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Formulating Adaptation Policy Strategies to Enhance Resilience under Climate Change (Case Study: Agriculture Zayandeh Rud Basin)

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Abstract

Climate change, with its gradual and complex impacts, has increasingly inflicted damages on the agricultural sector of arid and semi-arid regions in Iran, including the Zayandeh-Rud Basin. This study aims to develop strategic adaptation policies to enhance agricultural resilience in response to climate change in this basin. The research is based on the Sendai Framework for Disaster Risk Reduction (SFDRR) and the resilience criteria established by the World Economic Forum (2013). A descriptive-analytical methodology was employed, combining documentary studies, field surveys, and the Delphi policy method to achieve expert consensus. Purposive sampling targeted faculties, agricultural experts of the Ministry of Agriculture, as well as producers and exporters of agricultural products with substantial expertise in Climate change issues, adaptation policies, and resilience. Data collection instruments consisted of four structured questionnaires designed to identify strengths and weaknesses, weight resilience criteria ,prioritize policies, and select strategies, complemented by semi-structured interviews. Initially, to determine the strategic position of agriculture in the Zayandeh-Rud Basin, Internal Factor Evaluation (IFE), External Factor Evaluation (EFE), and Internal-External (IE) matrices were utilized. Subsequently, the Analytic Hierarchy Process (AHP) and the multi-criteria decision-making PROMETHEE method were employed to prioritize adaptation policies aimed at enhancing resilience to Climate Change. Suitable strategies were developed and extracted through SWOT analysis, and finally, the Quantitative Strategic Planning Matrix (QSPM) was used to evaluate the relative attractiveness and feasibility of each strategy, thereby selecting the implementable final policies. Findings indicated that agriculture in the Zayandeh-Rud Basin, with a final internal factor score of 2.04 and external factor score of 2.12, is in defensive position (survival mode) and exhibits low resilience due to water transfer and scarcity, land fragmentation and subsidence, and weaknesses in modern infrastructure. The most attractive adaptation policies identified under the defensive strategy include equitable water distribution (Total Attractiveness Score (TAS=1.46), development-oriented water resource planning (TAS=1.38), optimization of water. consumption and reduction of losses (TAS=1.35), control of groundwater levels (TAS=1.23), reform of regulations related to land fragmentation (TAS=1.18), and farmer participation in water resource management (TAS=1.16). The proposed solutions emphasize strengthening integrated and basin-based water governance, implementing participatory strategic management models, investing in modern and soft technologies, gradually revising water-related laws and regulations, and expanding research and national strategy formulation. The results of this study provide actionable, stakeholder-inclusive recommendations for policymakers to enhance sustainability and resilience in vulnerable agricultural regions.

Keywords: Adaptation policy, Agricultural resilience strategies, Participatory governance, Strategic planning

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Introduction

Agricultural economies worldwide face numerous risks, among which climate change has emerged as one of the most significant challenges in recent decades. According to the Intergovernmental Panel on climate change (IPCC[1]), climate change refers to irreversible alterations in the climate of a region, distinguished from short-term weather fluctuations, arising from both anthropogenic activities and natural variability (IPCC, 2022). The consequences of climate change-including increased frequency and intensity of extreme events, droughts, floods, and rising temperatures- have led to decreased agricultural productivity, food insecurity, economic losses, and heightened environmental instability (Bhatasara & Nyamwanza, 2018).

Due to its geographical location, Iran is highly vulnerable to climate change impacts. The Zayandeh-Rud Basin, spanning 26,917 square kilometers with approximately 120,000 hectares under cultivation, annually produces over 2 million tons of crop and horticultural products and provides direct employment for more than 172,000 agricultural workers. This region ranks first nationwide in onion and seed potato tuber production and holds prominent positions in safflower and melon cultivation (Isfahan Agricultural Jihad Organization, 2023). Nevertheless, it faces significant challenges such as declining water resources, land subsidence, and escalating competition for water among agricultural, industrial, and urban sectors. The drying up of the Zayandeh-Rud river, recurrent droughts, and unsustainable water resource management have exacerbated the region's socio-economic and environmental crises (Safavi *et al.*, 2015; Teymouri *et al.*, 2023).

