestration in the PA.

The Values of All Three Ecosystem Services

Finally, Table 8 presents the sum of the values of all the three ecosystem services examined in this study and their average value per hectare of the protected area. Figure 6 shows the ratio of economic value in forage production, oxygen production, and carbon sequestration. The redisplay is based on the percentage of each of the values (Fig. 6) because of the insignificant role of forage production in the economic value of the PA and the prominent role of carbon sequestration in the economic value of the PA.

Table 4 Aboveground biomass in different classes of plant palatability and total aboveground biomass of all plants

Aboveground biomass	Class 1	Class 2	Class 3	Total
Kg/ha	240.86	620.79	1095.82	1957.48
Ton/ha	0.24	0.62	1.09	1.95
Percentage	12	32	56	100

Research findings

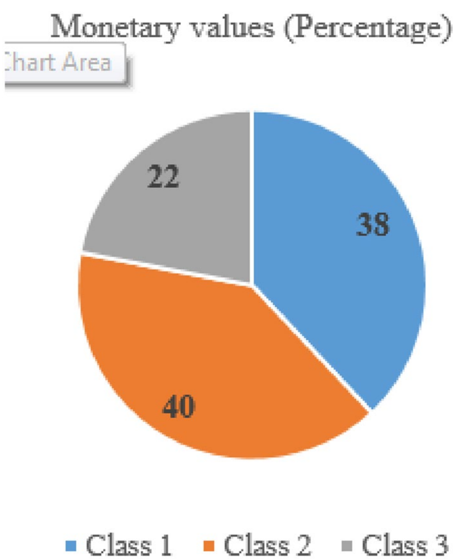

Fig. 4 The distribution of the monetary value of forage in different classes of plant palatability. *Research findings*

Discussion

An important issue in PAs is the difference between the values of regulatory and provisioning services (Sil et al. 2016). Therefore, in matters of politics and decision-making, issues related to ecosystem priorities is very important and influential for decision makers or local communities (Aryal et al. 2021). Social preference is especially important when decision-making comes to ecosystem services (Campbell 2018). Sometimes decision makers need to prioritize trade-offs and synergies among provisioning and regulatory services (Sil et al. 2016).

In previous studies (e.g., Chen 2021; Ninan and Inoue 2013), fewer provisioning services have been investigated in PAs. Therefore, in PAs, most studies have been made on conservation topics. Among the ecosystem services related to local communities, the valuation of livestock grazing is very important (Lutta et al. 2020). On the one hand, livestock grazing is crucial in ecosystems for the economy of the local community (Zandebasiri et al. 2017). On the other hand, livestock grazing in natural ecosystems can have many risks and weaken the sustainability of the ecosystem through soil compaction and grazing of small plants and seedlings (Zandebasiri et al. 2020). Despite strong actions for preserving PAs, the most important benefit from PAs is harvesting from the PAs for local communities (Guerbois and Fritz 2017).

In this article, in one of the PAs of Iran in in West Asia, the challenge between the importance of provisioning and regulation ecosystem services was examined quantitatively and economically. In this context, regarding the provisioning services, the fodder production service and in the regulation services as well as oxygen release and carbon sequestration were economically valued. Since carbon sequestration itself

Table 5 Oxygen release and its valuation in the PA and its computational components

Oxygen release	Ton/ha	Ton	Kg
The basis for calculation	(1.957487)*(1.2)	(2.348985Ton/ha)*(27000 ha)	63,422.59*1000
Result	2.34899	63,422.59	63,422,578.8
The price of oxygen release			
	1 kg Oxygen		Total Oxygen in the PA
Iranian Rial (IRR)	87,480		5,548,208,182,020
USD	0.33		21,008,774

Research findings

Table 6 Soil organic carbon in the PA and its computational components

$SOC_{concentration}$ (g kg^{-1})	BD g (cm^{-3})	Depth of sampling	1 – CRF	SOC_{stock} (kg C m^{-2})	SOC_{stock} (Ton/ha)	Total SOC_{stock} (Ton in PA)
9.46	1.16	0.3	0.88	2.90	29	783,000

Research findings

Table 7 Carbon sequestration valuation in the PA and its computational components

