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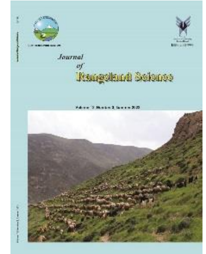

Research and Full Length Article:

Estimating the Contribution and Economic Value of Various Services of Pollinator Insects in a Northern Rangeland Ecosystem of Iran

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Abstract. Pollinators that feed on insect-pollinated plants have an important role in the food chain. Because pollinator insects have the potential to raise the value of agricultural crops and are very helpful in the nitrogen stabilization and the prevention of pest invasions. The present study mainly investigated the contribution of three services of insect pollination in rangeland along with the valuation of the services. In the study, to calculate the share of each service, cutting and weighing methods (for forage production) and engineering economics methods (replacement cost and Transfer of Benefits) were used to calculate the economic value in 2017. These services include increased yield of agricultural supply, upgraded nitrogen fixation by nitrogen fixing plants in rangelands, and reduction of plant pests and diseases by pollinator insects. Each service value was anticipated to be 15.31%, 48.9% and 35.78% of the overall of insect pollination, respectively. Besides, the extent of pollinator insects services value per hectare and the whole rangeland ecosystem was 62.37$ and 649096.5$, respectively. Consequently, following the outcome of the present study, preservation of insect pollination services is considerable to sustain and keep food security, sustainable agricultural development, sustainable employment, and protection of natural, environmental ecosystems and the environment, especially rangelands. Thus, insect pollinator services were regarded significant by policy makers and managers.

Key words: Biological control, Nitrogen fixation, Range economics, Replacement cost, Wild bee

Introduction

Cataloging natural resources, their outcomes, and functions is the initial movement in the environmental valuation. Thus, before considering the extent of an ecosystem, its services and functions are to be identified. In general, the latent qualities of rangeland ecosystems can be categorized into two factors: ecosystem services and ecosystem functions (Abedi *et al.*, 2014; Bazghandi *et al.*, 2020). These two factors are distinctive from one another (Braat and de Groot, 2012). Ecosystem functions are a mixture of structures and processes representing the possibility and availability of ecosystem services (Braat and de Groot, 2012; de Groot *et al.*, 2010). Conceptual ecosystem services are also useful ecosystem functions used by the public directly or indirectly (Braat and de Groot, 2012). Based on the previous studies, the segregation of ecosystem services and functions can be shown as in Fig. 1. (Braat and de Groot, 2012; Odum, 1971; de Groot *et al.*, 2010; Bostan *et al.*, 2019; Bostan *et al.*, 2020c).

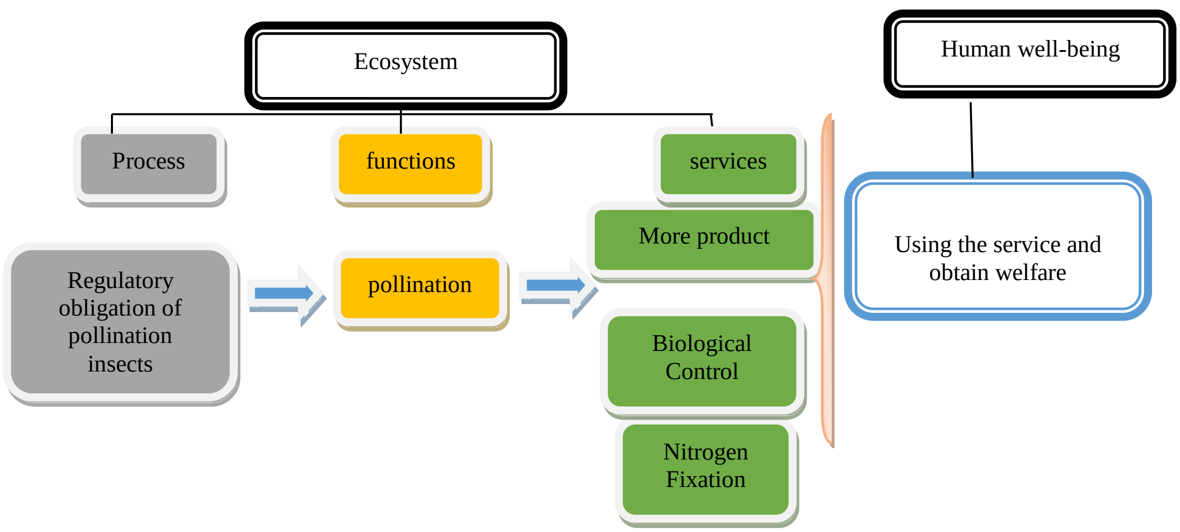

Fig. 1. Structure of ecosystem service

According to Fig. 1, rangeland ecosystems' services can lead to ecological structure and processes and their functions (Haines-Young, 2009; Braat and de Groot, 2012; Groot *et al.*, 2010; TEEB, 2010; Bostan *et al.*, 2020b). In this study, the authors' knowledge of an ecosystem's properties and insect pollination (entomophily) was considered in the Sheykh Musa rangeland ecosystem in north of Iran in the framework of three services including increasing agricultural production (forage production in the rangeland), controlling pests biologically, and nitrogen fixation.

