



Economic Assessment of *Ferula assa-foetida* Cultivation in the Koochekali Rangeland, South Khorasan, Iran

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ABSTRACT

Aims: *Ferula assa-foetida* is one of the most widely used pasture plants in pharmacy, industry, and traditional medicine. The products of this plant play an important role in the economic prosperity of local exploiting communities by providing adequate economic income. Therefore, this study investigates the role of planting and exploiting the *F. assa-foetida* plant in increasing the income of local communities in the Koochekali rangeland of Tabas, Iran.

Materials & Methods: To conduct this study, we first prepared a plan to improve this rangeland, focusing on constructing curved pits and planting *F. assa-foetida* in three segments. Then, based on field visits and face-to-face interviews, we determined the number of available plant bases, the number of required curved pits, and the number of cultivable plant bases per ha, and calculated the cost of constructing a pit and planting plants in each segment. Next, based on visits to the region and harvest data from available plant bases, we determined the amount of *F. assa-foetida* oleo-gum-resin and dried fruit produced during the years of operation. To estimate production income, we used prices for oleo-gum-resin and dried fruit from the South Khorasan Natural Resources and Watershed Management Organization and interviews with local communities. Finally, based on projected production and prices for each product, we determined the income for each year of operation and for the entire plan.

Findings: The research showed that of the 6311 ha of total pasture area, 1963 ha can be cultivated with the *F. assa-foetida* plant. Accordingly, in the first, second, seventh, and tenth years, 423.97, 50.97, 158.33, and 789.73 ha of pasture area were allocated to *F. assa-foetida* cultivation, respectively. Also, after deducting the regeneration rate and exploitation losses, 275580, 384130, 102914, and 513324 harvestable plant bases will be available for exploitation in the mentioned years, respectively. As shown in the results, total cost and revenue are 180617.58 and 1275950.00 Million Rials, respectively, and the plan will be profitable at discount rates ranging from 12% to 24%.

Conclusion: Accordingly, planting the medicinal plant *F. assa-foetida* in the Koochekali rangeland of South Khorasan, Iran, impacts the local community economy by increasing beneficiaries' income and creating sustainable income. If you are trained in the principles of using this plant, you can improve production and continuity of use; by preserving the mother plants and producing seeds and natural propagation, you can create sustainable income in the region for a long time. Of course, droughts and profiteering by non-native actors can destroy and eliminate this valuable plant, which requires urgent attention from the authorities.

Keywords: Medicinal Plants; Natural Resources South Khorasan; Rangeland Management; Sustainable Production.

CITATION LINKS

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Introduction

Understanding the key factors affecting vegetation distribution enables effective pasture management ^[1]. Iran is one of the best regions for growing medicinal plants due to its diverse climate, geography, altitude, and soil types. In Iran, 52% of the land consists of rangelands, which support the livelihoods of more than 916,000 rural and tribal households ^[2]. Iran is the origin of more than 8000 plant species, more than 2300 of which have medicinal and industrial uses. This matters because 1728 of its species are native to Iran, giving Iran a monopoly on them ^[3]. An economic analysis of medicinal plants by the Food and Agriculture Organization of the United Nations (FAO) shows that the trade in medicinal plants will increase from \$100 billion in 2010 to \$5 trillion in 2050 ^[4]. Accordingly, given the high potential of medicinal plants and Iran's history of traditional medicine, exploiting medicinal plants can support local employment and economic prosperity ^[5] and play an effective role in sustainable management, employment, and food security ^[6].

F. assa-foetida belongs to the Umbelliferae family and is a medicinal, industrial, and pasture plant used by doctors and local communities for a long time ^[7, 8, 9]. This plant can be considered one of the most important medicinal plants in the world ^[10]. The importance of *F. assa-foetida* stems from the oleo-gum-resin extracted from its root, which has medicinal and industrial uses and provides great economic value for villagers and exporters ^[11, 12, 13]. The central plateau of Iran and the desert areas up to the Zagros Mountain Range in the provinces of Kohgiluyeh and Boyer-Ahmad, Fars, Kerman, Khorasan, Yazd, Semnan, Hormozgan, Sistan and Baluchestan, Isfahan, Lorestan, and Bushehr are mentioned as the main habitats of this plant ^[14, 15]. Research shows that exploiting the *Ferula assa-foetida*