Carbon sequestration valuation ($)	Ton/ha	Ton (For the total PA)	Value (For 1 ton)	Value
C_1	1.957*0.5 = 0.978744	0.978744*27,000 = 26,426	109	26,426*109 = 2,900,194
C_2	1.3702*0.5 = 0.68512	0.68512*27,000 = 18,498	109	18,498*109 = 2,030,136
C_3	29	29*27,000 = 783,000	109	783,000*109 = 85,932,251
C_t	30.66	30.66*27,000 = 827,924	109	8,279,243*1,097,474 = 90,862,581

Research findings

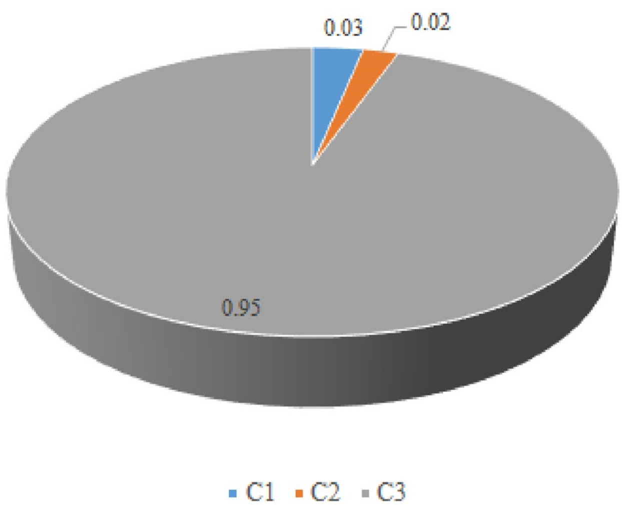

Fig. 5 Comparing the economic value of the three types of carbon*. *C_1 is carbon from aboveground biomass, C_2 is carbon from belowground biomass, and C_3 is organic carbon from the soil. *Research findings*

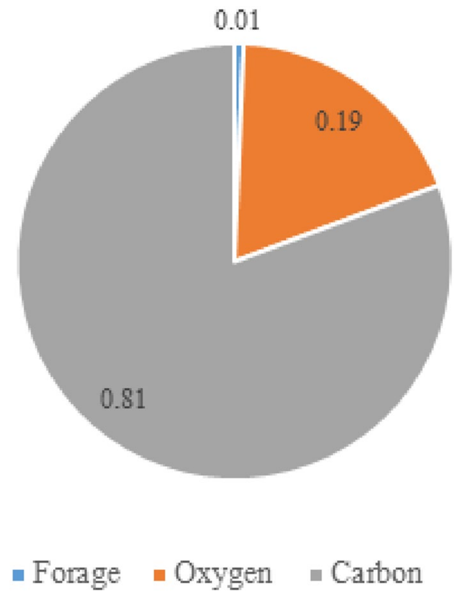

Fig. 6 The ratio of economic value in forage production, oxygen production, and carbon sequestration. *Research findings*

Table 8 The sum of the values of all three ecosystem services examined in this study

Forage	Oxygen	Carbon	Total	Per ha
1,011,603$	21,008,774$	90,862,581$	112,882,958$	4181$

Research findings

has three different forms of sequestration (aboveground, belowground, and carbon of soil), economic valuation was done for each of them separately.

Table 7 and Fig. 6 show that among the types of carbon sequestration, soil carbon sequestration has much more results than other sequestrations. The amount of USD 85932251 for soil carbon sequestration (Table 7) shows that about 95% of the value of carbon sequestration is in soil carbon sequestration (Fig. 5). In this way, it can be concluded that preserving soil in PAs is more important than preserving aboveground and belowground biomass. Therefore, it is necessary for the managers of PAs to put the planning to protect the soil of these areas as the first priority in the strategic planning of these areas.

A comparison of the values of Table 8 and Fig. 6 can guide the decision on prioritizing ecosystem services in an area. The most important achievement of this study in PAs is the expression of quantities of economic value of some ecosystem services related to the value of forage production and the value of oxygen production as well as the value of carbon sequestration in the region (Table 8 and Fig. 6). The evidence presented in this paper shows that the value of the ecosystem services in both carbon sequestration and oxygen production (as the regulatory services) is significant, especially in the field of carbon sequestration. Based on the results of Table 8, the total values of these three ecosystem services in Tang-e Sayad PA are equal to USD 112882958.