Pollination is considered mandatory in the reproduction of different kinds of plants. Without animal pollinators, agricultural production is assumed to be possible only by artificial pollination at a very high cost. Insect pollinators include wasps, ants, beetles, moths and butterflies. In the present study, honey bees (including wild ones) are regarded as insect pollinators, naturally pollinating flowers and playing various roles in rangeland production. The economic values obtained include bees and other insects.

Almost 70% of angiosperms are pollinated by insects (Mokhber and Ghaffari, 2019). The global value of the products pollinated by honey bees is estimated to be 50 times greater than the extent value of the honey market. The continuing existence of various herbaceous kinds and the survival of different insects are closely linked and the existence of one without another is unthinkable. Besides their role in pollination and increasing agricultural production, insect pollinators play a valuable role in farm animal production, soil nitrogen stabilization, and environmental reclamation. Different efforts and experiments on the role of different factors in plant pollination have determined that 99% of pollination is implemented and conducted by pollinator insects, especially bees, and only 1% is performed by wind (UNEP, 2004). The role of pollinator insects in maintaining environmental relationships is very important because lack of the insect pollination causes a severe demise in soil enrichment (FAO, 2005). Pollination by insects is a crucial component of farming production machineries and sustainable development (Fleming, 2009); pollinators can expressively surge the magnitude and quality of grains and fruits. Table 1 shows the special effects of pollinator creatures, especially bees, on some agricultural crops.

Table 1. The effect of pollinator insects, especially bees, on the yield of some agricultural products

Plant	Increase yield (%) kg/h	Plant	Increase yield (%) kg/h	Plant	Increase yield (%) kg/h
Sunflower	79	Black wheat	71	Strawberry	20
Mustard	55	Tomato	18	Rapeseed	20
Safflower	64	Pumpkin	81	Beans	40
Cotton	18	Peach	9	Apple	9
Pepper	10	Watermelon	10	Cucumber	9
Cantaloupe	8	Soy	5	Blueberries	10

Source: Abrol, (2012)

Ghazoul (2005) and Richards (2001, 1993) have stated that the universal food security is not endangered by the decline of pollinating insects since most of the staple crops in the world are fertilized by wind or by the plant itself. These researchers ignore the diversity of diets on which humans rely and their claims have consequently been rejected (Klein *et al.*, 2007). Abrol (2012) and Bos *et al.* (2007) criticize the pollination values that have been stated over the earlier decades and highlight two major flaws.

1. The calculated economic values are exaggerated since insect pollination is not the solitary factor involved in the making of a product and other features such as labor and irrigation are also effective.

2. Price elasticity of demand in markets is not considered. In other words, increasing or decreasing production has no effect on the price or pollination value.

Pollination services are a positive side effect resulting in the increased production and reduced costs and will not pay for artificial pollinators. In contrast, the elimination of pollination services by modern agricultural activities can be considered a negative side effect (Abrol, 2012). In Fig. (2), the comprehensive process of bees' pollination has been identified in various aspects (Gordon and Davis, 2003; Abrol, 2012).