plant is economically profitable and can contribute significantly to the country's non-oil exports while creating employment and empowering local communities ^[16]. Numerous studies have examined the exploitation of the medicinal plant *F. assa-foetida*. For example, Quiroz et al. ^[17] identified medicinal plants and investigated their economic value in Benin, South Africa. Their results also show that the sale of medicinal plants is of considerable economic importance to the country, and the medicinal plant trade in Benin is a major driver of the economy. In addition, Karimian et al. ^[8] investigated the effect of different methods of using *F. assa-foetida* on oleo-gum-resin production in the Tangsorkh rangelands of Kohgiluyeh and Boyer-Ahmad provinces, which have the highest number of users and the largest area of *Ferula assa-foetida* habitat. Their results showed that, considering the combined effects of age, method, and number of cuts, 5–6-year-old *F. assa-foetida* plants produced the least oleo-gum-resin. Plants cut 10 times using the one-sided method averaged 13.6 g of oleo-gum-resin, while 9–10-year-old plants cut 20 times using the conventional method produced the most, averaging 93.79 g. Abdollahzadeh et al. ^[18] also studied planting and propagation of *F. assa-foetida* and its economic assessment in Hormozgan. The results indicate that Bastak County has numerous *F. assa-foetida* habitats in Hormozgan Province, and these habitats have high economic value and exchange potential for local communities due to their gum production capacity. In another study, Sangchooli et al. ^[19] investigated the chemical composition, antioxidant properties, and antimicrobial activity of *F. assa-foetida* essential oil against diseases in different habitats in Iran (Tabas, Yazd, Neyshabur, and Kerman). Gas chromatography-mass spectrometry (GC-MS) analysis of the essential oil's main components

showed that Neyshabur essential oil had the highest component percentages, and Yazd EO showed the strongest antimicrobial activity, especially against Gram-positive bacteria, with a halo diameter of 22.5 mm. While previous research has demonstrated the economic importance of *F. assa-foetida* in various regions, long-term studies combining specific water management techniques with socio-economic impact assessments remain limited. Therefore, this study contributes to the field by presenting a 13-year assessment of a specific planting strategy using curved pits (water-catchment crescents). Thus, unlike previous studies that focused primarily on wild harvesting (excessive harvesting from natural habitats) or short-term economic returns, the present study offers a comprehensive perspective demonstrating how this specialized cultivation method impacts both the ecological restoration of the plant's habitat and the long-term economic resilience of local communities in the hyper-arid region of Tabas.

Materials & Methods

Study Area

The study area, covering 6311 ha, is located around the Koochekali well in Tabas City, South Khorasan Province, as shown in Figure (1). Tabas City is one of the important regions for *F. assa-foetida* production in Iran, and more than 80 thousand ha in this City are dedicated to *F. assa-foetida* habitats. Also, according to the climatic and topographical characteristics, medicinal plants in nature, if they are planted and cultivated in ecological conditions appropriate to their habitat, retain their compounds and properties to a large extent; therefore, this region has a high potential for the successful cultivation of *Ferula assa-foetida* [20,21]. The rangeland exploitation period in this area is 135 days (1.15 to 5.25), the rangeland type is summer, and exploitation is communal.

The region's maximum elevation is 1471 m, and the minimum is 1176 m. Rainfall was also calculated using the rainfall gradient formula (79 mm). The region has 720 livestock units, and the grazing season (135 days) allows 732 livestock units. The region has 4 *F. assa-foetida* farmers [22].

Research Methodology

Placement of *Ferula assa-foetida* Plant Cultivation with Curved Pits

The General Directorate of Natural Resources and Watershed Management of South Khorasan Province designated the 1963 ha area for *F. assa-foetida* cultivation within the 6,311 ha Koochekali rangeland as part of the Koochekali Rangeland Management Plan [22]. The Directorate based this designation on its existing spatial database, including topographic maps (1:25,000), soil survey data, and historical species distribution records, and verified it in the field during the 2024 growing season. The following ecological and operational criteria, reported by the Directorate and consistent with the autecological requirements of *F. assa-foetida*, were considered based on recent habitat suitability assessments and ecological zoning studies in Iranian arid rangelands [23].

(i) Elevation: 1,100–1,500 m a.s.l., corresponding to the known distribution range of *F. assa-foetida* in the arid rangelands of South Khorasan [14, 20]; the Koochekali rangeland spans 1176–1471 m, falling entirely within the suitable range.

(ii) Slope: 5–30%, suitable for construction of curved pits (pitting) and water infiltration [20, 24]; steeper slopes were excluded due to erosion risk.