Figure 6 also shows that 80% of ecosystem service values belongs to the carbon sequestration service and 19% belongs to the oxygen production service, and only 1% belongs to forage production. But there is an important and subtle point in this part: the pressure to use the produced forage (by local communities' cattle grazing) may lead to destruction of 99% of the other value. The results of this study show that although the service of forage production ecosystem has a value of 1% of the value of the oxygen production services and carbon sequestration, the issue of livestock grazing and economic management of local communities plays an important role in regional management.

Overall, it is necessary to state that the result of this study provide a very large economic value for carbon sequestration in the PA, compared to other examined ecosystem services. To calculate the oxygen release in the ecosystem, the quantity of total aboveground biomass was multiplied in number 1.2. After carbon sequestration, the economic value of oxygen production is also important. The economic value of forage production in PAs is in no way comparable to regulatory services, especially to carbon sequestration. But the noteworthy point is that since forage production is related to the local communities of these areas, it needs to be taken into account in participatory management discussions.

It should be noted that although the ecosystem of this study is a protected ecosystem, the role of various stakeholders, such as ranchers and local communities that need the ecosystem for grazing livestock as well as the role of environmental management, natural resources research centers (to conduct research projects), universities (to produce information), etc., has been considered in it. Thus, in the management of this PA, it is necessary to conduct a stakeholder analysis before (or at least at the same time as) examining ecosystem services. Stakeholder analysis in natural resources management is a basic analysis, and after performing this analysis, it is possible to identify key stakeholders in each region (Zandebasiri et al. 2017).

Langle-Flores and Quijas (2020) reported a key role for beneficiaries in the socio-environmental system of marine PAs. They also proposed long-term monitoring and restoration programs for social–ecological systems. In previous studies, Kolahi et al. (2012) and Soofi et al. (2018) showed the role of ecosystem services and their relationship with local communities as the key issue in participatory management. Local community's participation adds other implications to previous discussions including the discussion of participatory management and the design of participatory monitoring systems in PAs. Tiebel et al. (2021) reported a conflict in the implementation of Natura 2000 for PAs and that the program needed to adapt to the community. Our findings are consistent with Tiebel et al. (2021) by showing adaptation to the local community to solve the existing problems in the field of grazing in PAs.

As shown in Fig. 4, only about 10% (9.824) of the monetary value of fodder in the PA belongs to the first class palatable plants, 32% to the second class, and about 58% to the third class. The large value of this value in the third class, compared to other classes, has been due to the greater diversity of species and their greater number and volume than other species in this class. These results suggest that in this PA, there is little economic value in species with high palatability to wildlife. Thus, an effective management plan needs to strengthen class 1 palatable plants by focusing on more palatable species in the PA.

Although Tang-e Sayad is a protected ecosystem, it is used by local ranchers for grazing in some spring and summer months. Providing food for wildlife and livestock of local communities is one of the most important ecosystem services in this area. Thus, in planning for some species such as *Bromus tomentellus* Boiss., *Astragalus effusus* Bunge, *Melica persica* Kunth, *Stipa hoheneackeriana* Trin. & Rupr., *Gundelia tournefortii* L., *Astragalus rhodosemius* Boiss. & Hausskn., *Cousinai tenuiramula* Rech.f., *Astragalus susianus* Boiss. *and Eryngium billardier* F. Delaroche, the issue of their reproductions should be considered as a priority.

Overall, livestock grazing is one of the main components in determining the economic environment of the PA's ecosystem. Of course, forage is important for both grazing and some species of wildlife such as *Ovis orientalis isphahisa* and *Capra aegagrus*. Hence, it is necessary to monitor the livestock grazing to avoid the quantitative of forage volume for herbivorous wildlife. It is essential to consider the participation and cooperation of the local community in the optimal management of the PA to provide collaborative management between the local community and ecosystem management. Thus, the economic and ecological environment of the PA depends on its social environment. This makes the management of the region's ecosystem difficult and sensitive.