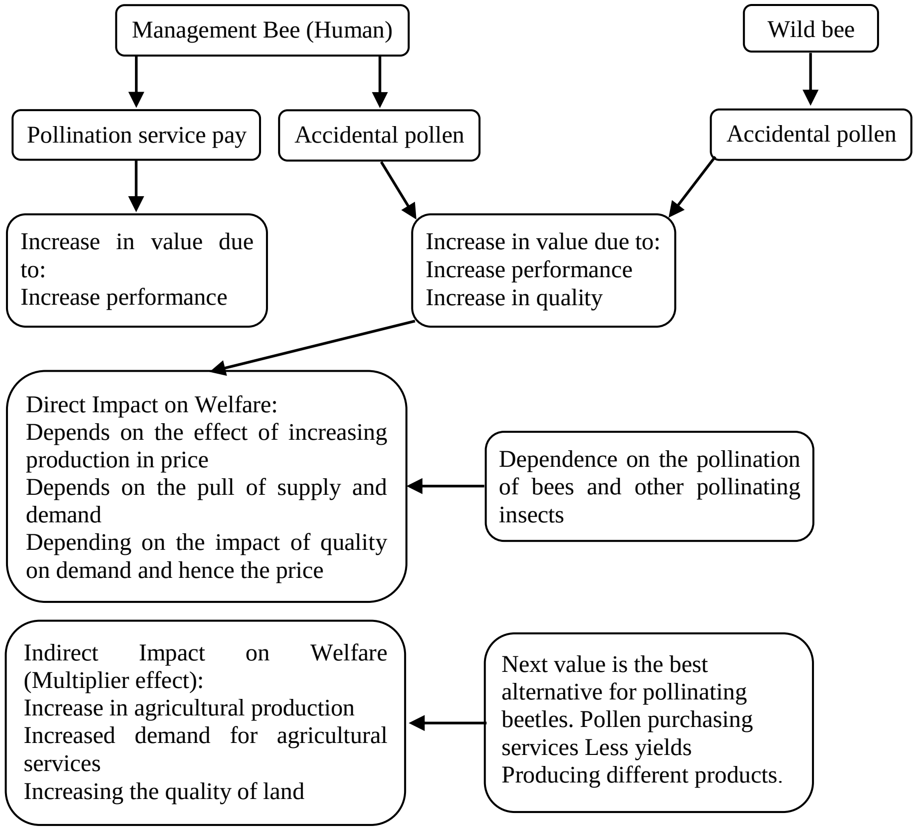

Fig. 2. Provide a complete approximation of the value of pollination function

Most rangelands of Iran are located in regions that are not suitable for cultivation because of water scarcity, limited rainfall, or intense soil erosion, and mountainous terrains. One of the most conjoint functions of such rangelands is beekeeping and honey production. Job creation with low capital investment is the most significant characteristic of beekeeping.

Organic control of pests is one of the central services of insect pollinator in rangelands which has begun to be appreciated in recent years. Through the biological control of pests and plant diseases in natural ecosystems not only would make chemical control of pests obsolete in rangelands and forests, but also this service would play an important role in reducing pest control costs in orchards and farms around rangelands and forests. Obviously, these avoided charges can be measured as benefits of this ecosystem service. However, it is not probable to compute the corresponding values due to the absence of documentation. Furthermore, the organic control of weeds through natural enemies and insects, especially bees, is reasonably economical. In recent years, the idea of biological control has become widely publicized. Overall, insecticides and herbicides can be replaced by this practical and affordable method.

Despite significant successes have been attained on the organic control of weeds, especially in non-cultivated parts such as rangelands or ponds, this method is not as widely adopted as approaches such as plowing and use of herbicides in weed management programs. The annual rate of biological control services in the production of crops where insects are deeply involved is estimated at more than $400 billion worldwide. In the USA, the value is placed at $4.5 billion annually (Norris *et al.,* 2010). Finally, scientific studies on the stated services are very central.

Few studies have been conducted on insect pollinators and biological control of natural ecosystems in Iran. Also, there are few global studies on ecological control of pests in ecosystems. Table (2) shows some studies conducted in Iran and other countries. Most studies investigate the value of bees.

Table 2. Summary of studies on the evaluation of pollinating services for bees and other insects

Study	Location	Methods	The value obtained
Breeze *et al.* (2015)	United Kingdom	Choice experiment	379 million $
Calderone (2012)	United States	Bee dependency ratio	10.6 billion £
Dong and Chen (2011)	China	Bee dependency ratio	29.3 billion £
Mwebaze *et al.* (2010)	United Kingdom	Contingent Valuation	1.77 billion £
Gallai *et al.* (2009)	world	Consumption surplus and dependency ratio	121.8 billion £
Allsopp *et al.* (2008)	South Africa	Cost of replacing	17.9 - 78.6 million £
Comprehensive Consulting Engineers Iran (2007)	Iran	Transfer benefits	4123.8 million IRR for the total aerial functions and biological control
Amirnejad *et al.* (2006)	Iran	Added value of agricultural products and market prices	414652.8 IRR per hectare
Allsopp and Cherry (2004)	South Africa	Bee dependency ratio	0.61 billion $
Xue and Tisdell (2001)	China	Cost of replacing	3.57 CNY per hectare
Tahmasebi and porgharaee (2001)	Iran	Added value of agricultural products and market prices	9536 billion IRR
Morse and Calderone (2000)	United States	Bee dependency ratio	14.6 billion $
Reid (1999)	United States	Contingent Valuation	1 $ per hectare
Tahmasebi (1996)	Iran	Added value of agricultural products and market prices	4359 billion IRR