(iii) Rainfall: minimum ~50 mm annual precipitation for establishment [25]; the Koochekali area receives approximately 79 mm, exceeding this threshold.

(iv) Soil texture: sandy-loam to loamy-sand,

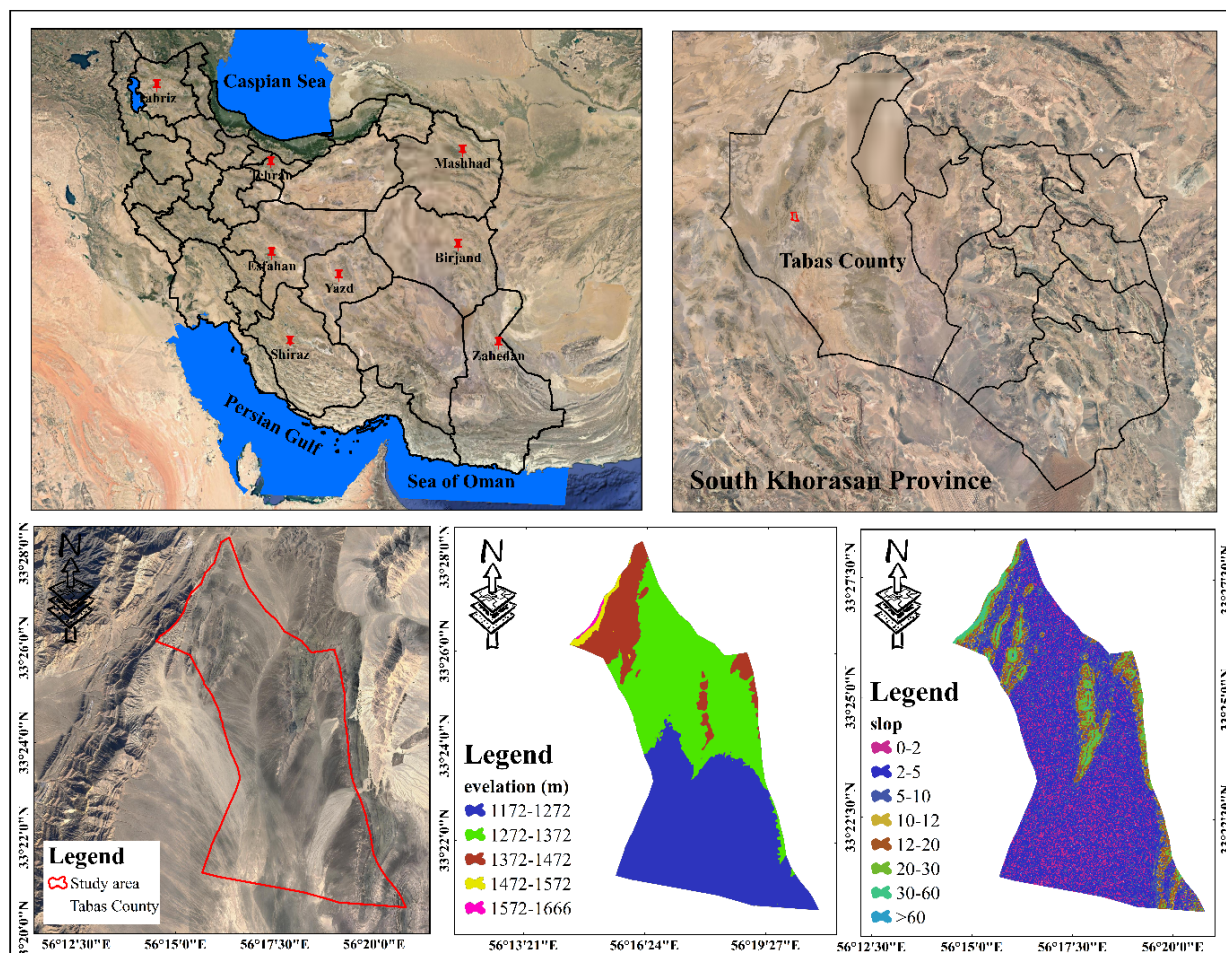


Figure 1) Geographical location and change elevation of the Koochekali region in South Khorasan, Iran

favoring taproot penetration ^[20, 21]; heavy clay and rocky outcrops were excluded.

(v) Aspect: south- and southwest-facing slopes preferred for higher solar radiation promoting resin flow during the tapping season (8, 14).

