

# Research Paper: Economic Assessment of Environmental Risks of Orchard Lands in Arid Regions with a Sustainable Rural Development Approach (Case Study: Rural Areas of Sistan and Baluchestan in Southeastern Iran)

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## ABSTRACT

**Purpose:** Horticultural products are essential for Sistan and Baluchestan provinces, but they have been severely affected by drought in recent years. Farming is an activity replete with risks. In this activity, a combination of natural, social, economic, and human-induced hazards exposes farm producers to fragile and vulnerable conditions, which ultimately cause income instability. Sistan and Baluchestan province in Iran is a fertile agricultural region for horticultural production, but its climatic conditions and hazards have increased the risks associated with agricultural production risks and impaired its economic sustainability.

**Methods:** This research analyzes the factors influencing natural hazards in the orchards of Sistan and Baluchestan province with an emphasis on sustainable rural development. Orchard farmers were selected from the northern part of the province, including Khash County, Saravan County, and Chabahar. The fuzzy technique for order of preference by similarity to the ideal solution (FTOPSIS) was used for modeling. Data were collected from 50 experts through a questionnaire.

**Results:** The findings indicated that the criteria of granting credits and loans, allocating budget and/or subsidies, and establishing family savings were of the highest importance. Furthermore, the final results of FTOPSIS revealed that the support-credit and economic alternatives were the top priorities with weights of 0.5764 and 0.5364, respectively.

**Conclusion:** Based on the results, it is recommended that relevant officials and agencies prioritize crop insurance as the best strategy for risk management. Additionally, regional crop insurance and compensating insurance claims when the actual regional yield is less than the guaranteed yield.

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### 1. Introduction

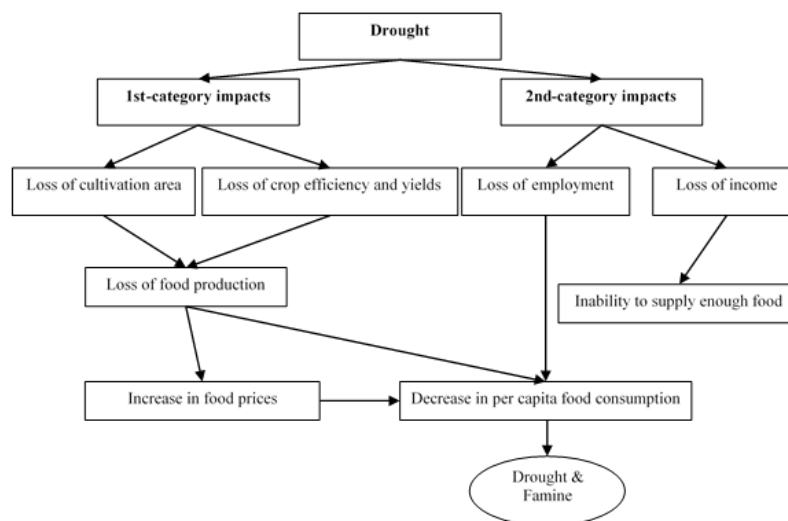
**S**ustainable development is socially feasible, economically justifiable, politically appropriate, environmentally friendly, non-destructive, managerially practical, and culturally suitable (Richard & Johan, 2001; Khairi et al., 2022; Salmanzadeh, 1992). According to the United Nations’ Development Goals 2030, attention to climate change is a major environmental and global issue in sustainable development (Ghaffari Moghadam et al., 2022).

Climate change refers to the change in the long-term averages of climatic factors and alteration in the long run and the change in the statistical distribution of atmospheric patterns (such as distribution of pressure patterns), which can be caused by factors like biological processes, variations in solar radiation intercepted by the Earth, and volcanic activities (Hulme, 2016).

Since education is the first step in strengthening orchard owners against climate change, it is essential to investigate the educational needs of orchard owners regarding adaptation to climate change (Sasani, 2013). Living in a high-risk environment does not necessarily correspond to susceptibility and damage often results from the lack of resilience and insufficient understanding of the degree and type of the risk and how it acts (Ali Ahmadi et al., 2021; Shahraki et al., 2012).

Therefore, the perspective on hazards has extensively changed worldwide shifting from a narrow focus on reducing susceptibility to an emphasis on increasing resilience to disasters. In this context, programs aimed at alleviating the effects of hazards should focus on creating and reinforcing resilience within societies and must consider the resilience of local communities as a key component in the chain of hazard management (Sardar Shahraki et al., 2018).