In response to these challenges, researchers, planners, and policymakers emphasize the importance of disaster risk reduction, enhancing agricultural resilience, and formulating climate adaptation policies tailored to local conditions. They seek to develop appropriate strategies based on various approaches and models to mitigate the economic damages caused by climate variability. Within disaster risk management literature, one pivotal approach focuses on strengthening existing community capacities to empower vulnerable local populations to better prepare for, cope with, and recover from adverse climate impacts—the resilience strategy (Scherzer *et al.*, 2019). Resilience is defined as the ability of social and economic systems to absorb disturbances, adapt to new conditions, and recover from climatic shocks while maintaining core functions (*Scherzer et al.*, 2019; Adger, 2000). According to this strategy, social subsystems, governance, technology, and environment must be designed to absorb both internal and external risks, adapt to highly variable conditions, and simultaneously sustain system stability and performance (World Economic Forum, 2013). Such adaptations—whether anticipatory, planned, or long-term response strategies—are implemented prior to events and, due to their broad nature, are commonly regarded as governmental responsibilities (Bandyopadhyay *et al.*, 2011).

Governments should employ comprehensive and inclusive strategy formulation to outline how policies can achieve missions and objectives given contextual conditions. Strategy formulation is a critical component of adapting to natural and social hazards (Saraei & Shamsiri, 2013). In other words, policymakers must first understand the Strengths, Weaknesses, Opportunities, and Threats (SWOT) within the system, then prioritize compatible policies (PROMETHEE[2]) to adopt suitable strategies (QSPM[3]) aimed at enhancing resilience.

Recent studies in Iran have demonstrated that multiple factors, such as the development of agricultural insurance, establishment of

1- Intergovernmental Panel on Climate Change

2- Preference Ranking Organization Method for Enrichment Evaluation

3- Quantitative Strategic Planning Matrix drought monitoring and early warning systems, and incorporation of indigenous knowledge, play key roles in boosting farmers' resilience (Sadeghloo *et al.*, 2014; Khakifirouz *et al.*, 2022). Moreover, research using multi-criteria decision-making methods like VIKOR, PROMETHEE-AHP, TOPSIS, and ANP have focused on prioritizing policies and identifying the most effective adaptation strategies (Dehghanpour *et al.*, 2020a; *Dehghanpour et al.*, 2020b; Ehsani *et al.*, 2021).

At the macro level, studies employing strategic models such as SWOT-QSPM have shown that defensive strategies, water consumption management, mechanization development, and economic diversification are among the most significant policy recommendations for enhancing agricultural resilience and sustainability in Iran's vulnerable regions (Sadeghi *et al.*, 2019; Ghasemi *et al.*, 2020). Furthermore, research highlights the importance of institutional policies and reforms in water governance processes, especially in critical areas like the Zayandeh-Rud watershed (Safavi & Afshar, 2006; Yadegari *et al.*, 2018; Madani, 2014).

Despite these efforts, substantial gaps remain in developing comprehensive and localized models for assessing and improving agricultural resilience at the watershed scale. Particularly, aligning adaptation policies with the Sendai Framework for Disaster Risk Reduction (SFDRR), the resilience criteria of the World. Economic Forum, and the utilization of integrated multi-criteria decision-making approaches can assist policymakers in designing more effective strategies to confront Climate Change.

Accordingly, this study aims to identify and prioritize adaptation policies to enhance agricultural resilience in the Zayandeh-Rud watershed and to formulate actionable strategies based on these policies using advanced multi-criteria decision-making and strategic analysis approaches. By leveraging the experiences and findings of previous research, this study seeks to provide a scientific and practical framework for policymaking and sustainable agricultural development planning in Iran's vulnerable areas. Ultimately, the research intends to fill the existing scholarly gap through the identification, formulation, prioritization, and analysis of adaptation policies to increase agricultural resilience in the Zayandeh-Rud Basin, aligned with the SFDRR, the World Economic Forum's resilience criteria and stakeholder participation.

Materials and Methods

This research was conducted with a descriptive-analytical and applied approach, employing both qualitative and quantitative methods. The study was based on the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR, 2015) and the resilience criteria of the World Economic Forum (World Economic Forum, 2013) to perform a comprehensive assessment of agricultural resilience and adaptation policies. Additionally, economic resilience models for farmers and the Delphi technique for expert consensus were utilized, emphasizing both quantitative and qualitative indicators to enable a multidimensional analysis of the capacities and constraints of the agricultural sector in confronting Climate Change. In this context, the "Comprehensive Strategic Management Model" (illustrated in Fig. 1) was applied to identify optimal strategies for strengthening the prescriptive resilience paradigm of agriculture in the Zayandeh-Rud Basin. This model encompasses three main stages: strategy formulation, implementation, and evaluation.