(vi) Existing *F. assa-foetida* presence: Areas with documented historical or current stands received priority designation based on field survey records in the Rangeland Management Plan ^[24].

These criteria and thresholds align with those reported in recent GIS-based habitat suitability studies for *F. assa-foetida* in South Khorasan ^[26]. The present study did not independently generate a new spatial suitability map; rather, the 1963 ha figure reflects the Natural Resources Directorate's official designation,

which used these ecological criteria in its planning process. The spatial suitability criteria and thresholds are summarized below in the order of their relative importance.

Determination of the Number of Plants

Field visits to the area in question and a survey of existing species showed that there are currently 84 plants per ha. To determine the target cultivation density of 1000 plants per ha, a combination of methods was employed: (i) systematic random sampling using 100 m² quadrats (10 × 10 m) across the existing *F. assa-foetida* stands in the Koochekali rangeland to measure the natural density and spacing; (ii) consultation with rangeland experts from the General Directorate of Natural Resources and Watershed Management of South Khorasan,

who recommended a planting spacing of approximately 3.16×3.16 m (~ 10 m² per plant) based on the ecological requirements and canopy spread of mature *F. assa-foetida* plants in comparable arid rangeland habitats; and (iii) reference to the technical guidelines of the National Forests, Rangelands and Watershed Management Organization ^[24], which specifies 250 curved pits per ha (with 4 plants per pit) as the standard density for *F. assa-foetida* restoration projects in arid zones. We applied the recommended 25% regeneration and 10% decline deductions to this target density, yielding 650 exploitable plants per ha at harvest time. This combined approach ensures that the assumed planting density is grounded in field measurements, expert knowledge, and institutional standards.

Cost of Implementing the Operation

To estimate the unit cost per hectare, we used the approved standard for implementing each hectare of the project in South Khorasan Province in 2024. Accordingly, the unit cost per hectare for curved pits with *F. assa-foetida* seeding was 22 Million Rials (including implementation and seed procurement costs) and was used in the calculations. Assuming a one-year implementation for each project component, we estimated the supervisor's cost for 90 days during operation and 30 days during implementation of the anticipated measures (hilling, seeding, etc.). After estimating implementation costs, we added 5% of the total initial cost for unforeseen costs. Because the curved pit is rainfed, the planted seeds receive no irrigation, and the Koochekali rangeland has no plant pests, we did not include the costs of spraying and irrigation operations.

In addition to the direct implementation costs, the following operational costs were estimated and included in the economic analysis based on field data and prevailing regional rates ^[24]:

- **Harvesting labor:** The tapping and seed collection of *F. assa-foetida* is a labor-intensive process spanning approximately 40 days per harvest season. Workers visit each plant about 10 times during the season. A worker can manage approximately 150 plant-visits per day in rangeland terrain. Therefore, for each section (130800 harvestable plants), the total plant-visits amount to 1308000 per season, requiring approximately 8720 worker-days. At the prevailing rural daily wage of 2.5 Million Rials, harvesting labor costs 21,800 Million Rials per section.
- **Processing:** Post-harvest processing, including oleo-gum-resin drying, seed cleaning, and basic packaging, requires additional labor and materials. This cost is estimated at 3,000 Million Rials per section per harvest cycle.
- **Transportation:** The harvested product is transported from the Koochekali rangeland to the Tabas City market (approximately 60 km). Freight costs are estimated at 500 Million Rials per section per harvest cycle.
- **Equipment:** Tapping knives, collection containers, drying mats, and basic storage facilities are required. The estimated cost is 1500 Million Rials per section per harvest cycle.
- **Management and supervision:** Annual project management and supervision costs are estimated at 1,500 Million Rials.
- **Maintenance:** Annual maintenance of fencing and infrastructure is estimated at 800 Million Rials.

Extracted Product

For this area, 250 curved pits per ha were predicted (the distance between the arcs varies with the area's slope, contour lines, vegetation status, and soil texture, and ranges from 5 to 7 m). Each curved pit contains 4 plants. In other words, each hectare of usable habitat contains 1,000 plants; after deducting 25% regeneration and 10% decline, 650 plants can