In PAs literature, Ninan and Inoue (2013) investigated total economic value in a case study of a forest reserve in Japan. Ninan and Kontoleon (2016) focused on valuing ecosystem services (and disservices) by norms and data from the office of the director Rajiv Gandhi national park in India. Guerbois and Fritz (2017) reported the provisioning ecosystem services in PAs in Zimbabwe. Langle-Flores and Quijas (2020) came up with a social–ecological system in a systematic review in a marine PA based on demand, social values, and economic values in the central Mexican Pacific. The results of this research are consistent with the results of the research conducted by Guerbois and Fritz (2017) in that it shows the proper functioning of a PA and managing socio-economic processes. This shows that the value of carbon sequestration of the ecosystem services in the region is very high, and if this issue is taken into account in decisions, it can be a good guide for preference in the ecosystem of the region, and this issue can no longer be ignored by policy makers. This can be considered both for decision-making in the direction of conservation and for promoting human well-being. Since the present study focused only on three ecosystem services, the total value of the three services of forage production, oxygen production, and carbon sequestration can be estimated at USD 112882958 (see Table 8). Given the level of 27,000 ha for this PA, the value of each hectare can be estimated at an average of USD 4181. In the study of economic valuation of seven ecosystem services in a forest reserve in Japan, Ninan and Inoue (2013) reported the value of ecosystem services to be at USD 17,016–17,671 per hectare per annum. The low number of ecosystem services calculated in this study (only three services of carbon sequestration, oxygen production, and forage production) can be the reason for the lower number of calculated cultivars in Tang-e Sayad area, compared to the study conducted in Japan. Compared to another previous study on the value of ecosystem services, Ninan and Kontoleon (2016) also reported significant values for ecosystem services in the national park Nagarhole in India. They valued 10 ecosystem services and two disservices in total between USD 203 and USD 2294 per ha per annum. They also calculated the values of ecosystem disservices. The results of this study in the PA of Tang-e Sayad showed the value of USD 4173 per ha per annum (Table 8). The reduction in value in the study related to India can be related to the values of disservices because the value of disservices is discounted from the value of ecosystem services. Valuing ecosystem disservices such as Asian elephants as an agricultural pest can be useful for valuing studies in PAs.

Finally, for better understanding of the situation of the PA, a DPSIR (Driving forces, Pressures, State, Impact, Responses) framework was developed by the data collected in different parts of the methods of this study, especially in sampling from plants in the field survey. The DPSIR framework is a useful framework for examining management issues and providing various solutions (Zandebasiri et al. 2021). In the framework of DPSIR, D is being used for the driving forces, including socio-economic developments in societies, P is being used for developments in release of emissions, S is being used for different environmental variables which can show the state of the ecosystem, I is being used for impacts on human beings, and, finally, R is being used for responses by societies and governments (Cooper 2012). Table 9 shows the results of the DPSIR framework based on analysis of total data collected in different sections of field observations, questionnaire analysis, and review of documents of previous plans in the protected areas.

To better illustrate the factors and description of the features of the protected area, a few pictures are presented in the appendix on the presence of wildlife (Appendix Fig. 7), dried plant species (Appendix Fig. 8), and drinking fountains created for wildlife drinking in the area (Appendix Fig. 9). According to the results of Table 9, some of the most important responses of the Environment Organization of Iran and the Department of Environment of Chaharmahal and Bakhtiari Province for the protection and preservation of this protected area are: national park setting, organizing livestock grazing in local communities, water trough installation for wildlife, preventing the activities of sand mines, and creating checkpoints and posts. Tang-e Sayad PA was registered as a PA in 1973, and in 1995, for more protection of its plants and wildlife, 5400 ha of it was registered as a national park. More regulations have been introduced in this national park to protect plants and wildlife. This issue affects preventing livestock grazing and reducing competition between domestic livestock and wildlife for nutrition. The grazing period is about 100 days for the PA (i.e., between June and September). However, grazing is also heavy at the same time and is a cause of degradation in the ecosystem (Consulting Engineers for Water Resources Investigation 2002a, b, c).

It is necessary to state that valuation does not include all matters related to management decisions, but it is essential to consider economic, social, and biological issues together in management decisions in addition to economic concepts (Zandebasiri et al. 2023). Economic valuation defines a part

Table 9 DPSIR framework for describing protected area management system

D	P	S	I	R
Dependence of local communities on agriculture and livestock grazing	Production of CO_2 due to degradation caused by livestock grazing	Density and distribution of plant species	Plant biomass changes	National park setting
Power transmission lines	Decreased O_2 production due to reduced food efficiency for wildlife	Density and distribution of wildlife species	Wildlife population changes	Organizing livestock grazing in local communities
Illegal Hunting	Expansion of species with less ecological value	Decline level of plant species	Local community migration	Water trough installation for wildlife
Demand for sand mining	Emission of pollution due to development-related activities	Level of vulnerable areas	Changes in ecosystem services	Preventing the activities of sand mines
Economic activities around the area			Change in human well-being	Creating checkpoints and posts

Research findings

of decision-making and prioritization of ecosystem services. However, in ecosystem management, it is necessary to communicate with economic, social, and biological concepts in a multi-criteria decision-making. In such a situation, appropriate decisions can be made for the management of ecosystems. In this way, one of the duties of managers is to correctly define the appropriate criteria (including economic, cultural, social, and environmental criteria) for the management of ecosystems (Zandebasiri et al. 2019).