The foundation for risk management for agricultural development in Iran can be established by developing a comprehensive risk management plan for the agricultural sector, attracting private sector participation, utilizing the support of crop insurance funds, allocating subsidies to poor farmers, developing agricultural infrastructure and non-governmental institutions, promoting cooperation among farmers, and holding educational and promotional courses (Sardar Shahraki et al., 2016; Rakhshani et al., 2021; Razzagi Bourkhani et al., 2017). Rural economies in Iran today face numerous risks across various aspects. One of these aspects is rural agriculture, which is threatened by such risks as land use change, the desolation of cultivated lands, and desertification since Iran is located within the drought belt (Kiani Ghalehsard et al., 2021). The main cause of this crisis can be traced back to the lack of attention to promoting drought crisis management and farmers’ resilience against these risks. Environmental hazards, such as drought, can potentially turn into catastrophic and destructive disasters if adequate risk-mitigation systems are not implemented (Ghafarimoghadam et al., 2021).



**Figure 1.** The impacts and consequences of drought and risk in agriculture with an emphasis on sustainable rural development (Keshavarz & Karami, 2008)

## 2. Literature Review

Halkrou (1949) was one of the first researchers to introduce the theory of group insurance in the mid-20th century. According to his research, voluntary and individual crop insurance is not effective. Halkrou (1949) stated that this type of crop insurance often faces significant destructive and reverse barriers. He highlighted the role of crop insurance in reducing farmers' risk aversion. Researchers argue that by distributing risk between insurance providers and farmers, agricultural producers are encouraged to cultivate more risk-prone crops and utilize agricultural inputs more efficiently (Rakhshani et al., 2021).

Drought is a natural and recurrent climatic phenomenon and can occur in almost all climatic zones, from low-rainfall regions to high-rainfall regions (Moslemi et al., 2021). It creates numerous economic, social, and environmental challenges. Agrarian and rural communities are among the first to experience heavy losses (Salamaty et al., 2001). In the last decade, drought-related loss in Iran's agricultural sector has been estimated at over 240,000 billion IRR (Anonymous, 2021). Many governments have now realized the invalidity of their crisis management practices and seek to gain information on the correct methods of risk management to mitigate drought-related damages to society and minimize the effects of future droughts (Arab & Mehdikhani, 2005; Ali Ahmadi et al., 2021; Darijani et al., 2010).

Sistan-va-Baluchistan ranks first in Iran for cultivation area and production rates for some horticultural crops, such as bananas and mangoes. This province has 4500 ha of bananas Orchards, of which 4000 ha are fertile and the remaining are non-productive. Bananas can be harvested throughout the year. Thanks to its proximity to the Equator and maritime humidity, this province supports the cultivation of tropical and subtropical fruits including pineapple watermelon, banana, papaya, guava, coconut, pomegranate, and citrus. Crops in Sistan-va-Baluchistan are cultivated year-round. Farms in areas such as Iranshahr, Nikshahr, Sarbaz, Chabahar, and Konarak are capable of producing two harvests annually. A key priority of the Agriculture Jihad Organization in this province is to promote chemical-free organic farming. However, this potential remains underutilized due to a shortage of investors.

In addition to tropical produce, this province is also a major producer of citrus fruits, including grapefruits, Bergamot oranges, oranges, and tangerines, as well as pomegranates and seasonal crops that have distinctive

flavors compared to those grown in other parts of Iran. The total fruit orchard area in the province is 80,620 ha, with 8,700 ha dedicated to tropical fruits. Annually, the province produces approximately 158,000 tons of crops. The banana plantations cover 5,000 ha with an annual production of 135,000 tons in this province. Other tropical fruits grown in the province include Sapodilla, papaya, date, mango, banana, jujube, guava, coconut, and tamarind. The province has 1,400 ha of mango orchards, with an average tree density of 156 trees/ha, producing 12,500 tons of mangoes annually (Anonymous, 2021).

This research aims to examine the factors influencing the impact of natural hazards on fruit orchards in Sistan-va-Baluchistan province with a focus on sustainable development. The study's specific objectives are to identify and analyze the most critical factors that contribute to mitigating natural risks affecting orchards in the province.

### Review of Relevant Studies

Geravandi and Alibeygi (2011) studied the factors affecting the use of production risk management strategies by corn farmers in Kermanshah County, Iran using the descriptive-correlational method. Similarly, Najafi Kani and Hajhosseini (2014) examined the determinants of risk management practices in the agricultural sector in a case study on wheat and soybean growers in the rural district of Kongor rural district of Kalaleh County, Iran. Their findings revealed that wheat and soybean growers utilized various risk management strategies, including human, social, and managerial approaches, as well as government-supported and price-risk management tactics.