be utilized ^[20]. The mean extracted product from each plant is 30 g, including 10 g of oleo-gum-resin and 20 g of dried *F. assa-foetida* seeds ^[27]. This value came from structured interviews with 15 local exploiters across the Koochekali rangeland and adjacent Tabas *F. assa-foetida* habitats during the 2024 harvest season (April-June). The reported per-plant yield ranged from 12 g to 55 g (oleo-gum-resin: 4-18 g; dried seeds: 8-37 g), with a standard deviation of ± 11.2 g. Yield varies considerably with plant age and tapping method. Karimian et al. ^[8] showed that 5-6 year-old plants cut 10 times using the one-sided method produced a mean of 13.6 g per plant, whereas 9-10 year-old plants cut 20 times using the conventional method produced up to 93.79 g per plant. In the present study, since exploitation begins in the fourth year after planting and all plants within a given section are of the same cohort age, the adopted mean of 30 g per plant represents a conservative mid-range estimate for plants aged 4-5 years at first harvest, consistent with the lower-to-middle range reported by Karimian et al. ^[8]. The sensitivity analysis (Table 8) further shows that the project remains profitable even with a 20% reduction in revenue, corresponding to yields as low as 24 g per plant. Local operators (local people) begin exploiting the *F. assa-foetida* plant from the fourth year onward, so this study considers the exploitation age from the fourth year. We based the amount of extracted product and the harvesting time on interviews with local operators (local farmers) in this range.

Economic Analysis

To determine income from harvesting the oleo-gum-resin and dried fruit of *F. assa-foetida*, we used prices from the General Directorate of Natural Resources and Watershed Management of South Khorasan and local operators. Based on this, we set the price of each g of oleo-gum-resin and dried

fruit at 60 and 20 thousand Rials, respectively. To evaluate the project economically, we used costs, revenues, and project life. We used Net Present Value (NPV) to evaluate the project's economic performance. NPV is a standard method for evaluating economic projects in engineering economics. In this method, the cash flow (incomes and expenses) is discounted to the present value based on the time of occurrence (income or expenses). Thus, the cash flow also accounts for the time value of expenses and income, as shown in Eqs. (1) and (2).

$$NPV = \sum \frac{C_t}{(r-1)^t} - C_0 \quad \text{Eq. (1)}$$

$$0 = \sum \frac{C_t}{(IRR + 1)^t} - C_0 \quad \text{Eq. (2)}$$

where C_t is the cash flow in year t , r is the discount rate, t is the year number, and C_0 is the initial investment. Based on this index, projects with $NPV > 0$ are approved, projects with $NPV < 0$ are rejected, and projects with $NPV = 0$ are considered to have the same profit and loss ^[28].

Cost and Income Sensitivity Analysis

To determine the cost and revenue sensitivity of the present study, three scenarios were considered as follows:

- 1-Pessimistic scenario: 10 and 20% decrease in revenue and 10 and 20% increase in cost,
- 2-Intermediate scenario: no change in revenue or cost,
- 3-Optimistic scenario: 10 and 20% increase in revenue and 10 and 20% decrease in cost ^[29].

Findings

Reclamation Measures for the Curved Pits and Planting of *F. assa-foetida*

To sustainably develop the *F. assa-foetida* habitat, the project proposes a curved-pit

operation with *F. assa-foetida* seeding on 1963 ha in three segments (A, B, and C), as shown in Figure 2. Table (1) also presents the annual implementation schedule for the proposed project. As shown, the anticipated operations will be implemented in segments C and B, covering 423.97 and 158.33 ha, respectively, in the first and seventh years. Segment A was also divided into two parts because of its size and will be implemented in the fourth and tenth years, covering 590.97 and 789.73 ha, respectively. Because it is exploited every 4 years, the cultivation period is divided accordingly, and after harvesting each segment, the next segment is cultivated.