In other words, the approach of valuing ecosystem services may be limited, given that some services with little market value are essential for local communities and social criteria. An example for this category of services can be the provision of fodder for domestic livestock. The lack of knowledge or the undervaluation of these services can put the management actions carried out in the PA at risk.

One of the limitations of this study was the lack of inventory ecosystem in the field of carbon calculation in the field of belowground biomass. Root sampling could also help root biomass data which could not be collected due to other work processes considered in this study. The protection of the area allowed for a lot of confusion in this area; therefore, sampling of roots was not done. It is suggested to investigate the issue of disservices in the valuation and comparison of values in PAs in future studies. Extending the study to the cultural services of PAs can also greatly contribute to the comprehensiveness of the discussion in this field.

Conclusion

In this study, a set of methods and issues were employed in the form of a case study in a PA in Iran. This study was conducted in several separate sections, and the results were put together. To address the research questions, in the first part, the ecosystem services of the PA were described. The results showed that the ecosystem of the region has a wide range of regulatory, provisioning, and socio-cultural services. In the second part of this study, some of the ecosystem services in the PA were economically valuated. This study adds to previous literature in environmental management by determining the value of ecosystem services in PAs. Also, this study reports superior value of regulatory services than to provisioning services for PAs. The results of the economic valuation of ecosystem services showed that the value of fodder is very low, compared to that of carbon sequestration. Therefore, it is necessary to plan to reduce the grazing pressure of livestock in the PA. However, complete elimination of livestock grazing from the region in the current situation is not possible due to socio-economic issues. The result of this study showed that the value of livestock grazing is less than the regulatory services such as oxygen production and especially carbon sequestration. The value of carbon sequestration in the region is very high and needs to be prioritized in planning and management processes. In the proposed solutions to solve problems in the field of socio-economic problems, taking into account the needs of local communities and the participatory management approach can be suitable solutions for PAs.

Less livestock grazing by local communities leads to better protection of the ecosystem; however, the local communities also need the ecosystem for their livelihood. Therefore, it is very important to consider a balance between this issue and proper monitoring. In this way, the connection of protection issues with livestock grazing in this PA is tangible and obvious.

In this way, this study has two main contributions for global studies. First, the management of PAs should give the most weight to soil carbon sequestration among different carbon sequestrations. Another issue is that among ecosystem services of PAs, fodder production is not economically comparable in any way to the regulatory services such as carbon sequestration, but due to the challenge of this issue, it is necessary to control it in combination with the participatory management of PAs. These value-added issues were concepts of valuing ecosystem services in PAs. These issues indicate the importance of the valuation of ecosystem services, and valuation gap can lead to ignoring some ecosystem services in management of PAs.

Another key issue in the management of Tang-e Sayad protected region is climate change and decline of species, which needs to be considered in planning processes. Continued drying of species reduces biomass and causes damage to habitats. These issues require policy-making to prevent ecosystem decline. The results of this study present policy implications for PAs. In the management of PAs, the issue of local communities should be considered in goal setting. Hence, the demand of local communities can be fulfilled by decision makers and policy makers for the management plan of PAs in the planning process.

With regard to different stages in this study, it was not possible to add other stages to this study. One issue which could complete this study is investigating the importance of ecosystem services. It is suggested that next studies focus on the importance of ecosystem services in PAs. Such studies could identify key priorities for PAs' strategies with respect to the outstanding ecosystem services in them. The priority of budgets and financial resources to prevent ecosystem decline is also better identified in such research projects. Further research could apply the system analysis of this study using operational research methods to find optimal values for different sub-system outputs in PAs. In terms of global knowledge, this study could be considered to examine management issues and validation to decide on conservation priorities. Examining ecosystem services can have limitations in terms of time, space, and ecosystem features.

Examining more attributes in ecosystem services, periodically reviewing observations, and expanding studies on regional, national, and international scales can remove these limitations.