The chi-squared test demonstrated significant relationships between risk management components and farmer activity levels, with qualitative factors such as human risks, the risk of production inputs, price, social risk, governmental risk, and financial risk all being statistically significant at the  $P < 0.01$  level. Furthermore, there was a notable correlation between job satisfaction and willingness to remain in the rural areas at the  $P < 0.05$  as well as between crop satisfaction and production conditions. This underscores the necessity of implementing strategic risk mitigation plans to enhance agricultural sustainability.

Shahbazi and Arsalanbod (2016) studied the significance of agricultural risk management among wheat growers in Farsan County. Their findings indicated that risk management was strongly associated with insur-

ance use, market factors, and experts' opinions. [Azizi et al. \(2016\)](#) analyzed on-farm risk management strategies used by farmers in response to drought crises. The study revealed that micro-level adaptation measures, such as crop diversification, adjusting sowing dates, employing deep tillage techniques, altering crop cultivation and livestock farming areas, modifying land use, adopting shared irrigation systems, and revising farm operation schedules, helped reduce production risk.

[Zanganeh \(2017\)](#) assessed agricultural risk management in response to climate change in Malard County. The study used the Analytic Hierarchy Process (AHP) to rank the primary risk factors affecting agriculture in the region. The study found that changes in precipitation timing posed the greatest threat, followed by groundwater depletion and rising temperatures. The SWOT method was employed to develop strategic responses to these challenges, which were categorized into four areas: executive and technical, agricultural, institutional and organizational, and legal frameworks. The results ranked executive and technical strategies as the most effective, followed by agronomic strategies.

[Zhang \(2004\)](#) examined drought risk management in maize cultivation using Geographical Information Systems (GIS) and climatological, geographical, and environmental data in the Songliao region, China. The study's findings suggested that proposed drought mitigation strategies could significantly contribute to risk reduction and sustainable agriculture development.

[Nelson and Loehman \(2005\)](#) investigated the relationship between farmers' agronomic practices and their willingness to adopt crop insurance. Their research revealed that farmers' interest in insurance coverage was influenced by cropping season, crop species, and farming systems. Farmers were more likely to adopt insurance policies during low-water seasons to mitigate financial risks.

[Bakker \(2007\)](#) explored the social and sociological influences on wheat growers' risk-taking behavior in India. The study indicated that social welfare and community participation played a key role in determining farmers' willingness to take risks. Higher levels of social welfare and engagement were associated with a greater likelihood of risk-taking in wheat farming.

### 3. Methodology

The research adopted multi-attribute decision-making models under fuzzy logic to achieve the research goal.

To deal with the ambiguity of human thinking, Professor Lotfi Zadeh, an Iranian-American scientist at Berkley University, presented the theory of fuzzy sets in 1965. The theory leans towards the rationality of uncertainty caused by imprecision and ambiguity. The key contribution of the theory of fuzzy sets is that it can represent ambiguous data and real-world phenomena that are subject to uncertainty ([Ravanshadnia & Bozorgmehr, 2014](#)). Fuzzy logic applies to various management systems, including decision-making, policymaking, planning, and modeling. An explicit or classic set is usually defined as collection of elements as  $x \in X$  which can be countable or uncountable. If  $R^n$  is a dimensional Euclidean space- $x = (x_1, x_2, \dots, x_n)^T$  and  $y \text{ Equals } = (y_1, y_2, \dots, y_n \text{ for } )^T$  are two vectors from  $R^n$  so that  $x_i, y_i \in X$  for  $i = 1, 2, \dots, n$  and T imply the transpose of the vectors. For both vectors  $x, y \in R^n$ , we have the following definitions:

$$\begin{aligned} (x, y) &= (x_1y_1 + x_2y_2 + \dots + x_ny_n) \\ x \geq y &\Leftrightarrow x_i \geq y_i, \quad i = 1, 2, \dots, n \\ x \geq y &\Leftrightarrow x \geq y, \quad x \neq y \\ x \succ y &\Leftrightarrow x_i \succ y_i, \quad i = 1, 2, \dots, n \end{aligned} \tag{1}$$

If we have  $x, x^* \in R^n$  for each  $a, b, c \in R^n$  and  $a \leq b \leq c$ , then

$$\begin{cases} (a, x) \leq (a, x^*) \\ (c, x) \leq (c, x^*) \end{cases} \tag{2}$$