As it is obvious in the studies, few have focused on the importance of insect pollination, and more attention has been given to the agriculture value-added in Iran. Most of the referenced studies have not focused on all three important services of insect pollinators and have only focused on bees. To date, no research has been conducted on the value of the three services' provided insect pollinator in rangeland ecosystems. Pollination by insects is one of the most imperative features of rangelands and that is because it can indirectly affect the industry along with its direct influence on rangeland vegetation through the increasing forest and farming production and eliminating invasive insects. Ecology services and functions are often very valuable, but are rarely traded in markets (Fatahi *et al.*, 2016).

In other words, they are not given enough attention due to the absence of accurate quantitative calculations in major decision- and policy-making (Karimzadegan *et al.*, 2007; Feizabadi and Hadian, 2015). It is unlikely to quantify such benefits to clarify the prominence of these resources (Bostan *et al.*, 2020a). Currently, attempts are taken to incorporate the value of these resources into national accounts using various economic theories (Fattahi Ardakani, 2016; Bostan *et al.*, 2018). Such efforts can be operational in maintaining these resources (Amirnejad *et al.*, 2006). Hence, the purpose of this study is to Estimate the Contribution and Economic Value of Various Services of

Pollinator Insects in Rangeland Ecosystem of Sheykh Musa.

Materials and methods

Study area

Sheykh Musa rangeland is located at 70 km south of Babol, Mazandaran province, Iran. It is located in the eastern Bandpey district, in FiroozJah village, between 36″ 9′ 21° and 36″ 6′ 10° north and 52″ 40′ 34° and 52″ 30′ 52° east, with an area of 10407 ha (equal to 104.07 km^2) and a perimeter of 44 km. It constitutes 87% of Sajjadrood watershed, 71% of rangelands of Babol, 2.68% of eastern rangelands of Mazandaran (Sari area), and 1.78% of rangelands in Mazandaran province. The area is mountainous with an altitude of 2500 m above sea level. It is enclosed by the Alborz Mountains in the north, Hyrcanian woods in the south and other rangelands to the east and west (Fig. 3). Based on the advent of symptoms of degradation in Sheykh Musa rangeland, the rangeland's condition is moderate showing a declining trend.

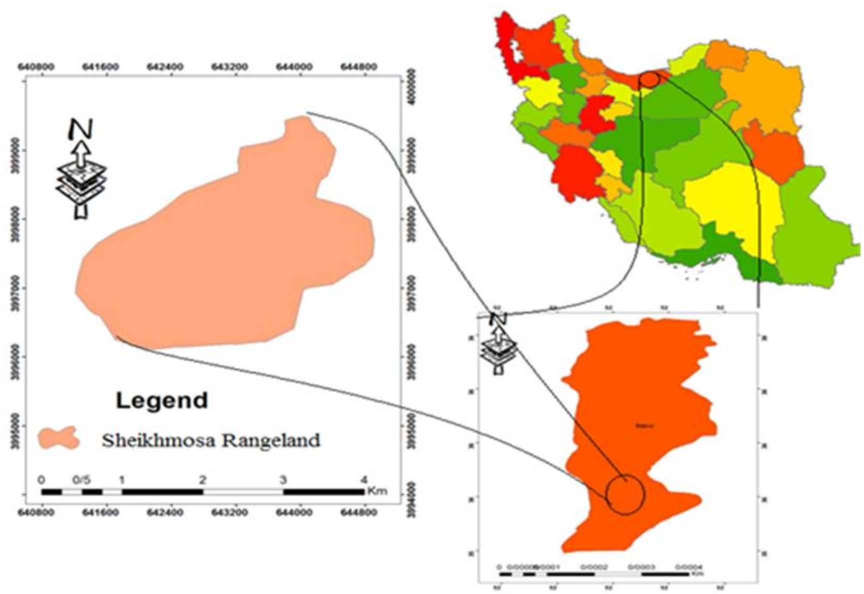

Fig. 3. The location of study site in Iran and Mazandaran province

Study method

To estimate the economic value of insect pollination, the price and amount of dry matter should be determined. First, the quantity of forage produced in Sheykh Musa was calculated using different methods and then, its economic value was obtained using engineering economics equations.