Appendices:

Annex A

Tables 10, 11, and 12 have been obtained after regression calculations for all species and generalization of the relationship between production and canopy in plots 1, 5, and 10 to all plots for all species.

Table 10 Average production, aboveground biomass, and average available livestock forage in class 1 of plants' palatability

Plant species	Area (in hectares)	Average production (grams per square meter)	Aboveground biomass (kg / ha)	Average available livestock forage (kg/ha)
Stipa hohenackeriana Trin. & Rupr.	18000	9.92	99.18	59.50
Poa bulbosa L.	18000	0.40	4.01	2.41
Bromus tomentellus Boiss.	18000	3.95	39.48	23.69
Melica persica Kunth.	15000	1.04	10.42	6.25
Oryzopsis holciformis (M.B.) Hack	15000	0.42	4.22	2.53
Agropyron trichophorum (Link) Richter	15000	1.55	15.47	9.29
Agropyrum repens (L.) P. Beauv.	15000	1.51	15.05	9.03
Agropyrum intermedium (Host) P. Beauv	15000	1.55	15.47	9.29
Cynodon dactylon (L.) Pres.	200	0.10	1.04	0.62
Convolvulus arvensis L.	200	0.06	0.64	0.38
*Scorzonera seidlitzi*i Boiss.	15000	0.04	0.41	0.24
Taraxacum montanum (C. A. Mey.) DC.	18000	0.28	2.77	1.66
Tragopogon longirostris Bisch.	15000	0.04	0.39	0.23
Cardaria draba (L.) Desv.	200	0.04	0.35	0.21
Astragalus effusus Bunge	5000	0.07	0.68	0.41
Prangos ferulacea (L.) Lindl.	5000	2.72	27.19	16.31
Astragalus podolobus Boiss. & Hohen.	5000	0.33	3.28	1.97
Astragalus curvirostris Boiss.	5000	0.02	0.16	0.09
Astragalus macropelmatus Bunge	5000	0.00	0.04	0.02
Silene longipetala Vent.	15000	0.01	0.10	0.06
Chaerophyllum macropodum Boiss.	5000	0.05	0.52	0.31

Research findings

Table 11 Average production, aboveground biomass, and average available livestock forage in class 2 of plants' palatability

Plant species	Area (in hectares)	Average production (grams per square meter)	Aboveground biomass (kg/ha)	Average available livestock forage (kg/ha)
Annual grasses	20000	12.87	128.66	64.33
Annual forbs	20000	6.39	63.93	31.97
Achillea wilhelmsii C.Koch	5000	0.24	2.40	1.20
Polygonum aridum Boiss. & Hausskn.	10000	0.88	8.75	4.38
Carex stenophylla Wahlenb.	200	0.05	0.47	0.23
Silene cholorifolia Sm.	5000	0.25	2.50	1.25
Gypsophila paniculata L.	2500	0.25	2.53	1.26
Gundelia tournefortii L.	5000	25.01	250.10	125.05
Stachys lavandulifolia Vahl	10000	0.14	1.43	0.72
Astragalus rhodosemius Boiss. & Hausskn.	15000	15.59	155.86	77.93
Crucianella gilanica Trin.	10000	0.14	1.36	0.68
Linum album L.	5000	0.28	2.81	1.41

Research findings

Table 12 Average production, aboveground biomass, and average available livestock forage in class 3 of plants' palatability