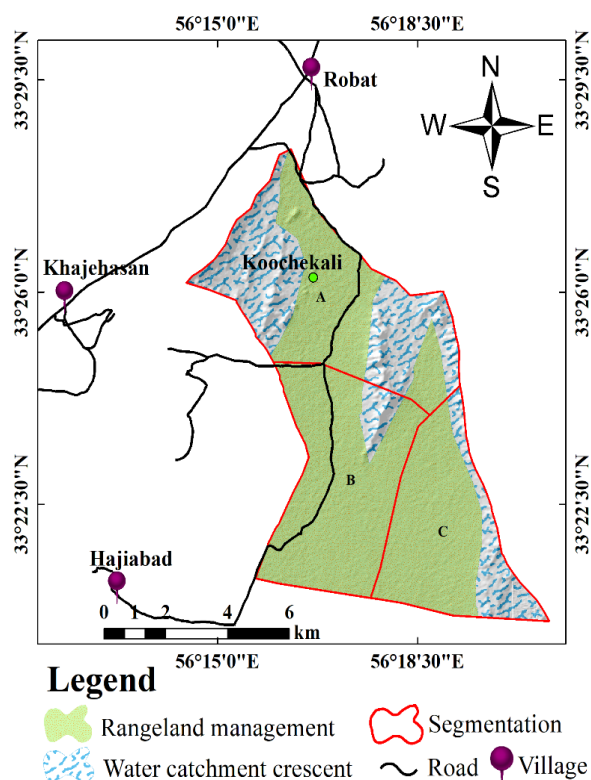


Figure 2) A view of the implementation of corrective actions of the curved pits and the planting of *F. assa-foetida* in the Koochekali rangeland system, separated by implementation parts.

Cost of Implementing the Operation

To determine the cost of monitoring and implementing the plan, the costs are based

on 2024 rates and do not include inflation. Accordingly, Tables 2 and 3 present the costs of monitoring and implementing corrective actions, respectively. To monitor the plan's implementation and the use of the *F. assa-foetida* plants, the Department of Natural Resources and Watershed Management requires 120 days of supervision and 365 days to fence the area. Based on the mean costs considered for experts, the total cost to supervise implementation of the plan was determined to be 1450 Million Rials.

Implementing each hectare of the curved pit, along with sowing *F. assa-foetida*, was estimated at 22 Million Rials. Table 3 presents the cost of implementing the project per plot and the total project cost. As shown, in the first, fourth, seventh, and tenth years, the total cost of project implementation and monitoring was estimated at 10777.34, 14451.34, 1608.33, and 2239.73 Million Rials, respectively. Overall, the cost of implementing and operating the plan over 13 years was determined to be 34916.74 Million Rials. The cost of fencing (preservation) is included for all years.

Harvestable Product

Table 4 presents income from harvesting *F. assa-foetida* products, including oleo-gum-resin and dried fruit, by year. Table 4 shows the number of exploitable plants and the income from them in the next cultivation period. In other words, plants cultivated in the first year will be usable in the fourth year, and the first-year profit is realized in the fourth year. As shown, income from cultivating the *F. assa-foetida* plant in the first, fourth, seventh, and tenth years will be 275580.50, 38413.50, 102914.50, and 513324.50 Million Rials, respectively. Overall, the project's revenue over 13 years was estimated at 1,275,950 Million rials.

Table 1) The annual schedule of the implementation of curved pit and *Ferula assa-foetida* planting measures in the Koochekali pasture system, by implementation parts (ha).

Segment	Implementation Year	Seeding Curved Pit (<i>F. assa-foetida</i>)	Segment	Implementation Year	Seeding Curved Pit (<i>F. assa-foetida</i>)
C	First (1)	423.97	B	Seventh (7)	158.33
A	Fourth (4)	590.97	A	Tenth (10)	789.73

Table 2) Estimated cost of monitoring (one year).

Costs	Number of Days of Monitoring	Unit Cost (Million Rials)	Total Annual Expenses (Million Rials)
Expert	120	3	360
Driver and Car Rental	120	3	360
Inhibitor	365	2	730
Total Costs		8	1450

Table 3) Estimated cost of implementing rehabilitation operations by year (Million Rials).

Implementation Year	Curved Pit	Monitoring	Plural	Implementation Year	Curved Pit	Monitoring	Plural
1	9327.34	1450	10777.34	Seventh (7)	158.33	1450	1608.33
2	-	730	730	Eighth (8)	-	730	730
3	-	730	730	Ninth (9)	-	730	730
4	13001.34	1450	14451.34	Tenth (10)	789.72	1450	2239.73
5	-	730	730	Eleventh (11)	-	730	730
6	-	730	730	Twelfth (12)	-	730	730
Total						34916.74	

Economic Analysis

Table 5 compares revenues and expenses incurred during the project implementation period. As shown, the total cost of implementing the entire project over 13 years, including direct implementation and operational costs, is 180617.58 Million Rials. The total revenue over 13 years will be 1275950.00 Million Rials. Accordingly, the profit after project completion is 1095332.42 Million Rials (all income and expenses are

considered without taking into account the inflation rate).

For the project's economic analysis, we used the evaluation criteria: net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (B/C). As presented in Table 6, the project remains economically viable across all discount rate scenarios. The revised IRR of 152.78%, while still high, reflects the unique economic structure of *F. assa-foetida* cultivation projects: relatively

Table 4) Estimated income from implementing correctional operations by year.