Various approaches are applied to determine rangeland capacity, of which clipping and weighing, ocular method, and double sampling are more common. We used the clipping and weighing technique because it is more precise than other methods (Baghestani Meybodi, 2008). We also used 1 × 1 m plot and selected Small square plots due to the dense vegetation cover. Larger numbers of smaller plots offer better accuracy in this method (Zare Chahoki *et al.,* 2013). The sampling sites were selected randomly. In the clipping and weighing method, plants were separated by vegetative form and placed in special paper envelopes. The amount of dry fodder consumed per livestock is 2 kg per day (Baghestani Meybodi, 2008). Considering the allowable use percent, the usable amount of dry forage for livestock per hectare was

50% (50% left untouched and 50% harvested). In a study conducted by Heshmatol Vaezin *et al.* (2010) in Iran, it was determined that there was a direct relationship between forage prices and Total Digestible Nutrient (TDN). Ranchers are more likely to pay per weight unit of forage when digestible nutrients and livestock production are higher. Therefore, for economic evaluation of forage production in Sheykh Musa rangeland, the replacement cost approach and market price were used. In this approach, the replacement forage value (barley) is calculated as the value of forage production. For this purpose, the global barley price is multiplied by Sheykh Musa rangeland's production considering the overall value of digestible nutrition.

Global barley prices will be taken into account as the replacement fodder. This way, the extent value of fodder per kg per ha was calculated based on the replacement forage (barley). In this study, three scenarios of global price, government guarantee price and wholesale price were used to calculate the total forage value in the rangeland. The information for 2017 was obtained from Organization of Agriculture Jahad Mazandaran, Iran, the Economic Council, and databases such as those of the Ministry of Industry, Mining and Trade, the Ministry of Agriculture- Jahad, customs, the Cereal Organization, the Department of Animal Production, and the International Trade Centre of United Nations (ITC). The calculation method is shown in equation (1).

$$V = h \times TDN \times b \times p \quad (1)$$

Where, V is the economic value of forage production in Sheykh Musa rangeland (in rials), h is for the quantity of fodder production in Sheykh Musa (kg), TDN is the amount of feed consumed by animals, b is TDN equivalent of barley (kg), and P is the price of barley under various price scenarios (in rials). The indirect function of insect pollination covers many services. These services are generally divided into three categories: 1) increasing agricultural yields, 2). increasing nitrogen fixation by nitrogen fixing plants in rangelands and its impact on rangeland products, and 3) eliminating and reducing plant diseases and pests (Abrol, 2012; Tahmasebi and Porgharaee, 2001; Bostan, 2017).

To calculate the value of increasing agricultural yields, the annual value of agricultural products and agricultural products' dependence of on insect pollination are usually used. Since there was no accurate information regarding the quantity of farming products in the Sheykh Musa rangeland, the forage produced by the rangeland was used as the agricultural products in form of medicinal and non-medicinal plants consumed by humans and animals. Equation (2) was applied to estimate the value of agricultural products obtained from insect pollination.

$$Y = V \times P \times D \quad (2)$$

Where, Y is the products value reliant on insect pollination, V is forage produced in the rangeland, P is price of the rangeland forage per kg and D is the dependence of forage production on insect pollination.

The dependence of farming yields on insect pollination (D) varies from product to product. The statistics are also different in various studies. In most studies, the lowest, typical and the highest data are 10% (0.1), 50% (0.5) and 90% (0.9), respectively (Abrol, 2012; Morse and Calderone, 2000). Tahmasebi and Porgharaee (2001) stated that the value of insect pollinators in rangelands was the outcome of the value of these insects for the stability and fertility of nitrogen fixing plants. They assumed the lowest fixed nitrogen to be 3% of dry weight of forage produced in rangelands. The indirect value of this function should be considered since it is the initial process in the production of livestock products. Tahmasebi and porgharaee (2001) stated 20% of the overall value of farming, animals' products was the indirect value of pollination. Equation (3) is used to evaluate the nitrogen fixation function.

$Y = V \times P \times 0.03 \times A$ (3)

Where, Y is the pollination value of Sheykh Musa rangeland (the value of fixed nitrogen in $), V is the quantity of dry matter produced in Sheykh Musa rangeland (kg/h), P is nitrogen fertilizer price (in $), A is the area of Sheykh Musa rangeland, and 0.03 is assumed the lowermost fraction of fixed nitrogen in Sheykh Musa rangeland.

When there are no insect pollinators and reduced nitrogen fixation in Sheykh Musa rangeland, nitrogen fertilizers should be used. Therefore, beside the value of fixed nitrogen as the insect pollination value, the charge of fertilizer application was added to the first value in the present study. The sum of the charge of fertilizer and the cost of fertilization are the charge of insect pollination as nitrogen fixation service in Sheykh Musa rangeland.