Then,  $0 \leq (c, (x^* - x))$  and  $0 \leq (a, (x^* - x))$ , so Equation (3) holds given the inequality  $a \leq b \leq c$ :

$$\begin{aligned} (c, (x^* - x)) - (a, (x^* - x)) &= ((c - a), (x^* - x)) \leq ((c - b), (x^* - x)) \\ &= (c, (x^* - x)) - (b, (x^* - x)) \\ \Rightarrow (c, (x^* - x)) - (a, (x^* - x)) &\leq (c, (x^* - x)) - (b, (x^* - x)) \\ \Rightarrow (b, (x^* - x)) &\geq (a, (x^* - x)) \geq 0 \\ \Rightarrow ((b, x^*) - (b, x)) &\geq 0 \end{aligned} \tag{3}$$

Consequently,

$$\begin{cases} (a, x) \leq (a, x^*) \\ (c, x) \leq (c, x^*) \end{cases} \Rightarrow (b, x) \leq (b, x^*) \tag{4}$$

In the classical set theory, membership is a definitive concept for a set, i.e., an element either belongs to the set or does not. In a classic set A, membership can be represented by Equation (5):

$$X_A(x) = \begin{cases} 1 & \text{if } x \in A \\ 0 & \text{if } x \notin A \end{cases} \tag{5}$$

Where the pair of numbers  $\{0, 1\}$  is called the attribute set, a fuzzy set is an extension of the attribute set  $\{0, 1\}$  to all numbers in the interval  $[0, 1]$ . Then, the form of the attribute set transforms into the membership function represented by  $\mu_i(x)$ . As such, if X is a reference

set whose members are represented by  $x$ , then, the fuzzy set  $\tilde{A}$  in  $X$  is represented as a set of ordered pairs as  $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in R\}$  in which  $\mu_{\tilde{A}}(x)$  is called the membership function of  $x$  in  $\tilde{A}$ . Fuzzy sets are displayed as follows (Ravanshadnia & Bozorgmehr, 2014).

$$\begin{aligned} \tilde{A} &= (x, \mu_{\tilde{A}}(x)) \\ \tilde{A} &= \mu_{\tilde{A}}(x_1) / x_1 + \mu_{\tilde{A}}(x_2) / x_2 + \mu_{\tilde{A}}(x_3) / x_3 + \dots = \sum_{i=1}^n \mu_{\tilde{A}}(x_i) / x_i \quad (6) \\ \tilde{A} &= \int_x \mu_{\tilde{A}}(x) / x \end{aligned}$$

The support of the fuzzy set  $\tilde{A}$  is represented by  $S(\tilde{A})$ , which is an explicit set of  $x$ 's belonging to the reference set  $X$ , where the membership function is non-zero. The core of the fuzzy set  $\tilde{A}$ , which is represented by  $Core \tilde{A} = \{x \in X | \mu_{\tilde{A}}(x) = 1\}$ , is a subset of the reference set  $X$  in where the membership degree of all elements in  $\tilde{A}$  is (1). The height of a fuzzy set is the largest membership degree in it and is denoted by  $hgt(\tilde{A}) = \max\{\mu_{\tilde{A}}(x)\}$ . Two fuzzy sets  $\tilde{A}$  and  $\tilde{B}$  are said to be equal if and only if  $\forall x \in X, \mu_{\tilde{A}}(x) = \mu_{\tilde{B}}(x)$ . The fuzzy set  $\tilde{A}$  is said to be the fuzzy subset of  $\tilde{B}$  if and only if  $\forall x \in X, \mu_{\tilde{A}}(x) \leq \mu_{\tilde{B}}(x)$ , and the fuzzy set  $\tilde{A}$  is empty if and only if  $\forall x \in X, \mu_{\tilde{A}}(x) = 0$ . In the fuzzy set  $\tilde{A}$ , Sup means the upper bound  $\mu_{\tilde{A}}(x)$  In that set, which is also called the weight of the set  $hgt_{(\tilde{A})} \sup_{x \in X} \mu_{\tilde{A}}(x)$ . If  $\alpha \in (0,1]$  is a real number for a fuzzy set  $\tilde{A}$ , then we define (Taheri, 1999).