Implementation Year	Area (ha)	Plant ha of Executive	Production Amount (kg)		Oleo-gum-Resin Price*	Dried Fruit**	Gross Income (Million Rials)
			Oleo-Gum-Resin	Dried Fruit			
1	423.97	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	590.97	275580.5	2755805	551161	1653483	1102322	2755805
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	158.33	384130.5	3841305	768261	2304783	1536522	3841305
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	789.73	102914.5	1029145	205829	617487	411658	1029145
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	513324.5	5133245	1026649	3079947	2053298	5133245
Total	1963	1275950	12759.5	25519	765570	510380	1275950

Note: * includes the price of each g of sap at 60000 Rials, and ** includes the price of each g of dried fruit at 20000 Rials.

Table 5) Comparison of costs and income in Million Rials, including operational costs.

Year	Implementation Costs by Year (Million Rials)	Operational Cost Breakdown (Million Rials)	Total Cost	Income	Profit/Loss
1	10,777.34	2300	13077.34	0.00	-13,077.34
2	730.00	2300	3030.00	0.00	-3,030.00
3	730.00	2300	3030.00	0.00	-3,030.00
4	14,451.34	29100	43551.34	275580.50	232029.16
5	730.00	2300	3030.00	0.00	-3,030.00
6	730.00	2300	3030.00	0.00	-3,030.00
7	1,608.33	29100	30708.33	384130.50	353422.17
8	730.00	2300	3030.00	0.00	-3,030.00
9	730.00	2300	3030.00	0.00	-3,030.00
10	2,239.73	29100	31339.73	102914.50	71574.77
11	730.00	2300	3030.00	0.00	-3,030.00
12	730.00	2300	3030.00	0.00	-3,030.00
13	0.00	29100	29100.00	513324.50	484224.50
Sum	34,916.74	137100	172016.74	1275950.00	1103933.26
5% Unforeseen			8600.84		
Total	36662.58		180617.58	1275950.00	1095332.42

low recurring annual costs (management and maintenance) compared to the substantial harvest revenues occurring every 4 years. This pattern is characteristic of long-cycle medicinal plant cultivation in arid rangelands, where most expenditures are front-loaded during planting, and most revenues are realized in discrete, large harvest events. As the project progresses and operational costs stabilize, the high IRR also declines toward more conventional levels over a longer time horizon beyond the initial 13-year period.

Cost and Revenue Sensitivity Analysis

To assess sensitivity to the discount rate, we considered three scenarios: a low social discount rate of 12%, a moderate rate of 18%, and the market-based interbank rate of 24%. While the interbank rate reflects the opportunity cost of capital in Iran's financial market ^[30], lower social discount rates are more appropriate for public rangeland restoration projects where societal welfare is the primary objective ^[28]. As shown in Table 7, the project remains economically viable across all discount-rate scenarios. Based on the revised analysis, the NPV was 194553.37 Million Rials, the IRR was 152.78%, and the B/C ratio was 4.85 at the 24% discount rate (Table 7). The IRR considerably exceeds all three discount rates, confirming the project's profitability.

Discussion

This study evaluated the planting, management, and exploitation plan of the *F. assa-foetida* habitat over 13 years in the Koochekali rangeland of Tabas, Iran. Tabas, in South Khorasan Province, is one of the most important areas for *F. assa-foetida* production in Iran ^[14]. Cultivation of this plant and exploitation of its oleo-gum-

resin and dried fruit play an important role in increasing local community income ^[12]. In other words, multiple processing and uses of this plant's oleo-gum-resin in pharmaceutical and industrial applications can increase its economic productivity ^[31,32], support sustainable regional management, and reduce migration to other regions ^[33]. Implementing this plan requires a total cost of 180617.58 Million Rials, which, because of limited government budgets and low incomes, has been divided into several parts over different years. As stated in the research, and as a review of the sources also shows, planting the *F. assa-foetida* plant reaches exploitation after 4-5 years ^[27]. Therefore, to secure financial resources, planting and exploitation of the *F. assa-foetida* plant are planned in 4 periods so that, with harvest and income generation, people's role and participation in further project management will increase and self-reliance will be formed in the region ^[34,35]. The results show that after 14 years, income from implementing this project will be 1275950 Million Rials, which, after deducting costs, will yield 1095332.42 Million Rials in net profit for the project. Given the total area of the *F. assa-foetida* plantation (1963 ha), each hectare of the project will generate 559 Million rials in profit. Research by Azizi et al. ^[27] on determining the economic value of *F. assa-foetida* in Bardsakn, Khorasan Razavi, Iran, states that planting 2800 *F. assa-foetida* plants will yield a profit equivalent to 10041355466 Rials, which is also profitable with a discount rate of 3.3 and is in line with the results of this research. In another study in Tabas City, Khosravi and Mehrabi ^[14] also found that exploiting the *F. assa-foetida* plant in Tabas was profitable, with a benefit-to-cost ratio of 1.9 and economic justification.