Biological control of pests plays a significant role in the pest control cost reduction in orchards and farms around Sheykh Musa rangeland. These avoided costs can also be measured as benefits of this ecosystem service. To evaluate the minded ecosystem service, the avoided cost method or the cost of prevention method can be used. The value of this service in natural rangelands can be regarded as the cost of pest and bug control in the absence of this function. Therefore, the value of this facility can be considered using the equation (4).

$V = A \times P$ (4)

Where, V is the value of organic control by the rangeland, A is the area of the rangeland, and P is the cost of chemical control of pests per hectare in Sheykh Musa rangeland in the absence of pollinator insects (Amirnejad, 2005; Bostan, 2017)

The replacement cost and transfer of benefits approaches, which are amongst the approaches of engineering economics, were used in the current paper. By examining 100 studies on ecosystem valuation, pas summarized the results of replacement cost and transfer of benefit approaches as shown in Table 3 (Pascual *et al.*, 2010). Based on other studies, the advantages and disadvantages of the two common approaches of evaluating natural and semi-natural ecosystems are presented in Table 4 (Alpizar and Vega, 2011; Davies *et al.*, 2000; King, 2007).

Table 3. The extent to which different valuation methods are used in the ecosystem valuation literature

	Valuation method	Cultural aspect	Hedging aspect	Regulatory	Supportive
1	Transfer benefits	9	3	4	6
2	Replacement cost	2	3	20	11

Table 4. Advantages and disadvantages of valuation methods

	Method	Advantages	Disadvantages
1	Transfer of benefits	Low cost and high speed	The results of the early studies are not sufficient for the required modifications; and the accuracy of the studies is questionable
2	Replacement cost	Based on observable data of actual behavior, at relatively low cost	Requires observable behaviors about inhibiting behaviors or expenses
			Estimates do not include damages caused by complete environmental degradation.
		In the case of certain assumptions, the lower bound determines the willingness to pay	The need for several key assumptions
			Limited to assessing the current condition
		A useful benchmark when social constraints exist for using the environment	Is a late-stage valuation method
			Failure to measure non-consumable values
		Relatively easy to implement	Only provides a minimal estimate
			Repair costs may be less or more than losses and benefits
			Replacement goods and services should be identical to the main service or at least be a good replacement
			Replacement should be accompanied by the return of the lost benefits resulting from normal depreciation.

Results

According to the obtained data from Department of Natural Resources and Watershed Management of Babol, Iran in (2017) and field observations, the total forage produced in Sheykh Musa rangeland was 2081.4 kg, so 200 kg dry matter per hectare was estimated.

The replacement cost method was used to determine forage value. The global price of barley, as the replacement forage was 0.172 $ per kg (ITC, 2015). Thus, the value of forage in Sheykh Musa rangeland was calculated using the replacement forage. In addition, TDN and b in equation (1) were considered 60% and 0.8 kg, respectively. Considering different kinds of price scenarios, economic value of forage production in Sheykh Musa rangeland is presented in Table 5 in line with the equation (1).

Table 5. Economic value of forage production in Sheykh Musa rangeland ecosystem

Dried fodder produced (Kg/ha)	Barley equivalent weight of dry fodder (Kg/ha)	Total rangeland area (ha)	Price ($)		Total economic value of forage production	
					Unit level ($)	Hectare ($)
200	96	10407	World (CIF)	0.172	172142.8	16.54
			Guaranteed	0.238	238333.3	22.92
			Wholesale	0.185	185476.2	17.82
Mean			0.198		198571.4	19.09

As is shown the Table (5), the arithmetic mean of the entire value of Sheykh Musa rangeland as forage production was estimated 198571.4 $ and the average value per hectare was 19.09 $. The average value of one kilogram of forage in Sheikh Mussa rangeland was estimated 0.09 $ which is likely to be used as the forage price in the region. The value of one kilogram of forage in Taham Watershed was estimated 0.136 $ (Yeganeh *et al.*, 2016). Thus, the price obtained was consistent with other studies.

Since the concentration of herbaceous plants in the environment was high, and information on the extent of plants' dependence on pollinator insects is not obtainable for this ecosystem, all three scenarios of plants' dependence on the insects were applied in this study. Given the per-kg value of forage made in the rangeland and equation (2), the economic value of increased yield of farming products is presented in Table 6 in three scenarios (10, 50 and 90%). Accordingly, the total economic value was between 19857.14 and 178890.5 $ which was the lowermost value estimated for the intended service. Due to the lack of information in the present study, only the amount of forage production was used to calculate the desired value. Also, the influence of insect pollinators on other rangeland and agricultural sub-products was not estimated.