$$[\tilde{A}]^\alpha = \{x \in R | \mu_{\tilde{A}}(x) \geq \alpha\} \quad (7)$$

$-\alpha$  is called a cut of the set If it is defined as:

$$[\tilde{A}]^\alpha = \{x \in R | \mu_{\tilde{A}}(x) > \alpha\} \quad (8)$$

For a finite set  $\tilde{A}$ , the main number  $|\tilde{A}|$  Is defined as Eq. (9) and (10) (Taheri, 1999):

$$|\tilde{A}| = \sum_{x \in X} \mu_{\tilde{A}}(x) \quad (9)$$

$$\|\tilde{A}\| = \frac{|\tilde{A}|}{|X|} \quad (10)$$

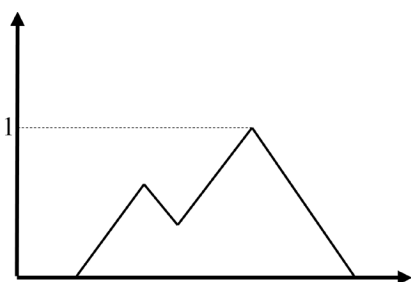


Figure 2. A non-convergent fuzzy set JSRD

Which is called the relative cardinal number. Regarding sets that have a continuous reference set, the cardinal number is defined as  $|\tilde{A}| = \int_x \mu_{\tilde{A}}(x) dx$ . A fuzzy set  $\tilde{A}$  is called convergent over  $R$ , if and only if (Taheri, 1999).

$$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min\{\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\} \quad (11)$$

in which  $x_1, x_2 \in X, \lambda \in [0,1]$ . Figures 2 and 3 present a convergent and a non-convergent set (Asgarpour, 2002).

Two conventional fuzzy numbers are triangular fuzzy numbers and trapezoidal fuzzy numbers. A fuzzy number  $\tilde{A} = (a, b, c)$  Is called a triangular fuzzy number if its membership function is ascending and equal to  $\mu_{\tilde{A}}(x) = x - a / b - a$  in the interval  $[a, b]$  and descending and equal to  $\mu_{\tilde{A}}(x) = c - x / c - b$  in the interval  $[b, c]$ .  $b$  is the intermediate dimension and  $a$  and  $c$  are the left and right feet of the triangular fuzzy number, respectively. Figure 3 displays a triangular fuzzy number. Also, a fuzzy number  $\tilde{A} = (a, b, c, d)$  Is called a trapezoidal fuzzy number if its membership function is ascending and equal to  $\mu_{\tilde{A}}(x) = x - a / b - a$  in the interval  $[a, b]$ , is unit and uniform in the interval  $[b, c]$ , and descending and equal to  $\mu_{\tilde{A}}(x) = d - x / d - c$  in the interval  $[c, d]$ .  $b$  and  $c$  represent the left and right feet of this fuzzy number, respectively. Figure 4 depicts a trapezoidal fuzzy number (Asgarpour, 2002).

In multi-criteria decision-making models, data were collected from experts through a questionnaire in both qualitative and quantitative formats. The relevant indicators were developed using researcher-made questionnaires and were validated over multiple stages by university professors and leading experts. The current research used the Fuzzy Technique for Order of Preference by Similarity to the Ideal Solution (FTOPSIS). Data were collected from 50 experts during the 2021-2022 cropping year. The Fuzzy MADMsolver 2018 software suite was employed for modeling this technique. The gardeners surveyed were selected from the northern regions of the province, including Khash County, Saravan County, and Chabahar.