Given that the primary objective of this research is to formulate adaptation policy strategies to enhance Climate change resilience in the agriculture of the Zayandeh-Rud Basin—and that. Policy implementation depends on subsequent governmental approval and executive actions—only the first stage of the Comprehensive Strategic Management Model, namely strategy formulation, was examined in this study.

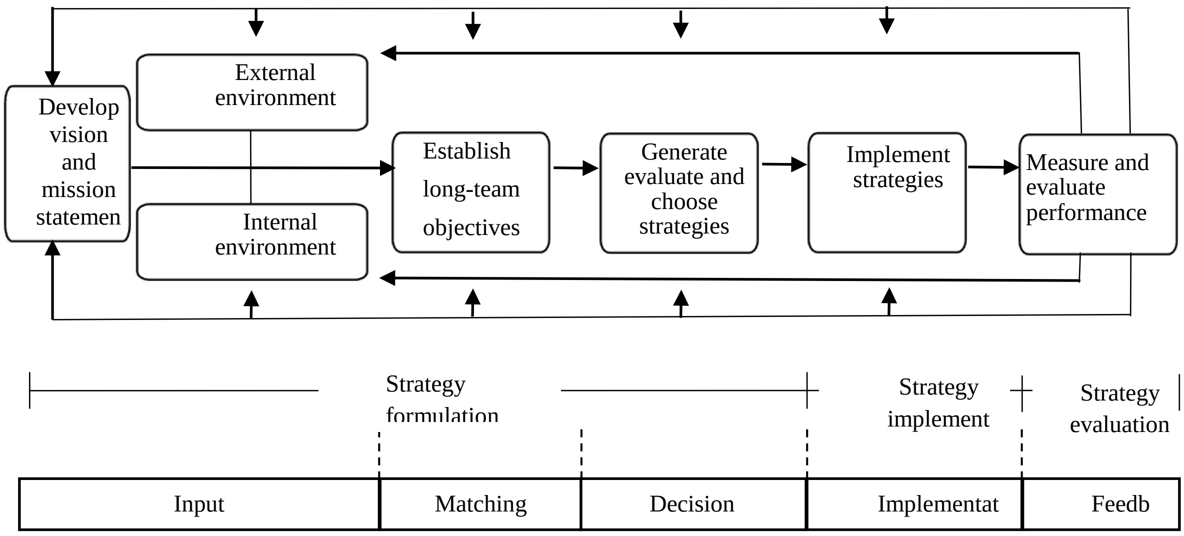


Figure 1– The comprehensive strategic management model (David & David, 2017; Moradi, 2011)

The main techniques for strategy formulation can be integrated into a three-stage framework consisting of the input stage, matching stage, and decision-making stage. This research followed the Comprehensive Strategic Management Model (David & David, 2017) sequentially and iteratively, such that the output of each stage (internal and external. factor analysis via the IFE and EFE matrices) served as the input to the next stage (strategic positioning via the IE matrix and SWOT analysis). Subsequently, adaptation policies were prioritized using the Analytic Hierarchy Process (AHP) and PROMETHEE methods and evaluated for attractiveness and selection using the Quantitative Strategic Planning Matrix (QSPM). This staged structure ensures theoretical and practical coherence, providing a logical transition from situational analysis to strategic decision-making. The stages and corresponding tools are depicted in Fig. 2.

Stage one: Input stage			
Internal factor evaluation (IFE) matrix		**External factor evaluation (EFE) matrix**	
Stage two: Matching stage			
Internal-external (IE) matrix	Analytic hierarchy process (AHP)	PROMETHEE method	SWOT matrix
Stage three: Decision-making phase			
Quantitative strategic planning matrix (QSPM)			

Figure 2– The stages of strategy formulation (David & David, 2017)

Stage One: Input Stage

The first stage summarizes the initial input data necessary for strategy formulation. This includes the External Factor Evaluation (EFE) and Internal Factor Evaluation (IFE) matrices. The EFE and IFE matrices are tools used to analyze the strengths, weaknesses, opportunities, and threats (SWOT) of an economic sector. The development of these two matrices involves five steps:

1. Identifying and listing key external and internal factors (including strengths, weaknesses, opportunities, and threats) through document review and expert judgment.
2. Weighting each factor according to its relative importance: each factor is initially scored from 1 to 10, then normalized so that the total weights sum to one.
3. Ranking each factor on a scale from 1 to 4 (4 = excellent strength/opportunity, 3 =

average strength/opportunity, 2 = average weakness/threat, 1 = critical weakness/threat).