Table 6. Economic value serving to increase the yield of agricultural products

Desired service	Forage price ($)	The amount of forage production (Kg)	Dependency scenarios (D) (percent)	Total Ecosystem Value ($)	Value of each hectare ($)
Increasing the yield of agricultural products	0.09	2081400	10	19876.8	1.90
			50	99383.9	9.54
			90	178891.2	17.18

The cost of using nitrogen fertilizers in Sheykh Musa rangeland includes the cost of fertilizer, the cost of transfer of fertilizer to the rangeland and the fertilization effort (labor cost). The value of fixed nitrogen in Sheykh Musa rangeland was estimated 10407 $ using equation (3). The cost of fertilization activity for one hectare of Sheikh Musa rangeland was 21.32 $ in 2017 multiplying this amount by the area of rangeland, labor cost for the entire rangeland was calculated at 221892.1 $. Finally, by addition of the cost of fertilizer and fertilization, the value of insect pollination in the form of nitrogen fixation service in Sheykh Musa rangeland was 232299.1 $ and its value per hectare was estimated 22.32 $.

Due to the lack of information on pesticide use and the absence of data on the effect of insects pollinators on pest control in Iranian rangelands, the study of Nabradi (2007) was used in the form of a transfer of benefits. Known as “The Economic Value of Rangeland Products in Hungary”, this research reported a cost of €15-46 per ha for the control of weed in rangelands. Since the covering of vegetation in northern rangelands of Iran is similar to Hungarian rangelands, we applied their obtained cost in our study. Based on the exchange rate of euro in Iran in 2017 (42000 Rials and considering a constant rate) and the study by Nabradi (2007), weed control per hectare in Sheykh Musa rangeland will cost 30.5 $. Finally, according to equation (4), the economic value of the biological control of pests was estimated 317413.5 $ for the entire Sheykh Musa rangeland and 30.5 $ per hectare. The value obtained is the lowermost value for the service and including merely weed control in Sheykh Musa rangeland.

Discussion and conclusion

Given the high prominence of insect pollinators over the natural ecosystems and indirectly on the food security, the research team studied its economic characteristic in Sheykh Musa rangeland, Iran. Insect pollination function is a regulatory process for rangeland ecosystems consisting of three major services: increased yield of agricultural products, increased nitrogen fixation by nitrogen fixing plants in rangelands and its influence on rangeland products, and reduction of plant pests and sicknesses.

To estimate the value of these three services of pollinators, first the quantity of forage production and the price of forage per kg were estimated, then deliberated in line with the replacement cost technique and the transfer of benefits approach. Given the latest data (Office of Economic Accounts, 2014), the gross domestic product and value-added of the farming sector in Iran were 2031596 and 135912 billion rials, respectively. Table (7) shows the share of each ecosystem service in Sheykh Musa rangeland.

Table 7. Share of selected services of Sheikh Musa rangeland ecosystem in GDP and agricultural additive value

Process	Function	Services	Value per hectare ($)	Total Ecosystem Value ($)	Share in GDP (%)	Agricultural added value (%)	The contribution of each service to pollination performance (%)
Regulatory	Bee and other pollinator insects	Nitrogen fixation	22.32	232299.1	0.00048	0.0071	35.78
		Biological control of pests	30.5	317413.5	0.0006	0.009	48.9
		The value of agricultural products	1.90	19876.8	0.000021	0.00061	-
			9.54	99383.9	0.0002	0.003	15.31*
			17.18	178891	0.0003	0.005	-
	The total value of pollination		62.37	649096.5	0.001	0.02	100

*To keep shares of services consistent, an average dependence of 50% on insects was considered for products in calculating the increase of agricultural production

As presented in Table 7, the organic control service by insect pollinators is about 49% of their overall contribution, which has the largest share. This contribution shows that insect pollinators play a significant role in the organic control of diseases and in precluding the onset of pests. It is worth noting that the value obtained for other services is presented as its lowest estimate because the evidence required to evaluate all features of the service was not available. Given the dependence of 50% of plants on insect pollination, the total value of the ecosystem was 27262 million Rials, equivalent to $ 649096.5, which is 2619588 rials per hectare, equivalent to $62,377 in 2017. Since much of the information about the ecosystem was not accessible and other aspects of bug pollination were also ignored, the value gained was the least possible value of insect pollination services in Sheikh Musa rangeland.