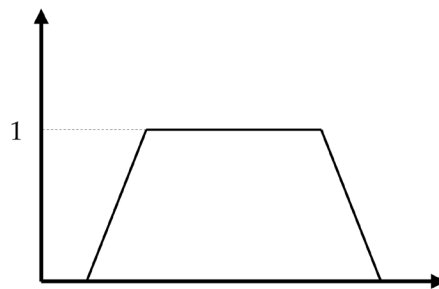


Figure 3. A convergent fuzzy set JSRD

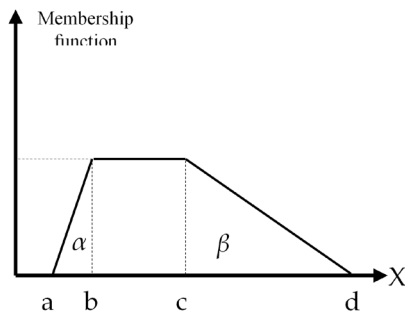


Figure 4. A trapezoidal fuzzy number  $\tilde{A} = (a, b, c)$

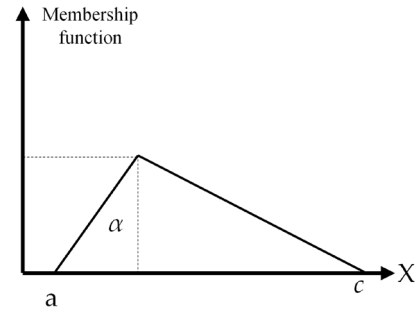


Figure 5. A triangular fuzzy number  $\tilde{A} = (a, b, c, d)$



Table 1. Criteria and alternatives considered in the research

Alternatives	Criteria
Support-credit (O1)	Crop insurance (A1)
	Granting credits and loans (A2)
	Budget allocation and/or subsidization (A3)
Economic (O2)	Access to crop sale markets in rural (A4)
	Off-farm income sources and income diversification with new businesses in rural (A5)
Infrastructural-institutional (O3)	Family saving (A6)
	Improvement of production infrastructure (A7)
	Development of processing industries in rural (A8)
	Storage availability (A9)
	Transportation network in rural (A10)
Social-participatory (O4)	Availability of innovation and technology (A11)
	Social networks in rural (A12)
	Development of local communities and religious groups (A13)
	Social capital in rural (A14)
Educational information (O5)	Reinforcement of the participation of local farmers and communities (A15)
	Holding educational courses and workshops for extension agents (A16)
Knowledge and awareness (O6)	Availability of information in rural (A17)
	Establishment of monitoring and early warning system (A18)
	Attention to Indigenous knowledge and local experiences (A19)
Environmental-spatial (O7)	Enhancement of knowledge and risk awareness (A20)
	Proper farm practices, e.g., selection of chilling-resistant cultivars (A21)
	Aerial and spatial survey (A22)
	Conservation agriculture in rural (A23)
	Meteorological and smart agriculture information (A24)
	Land use in rural (A25)



### 4. Findings

Based on the steps of FTOPSIS, a decision matrix should first be constructed. The research studied seven alternatives with 25 criteria. Table 2 presents this matrix.

Based on the results in Table 2, the seven alternatives were explored within the first five criteria. Alternative O1 gained 8/9/10 based on criterion A1. It, on the other hand, gained 7/8/9 based on criterion A2 and 6/7/8 based on criterion A3. Alternative O2 gained 6/7/8, 4/5/6, and 6/7/8 based on criteria A3, A4, and A5, respectively. Data for the other alternatives are available in Table 2.

**Table 2.** The decision matrix based on FTOPSIS

	A1	A2	A3	A4	A5
O1	(8/9/10)	(7/8/9)	(6/7/8)	(4/5/6)	(6/7/8)
O2	(7/8/9)	(7/8/9)	(6/7/8)	(4/5/6)	(6/7/8)
O3	(6/7/8)	(7/8/9)	(3/4/5)	(4/5/6)	(6/7/8)
O4	(3/4/5)	(6/7/8)	(3/4/5)	(6/7/8)	(7/8/9)
O5	(1/2/3)	(5/6/7)	(3/4/5)	(6/7/8)	(7/8/9)
O6	(1/2/3)	(5/6/7)	(2/3/4)	(6/7/8)	(3/4/5)
O7	(1/1/1)	(2/3/4)	(1/2/3)	(7/8/9)	(2/3/4)



**Table 3.** The decision matrix based on FTOPSIS (continued)

	A6	A7	A8	A9	A10
O1	(5/6/7)	(3/4/5)	(2/3/4)	(4/5/6)	(2/3/4)
O2	(5/6/7)	(3/4/5)	(2/3/4)	(2/3/4)	(2/3/4)
O3	(5/6/7)	(3/4/5)	(2/3/4)	(2/3/4)	(2/3/4)
O4	(2/3/4)	(5/6/7)	(5/6/7)	(3/4/5)	(3/4/5)
O5	(2/3/4)	(5/6/7)	(5/6/7)	(3/4/5)	(3/4/5)
O6	(2/3/4)	(2/3/4)	(6/7/8)	(5/6/7)	(3/4/5)
O7	(2/3/4)	(2/3/4)	(6/7/8)	(5/6/7)	(3/4/5)



Table 3 presents the decision matrix based on FTOPSIS for the seven studied alternatives under criteria A6-A10. For example, criterion A6 was estimated at (5/6/7), (5/6/7), (5/6/7), (2/3/4), (2/3/4), and (2/3/4) for alternatives O1 to O7, respectively.

In Table 4, the decision matrix has been built for different alternatives based on criteria A11-A15. Accordingly, alternatives O1-O7 gained (1/2/3) based on criterion A12. They gained (1/2/3) under criterion A13, too. However, the results show that the seven alternatives gained (2/3/4), (3/4/5), (2/3/4), (2/3/4), (1/1/1), (1/2/3), and (1/2/3) under criterion A11, respectively.