Plant species	Area (in hectares)	Average production (grams per square meter)	Aboveground biomass (kg / ha)	Average available livestock forage (kg/ha)
Echinops shulabadensis Mozaff.	5000	0.44	4.43	1.55
Jurinea eriohasis DC.	5000	0.53	5.31	1.86
Artemisia aucheri Boiss.	2500	0.85	8.54	2.99
*Asperula rechnger*i Ehrend. & Schoneb.	10000	0.85	8.49	2.97
Onopordon leptolepis DC.	2500	0.16	1.60	0.56
Fibigia macrocarpa (Boiss.) Boiss	10000	0.01	0.09	0.03
Eryngium billardieri F. Delaroche	15000	2.47	24.69	8.64
Stachys inflata Benth	15000	0.21	2.08	0.73
Nepeta persica Boiss	5000	0.00	0.03	0.01
Phlomis olivieri Boiss	10000	1.29	12.89	4.51
Teucrium polium L.	5000	0.10	0.97	0.34
Echinophora platyloba DC.	10000	0.71	7.11	2.49
Euphorbia spp.	10000	0.29	2.92	1.02
Plomis aucheri Lam.	5000	0.31	3.13	1.10
Iris songarica Schrenk	2500	0.13	1.32	0.46
Scariola orientalis (Boiss.) Sojak	20000	9.94	99.38	34.78
Cousinia tenuiramula Rech.f.	15000	6.89	68.91	24.12
Marrubium cuneatum Russell	15000	0.05	0.51	0.18
Phlomis persica Boiss.	10000	0.83	8.33	2.92
Centaurea virgate Lam.	15000	0.33	3.28	1.15
Centaurea gaubae (Bomm.) Wagenitz	5000	2.77	27.66	9.68
Cousinia cylindraceae Boiss.	10000	0.10	1.04	0.36
Echinops leipolyceras Bornm.	15000	0.88	8.80	3.08
Cirsium spectabile DC.	5000	0.08	0.83	0.29
Astragalus campylanthus Boiss.	5000	0.91	9.06	3.17
Ajuga chamaecistus Ging. ex Benth.	5000	0.44	4.38	1.53
Astragalus albispinus Sirj. & Bornm.	5000	0.31	3.13	1.09
Acanthophyllum microcephalum Boiss.	7500	14.93	149.35	52.27
Astragalus gossypinus Fisch.	10000	6.86	68.62	24.02
Hertia angustifolia (DC.) O. Kuntze	7500	0.83	8.33	2.92
Astragalus susianus Boiss.	7500	9.43	94.27	32.99
Noaea mucronata (Forssk.) Aschers. et Schweinf.	20000	1.45	14.53	5.09
Astragalus microcephalus Willd.	15000	29.90	298.96	104.64
Acantholimon festucaceum (jaub. & Spach) Boiss.	7500	1.79	17.92	6.27
Astragalus cephalanthus DC.	1000	1.27	12.71	4.45
Lagochillus aucheri Boiss.	2500	0.14	1.41	0.49
Astragalus myriacanthus Boiss.	5000	0.78	7.81	2.73
psthyrostachys fragilis (Boiss). Nevski.	5000	6.73	67.27	23.54
Daphne mucronata Royle	1000	2.86	28.65	10.03
Krascheninnikovia ceratoides (L.) Gueldenst.	500	0.46	4.58	1.60
Hypericum scabrum L.	1000	0.01	0.07	0.02
Ziziphora clinopodioidei Lam.	1000	0.20	2.04	0.71
Varthemia persica DC.	1000	0.04	0.42	0.15

Research findings

Annex B

Description of the carbon content (percentage of carbon) in the different plots in the PA soils.

Number of plots	OC%	Number of plots	OC%	Number of plots	OC%	Number of plots	OC%
1	0.6825	19	0.5655	37	0.507	55	0.741
2	0.507	20	0.5655	38	1.248	56	0.741
3	2.145	21	0.312	39	0.819	57	0.9555
4	3.8025	22	0.3705	40	0.78	58	0.39
5	0.8385	23	0.663	41	0.897	59	1.209
6	0.624	24	0.7605	42	0.663	60	0.7995
7	0.273	25	0.3315	43	1.131	61	0.741
8	0.4095	26	0.507	44	1.2285	62	0.663
9	0.7605	27	2.457	45	0.741	63	2.0085
10	0.468	28	2.067	46	0.312	64	0.897
11	1.3845	29	1.638	47	1.3455	65	2.3205
12	1.404	30	1.3065	48	0.2535	66	1.404
13	0.4485	31	0.4485	49	0.4095	67	0.3705
14	0.234	32	1.2285	50	0.6435	68	1.755
15	1.3065	33	0.78	51	0.8385	69	0.273
16	0.78	34	0.7605	52	0.819	70	1.0335
17	2.3985	35	0.2925	53	0.975	71	1.521
18	1.014	36	0.39	54	0.975	72	0.7995

Research findings

Annex C

Fig. 7 The presence of wildlife in the PA; Wildlife is concentrated on the right. *Photograph was taken by the authors, summer of 2021*

Fig. 8 Dried plant species in the PA. *Photograph was taken by the authors, summer of 2021*

Fig. 9 Water trough installation for wildlife; the wildlife in the middle of the image is drinking. *Photograph was taken by the authors, summer of 2021*

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Declarations

Conflict of interest The authors declare no conflict of interest.

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