These Figs are very significant as they influence the gross local product and the value-added of Iranian agriculture. Amirnejad *et al.* (2006) estimated the economic value of insect pollination per hectare of northern forests (Mazandaran) at $ 46. In the present study, it is $ 62.3 per ha. Breeze *et al.* (2015) and Dong and Chen (2011) also estimated the economic value of pollination at 379 million $ and 10.6 billion €, respectively. As a result, according to the results, the present study is in line with most domestic and foreign studies on the importance of pollination services (from the perspective of economic value). But it is different in terms of economic value. Because studies are different in terms of economic indicators, methods and time period studied.

According to the results, suggestions for appropriate management of rangeland ecosystems regarding insect pollination are presented below.

Beekeeping has been completed in Iranian rangelands for many years providing great values to the local people. Pollinator services, in particular beekeeping, can be seen as a secondary occupation along with animal husbandry, or as the main occupation for local people. Hence, it is suggested that agricultural organizations and NGOs educate people about the insect pollinators, especially bees, and raise awareness. Financial facilitation is also required to create passion and willingness in this field.

Regarding the values obtained in the present study, authorities and managers of natural resources and agriculture should pay more attention to these kinds of ecosystem services and develop strategies to maintain them. These strategies include:

- Paying more attention to the organic control service of insect pollinators to reduce pesticide use, and moving towards viable development and organic agriculture.
- Supporting (through promotion) insect pollination plans to achieve sustainable agricultural goals, meeting growing demand, and reducing agricultural costs.
- Undertaking comprehensive studies about the positive effects of pollinator insects, especially bees, to enter their services into national accounts.

We recommend an inspection of all services of pollinator insects in natural and semi-natural ecosystems in future studies. Scientific studies from all over the world should be reflected and used to train specialists in this arena to conserve pollinator services by providing appropriate solutions.

Finally, following the present study and other studies in the field of ecosystem services (Braat and Groot, 2012; TEEB, 2010; Costanza *et al.*, 2014; Farley, 2012), it is recommended that services and functions of a bionetwork can be determined before examining its economic value.

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بررسی سهم و ارزش‌گذاری اقتصادی خدمات مختلف گرده‌افشانی حشرات در اکوسیستم مرتعی شمال ایران

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چکیده. گرده‌افشان‌ها عناصر کلیدی در شبکه مواد غذایی هستند. چون تغذیه حیوانات و پرندگان از گیاهانی است که توسط گرده‌افشان‌ها، گرده‌افشانی می‌شود. حشرات گرده‌افشان می‌توانند ارزش محصولات کشاورزی را افزایش دهند و در تثبیت نیتروژن خاک و در جلوگیری از هجوم آفات بسیار موثر هستند. در نتیجه هدف اصلی از پژوهش پیش‌رو، بررسی سهم خدمات سه گانه عملکرد گرده‌افشانی حشرات در اکوسیستم مرتعی و ارزش-گذاری اقتصادی هر یک از آن‌ها است. از این‌رو در مطالعه حاضر از اطلاعات در دسترس و روش قطع و توزین برای به‌دست آوردن میزان تولید علوفه در مرتع و روش‌های اقتصاد مهندسی (هزینه جایگزین و انتقال منافع) برای محاسبه ارزش اقتصادی هر یک از خدمات گرده افشانی حشرات در سال ۱۳۹۶ استفاده شد. نتایج نشان داد سهم هر یک از خدمات افزایش عملکرد محصولات کشاورزی، افزایش عملکرد تثبیت نیتروژن توسط گیاهان تثبیت کننده نیتروژن و از بین بردن آفات گیاهی و کاهش بیماری‌ها توسط حشرات گرده‌افشان به‌ترتیب؛ ۱۵/۳۱، ۴۸/۹ و ۳۵/۷۸ درصد از کل ارزش گرده‌افشانی حشرات است. همچنین ارزش هر هکتار و کل اکوسیستم مرتعی از جنبه حشرات گرده‌افشان به‌ترتیب؛ بالغ بر ۲۶۱۹۵۸۸ ریال (۶۲/۳۷ دلار) و ۲۷۲۶۲ میلیون ریال (۶۴۹۰۹۶/۵ دلار) به‌دست آمد. در نتیجه با توجه به نتایج تحقیق حاضر، حفظ خدمات گرده‌افشانی حشرات در جهت حفظ امنیت غذایی، توسعه پایدار کشاورزی، اشتغال پایدار، حفظ اکوسیستم‌های طبیعی به‌ویژه مراتع و محیط زیست حائز اهمیت است و باید از سوی سیاست‌گذاران و مدیران مربوطه مورد توجه قرار گیرد.

کلمات کلیدی: اقتصاد مرتع، تثبیت نیتروژن، زنبور وحشی، کنترل بیولوژیکی، هزینه جایگزین