Table 6) Sensitivity analysis of NPV to different discount rates (Million Rials).

Discount Rate (%)	NPV (Million Rials)	IRR (%)	B/C Ratio
12	413788.11	152.78	5.82
18	277594.66	152.78	5.30
24	194553.37	152.78	4.85

Table 7) Sensitivity analysis to changes in income and expenses (Million Rials).

Revenue Change (%)	Net Profit	Total Income	Cost Change	Net Profit	Total Cost
-20	840142.42	1020760	-20%	1131455.94	144494.06
-10	967737.42	1148355	-10%	1113394.18	162555.82
+10	1222927.42	1403545	+10%	1077270.67	198679.33
+20	1350522.42	1531140	+20%	1059208.91	216741.09

In the present study, the revised benefit-to-cost ratio was 4.85, which is substantially lower than the previously reported value of 33 and more consistent with the nature of the project. The remaining difference from the B/C ratio of 1.9 reported by Khosravi and Mehrabi ^[14] can be primarily attributed to two factors: (1) their study was conducted in 2006, and the market price of *F. assa-foetida* oleo-gum-resin has increased approximately 15-20 fold since then, while costs have not increased at the same rate; and (2) the scale of the present project (1963 ha, 392600 plants) benefits from economies of scale compared to smaller individual operations. These distinctions highlight the importance of using current market prices and project-specific cost data in economic evaluations. The mean yield of 30 g per plant used in this study is a point estimate derived from structured interviews with local exploiters. The reported range of 12- 55 g per plant (SD = ± 11.2 g) reflects substantial variation driven by plant age, tapping method, soil

conditions, and annual rainfall. Karimian et al. ^[8] demonstrated that plant age and cutting method considerably affect oleo-gum-resin yield: 5-6-year-old plants produced as little as 13.6 g per plant under one-sided cutting with 10 visits, while 9-10-year-old plants produced up to 93.79 g per plant under conventional cutting with 20 visits. In the present study, all plants within a given section are the same cohort age (first harvested at 4- 5 years), and the conventional tapping method is applied with approximately 10 visits per season. Under these conditions, the adopted mean of 30 g per plant represents a conservative mid-range estimate. The sensitivity analysis (Table 8) further confirms that the project remains profitable even with a 20% revenue reduction, corresponding to yields as low as 24 g per plant, well within the lower range reported for 4-5-year-old plants under conventional tapping. Future studies should consider age-specific yield modeling and longitudinal monitoring to capture

the temporal dynamics of *F. assa-foetida* productivity more precisely.

As this and previous research show, using *F. assa-foetida* can increase farmers' income and support sustainable regional management, and its high economic value can also boost the development of non-oil exports.

Conclusion

F. assa-foetida is one of the most widely used medicinal-industrial plants that can be exploited from rangelands, and paying attention to it plays a considerable role in increasing the economic power of users. Therefore, this study investigated the role of implementing a rangeland management plan for planting *F. assa-foetida* in curved pits (water-catchment trenches) in the Koochekali rangeland of Tabas County, Iran. The results indicate that implementing this plan properly can provide appropriate profitability for local operators in the region. In other words, the projected exploitation over 4 periods can provide sustainable income for local operators. Given the plant's natural propagation under suitable conditions, operator and official attention to principled exploitation, preservation of seed-bearing mother plants, and prevention of non-native operators can play an effective role in reducing income and migration in the long term. Accordingly, empowering customary systems and establishing social oversight mechanisms can prevent non-local resource users from entering. In the revised analysis, we included labor, processing, transportation, equipment, management, and maintenance costs in the economic evaluation. However, we did not quantify socio-environmental co-benefits such as reduced soil erosion, local employment

creation, and rangeland ecosystem services, which future studies could consider. Future research should also incorporate age-specific yield modeling and longitudinal field measurements to refine productivity estimates and account for inter-annual variation.

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