**Table 4.** The decision matrix based on FTOPSIS (continued)

	A11	A12	A13	A14	A15
O1	(2/3/4)	(1/2/3)	(1/2/3)	(2/3/4)	(2/3/4)
O2	(3/4/5)	(1/2/3)	(1/2/3)	(2/3/4)	(2/3/4)
O3	(2/3/4)	(1/2/3)	(1/2/3)	(2/3/4)	(2/3/4)
O4	(2/3/4)	(1/2/3)	(1/2/3)	(2/3/4)	(2/3/4)
O5	(1/1/1)	(1/2/3)	(1/2/3)	(2/3/4)	(2/3/4)
O6	(1/2/3)	(1/2/3)	(1/2/3)	(2/3/4)	(2/3/4)
O7	(1/2/3)	(1/2/3)	(1/2/3)	(2/3/4)	(2/3/4)



The results of the decision matrix based on TOPSIS are presented in Table 5 for the seven studied alternatives under criteria A16-A20. The results reveal that the studied seven alternatives gained (3/4/5) under criterion A16 and (5/6/7) under criterion A20.

Table 6 presents the results of the decision matrix based on FTOPSIS for the seven alternatives under criteria A21-A25. After building the decision matrix, the next step in FTOPSIS is to build normalized matrices whose results are presented in Table 7. The weights assigned to the criteria are of high importance in FTOPSIS. Accordingly, the criteria were assigned with weights based on FTOPSIS. The results are observed in Table 7.

**Table 5.** The decision matrix based on FTOPSIS (continued)

	A16	A17	A18	A19	A20
O1	(3/4/5)	(1/1/1)	(1/1/1)	(4/5/6)	(5/6/7)
O2	(3/4/5)	(1/1/1)	(1/1/1)	(4/5/6)	(5/6/7)
O3	(3/4/5)	(2/3/4)	(1/1/1)	(4/5/6)	(5/6/7)
O4	(3/4/5)	(2/3/4)	(2/3/3)	(4/5/6)	(5/6/7)
O5	(3/4/5)	(1/2/3)	(2/3/3)	(4/5/6)	(5/6/7)
O6	(3/4/5)	(1/2/3)	(3/3/3)	(4/5/6)	(5/6/7)
O7	(3/4/5)	(1/2/3)	(2/3/4)	(4/5/6)	(5/6/7)



**Table 6.** The decision matrix based on FTOPSIS (continued)

	A21	A22	A23	A24	A25
O1	(4/5/6)	(5/6/7)	(5/6/7)	(2/3/4)	(6/7/8)
O2	(4/5/6)	(1/1/1)	(5/6/7)	(2/3/4)	(1/2/3)
O3	(4/5/6)	(1/2/3)	(7/8/9)	(1/1/1)	(4/5/6)
O4	(2/3/3)	(1/2/3)	(4/5/6)	(1/2/3)	(4/5/6)
O5	(1/2/3)	(2/3/4)	(4/5/6)	(1/2/3)	(6/7/8)
O6	(4/5/6)	(4/5/6)	(2/3/4)	(2/3/4)	(6/7/8)
O7	(1/2/3)	(4/5/6)	(2/3/4)	(4/5/6)	(1/2/3)



**Table 7.** Weights assigned to the criteria based on FTOPSIS

Variable (criterion)	Value	Variable (criterion)	Value	Variable (criterion)	Value
A1	(0.1/0.1/0.1)	A10	(0.2/0.2/0.2)	A18	(0.2/0.2/0.2)
A2	(0.9/0.9/0.9)	A11	(0.4/0.4/0.4)	A19	(0.7/0.7/0.7)
A3	(0.8/0.8/0.8)	A12	(0.5/0.5/0.5)	A20	(0.5/0.5/0.5)
A4	(0.4/0.4/0.4)	A13	(0.1/0.1/0.1)	A21	(0.2/0.2/0.2)
A5	(0.7/0.7/0.7)	A14	(0.1/0.1/0.1)	A22	(0.1/0.1/0.1)
A6	(0.8/0.8/0.8)	A15	(0.6/0.6/0.6)	A23	(0.3/0.3/0.3)
A7	(0.5/0.5/0.5)	A16	(0.6/0.6/0.6)	A24	(0.2/0.2/0.2)
A8	(0.4/0.4/0.4)	A17	(0.4/0.4/0.4)	A25	(0.3/0.3/0.3)
A9	(0.3/0.3/0.3)				



According to the results, the weights assigned to criteria A1, A2, and A3 were (0.1/0.1/0.1), (0.9/0.9/0.9), and (0.8/0.8/0.8), respectively. Also, the weights of criteria A23, A24, and A25 were (0.3/0.3/0.3), (0.2/0.2/0.2), and (0.3/0.3/0.3), respectively. The final step of FTOPSIS is to rank the alternatives as presented in Figure 6.

### 5. Discussion

According to the results for the criteria of “proper farm practices”, “conservation agriculture”, and “meteorological and smart agriculture information” in the environmental-spatial dimensions, it is recommended to simul-

taneously consider the adoption of proper farming and conservation operations, enhancing economic status in terms of production and consumption, improving social life quality and social responsibility, and addressing environmental issues and natural resources of the system.

Since crop insurance programs vary across different regions of the province based on governmental support levels, types of hazards covered, and crop diversity in various growth conditions, it is recommended to adopt tailored insurance schemes suited for different regions considering crop growth stages and regional climatic conditions.

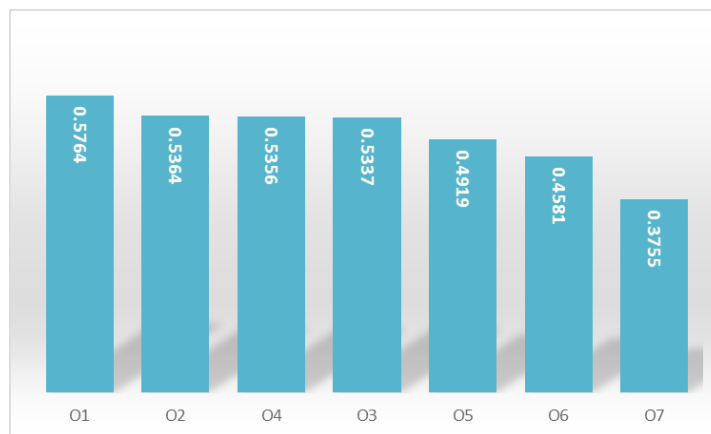


Figure 6. Diagram The final ranking of the alternatives by FTOPSIS

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According to the ranking results, the “support-credit” factor is of primary importance in Sistan and Baluchestan rural areas. The most effective strategies include crop insurance as the optimal risk management approach, as well as regional crop insurance and timely insurance claim payments when the actual regional yield falls below the guaranteed yield. Additionally, within the support-credit dimension, increasing credit amounts and providing accessible loans and grants for low-income orchard owners to invest in smart irrigation systems and geographical information systems (GIS) can serve as a key mechanism for encouraging farmers toward proactive risk management in their orchards and to mitigate natural disasters.

Given that most orchard owners in Sistan-va-Baluchestan province have low literacy levels, the establishment of a comprehensive database by the Agriculture Jihad Organization could significantly reduce risk. This database should include reliable information on smart meteorology, optimal harvest time, and irrigation scheduling to minimize crop exposure to heat stress and reduce the risk of pests and disease outbreaks. Enhancing farmers’ access to information through demonstration farms, farmer field schools, educational workshops, farm days, face-to-face visits, SMSs, and modern ICT communication channels would improve their professional skills and farming practices. Additionally, to support orchard owners’ access to efficient crop sale services, it is recommended to establish a market-driven modern extension system where farmers can access timely, accurate market information.

Given the proven success of crop insurance based on meteorological indices in other regions and provinces, it is recommended to design and implement this project

as strategic agricultural risk management in Sistan-va-Baluchistan province.

It is also essential to ensure the insurance coverage aligns with appropriate risks and fundamental risk management principles.

For the implementation of crop insurance based on climatic factors, it is advised to leverage the expertise and resources of private insurance companies to enhance efficiency and reach.

Based on the results, the following recommendations can be drawn to help farmers and enhance the effectiveness of their coping strategies:

- **Diversification of rural economy:** Since agriculture, is the primary livelihood in studied villages, farmers are highly vulnerable to drought. Developing alternative, job opportunities can increase resilience against climatic hazards and serve as a financial buffer for rural families during times of crisis.
- **Drought Risk Management:** Drought management remains underdeveloped in many parts of the world. Historically, droughts have been addressed through reactive measures, with risk management often considered only in post-disaster response efforts. A shift towards proactive drought risk management can significantly minimize negative impacts. In this regard, it is critical to identify drought-prone areas in Sistan-va-Baluchestan province and estimate the probability of drought occurrence to enable the development of food security programs. A data-driven approach is crucial for effective risk management and successful program implementation.
- **Sustainable Water Resource Management:** Additionally, long-term planning for surface and groundwater re-

source management is essential for drought mitigation. Optimizing water consumption and promoting water-saving practices must be prioritized as core strategies for sustainable drought resilience.

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## Conflict of Interest

The authors declared no conflicts of interest.

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