4. Calculating the final score for each factor by multiplying its weight by its rank.
5. Summing the final weighted scores to obtain overall internal and external factor scores (David & David, 2017).

Stage Two: Matching Stage

The second stage seeks to align internal strengths and weaknesses with external opportunities and threats. This involves the Internal-External (IE) matrix, weight determination of criteria using Analytic Hierarchy Process (AHP), the PROMETHEE method, and SWOT analysis (David & David, 2017).

To analyze internal and external factors simultaneously, the IE matrix places scores from the IFE and EFE matrices along the horizontal and vertical. Axes to determine the strategic position of the economic sector and select the appropriate strategy (Saraei & Shamsiri, 2013; David & David, 2017).

Policy option prioritization can employ various approaches; one prominent method is Multi-Criteria Decision Making (MCDM), suitable for ranking policy options. As this research aims to prioritize adaptation policies, the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) was applied. PROMETHEE is a non-compensatory, preference-based model favored for its simplicity, transparency, interpretability, and ability to handle incomparable alternatives, distinguishing it from scoring methods such as TOPSIS and compromise methods like VIKOR. Moreover, the AHP technique was combined with PROMETHEE solely to weight criteria based on pairwise comparisons.

Following the identification of adaptation policies and weighting of resilience criteria through AHP, policy prioritization was conducted using PROMETHEE. Rankings were presented as PROMETHEE II complete rankings based on the net flow (Phi), derived from the positive (Phi+) and negative (Phi−) flows. The degree of preference of option a over option b, denoted π (a, b), is calculated by:

$$\pi(a.b) = \sum_{j=1}^{k} wjpj\,(a.b).[\sum_{j=1}^{k} wj = 1] \quad (1)$$

In relation (1), wjwj (for j=1,2, …, nj=1,2, …, n) represents the normalized weight of each criterion. To calculate the overall preference strength of option aa compared to other options, the leaving flow (positive outranking flow) is computed using Equation (2). This flow indicates how much option aa is preferred over others and reflects its strength (the maximum positive flow ϕ^{+} (a) corresponds to the best choice).

The preference degree of other options over option aa, called the entering flow (negative outranking flow), can be calculated using Equation (3). This flow shows the preference of others over option aa (the smallest negative flow ϕ^{-} (a) indicates the best option).

The positive ranking flow or leaving flow is expressed by:

$$\emptyset^{+}(a) = \frac{1}{n-1}\sum_{x\epsilon A}\pi(a.x) \quad (2)$$

The negative ranking flow or entering flow is given by:

$$\emptyset^{-}(a) = \frac{1}{n-1}\sum_{x\epsilon A}\pi(a.x) \quad (3)$$

With these flows, the available options can be compared to select the best one. The partial ranking, PROMETHEE I, is performed by separately evaluating the two flows ϕ^{+} (a) and ϕ^{-} (a). For a complete ranking of options, PROMETHEE II calculates the net flow for each option as shown in Equation (4):

$$\emptyset(a) = \emptyset^{+}(a) - \emptyset^{-}(a) \quad (4)$$

PROMETHEE II refers to the complete ranking based on this net flow (Amiri *et al*., 2017).

SWOT[1] analysis is a critical tool used to align internal strengths and weaknesses within the economic sector with external opportunities and threats. It provides a systematic analysis to determine policies and formulate strategies that create optimal fit among these factors. Based on this balance, four types of strategies can be identified: SO (Strength-Opportunity), WO (Weakness-

1- Strength-Weaknesses-Opportunities-Threats

Opportunity), ST (Strength-Threat), and WT (Weakness-Threat) (David & David, 2017).

Stage Three: Decision-Making Phase

The third phase assists in strategy formulation decision-making, enabling planners and policymakers to use inputs from Stage One to objectively evaluate the strategies identified in Stage Two, showing the relative attractiveness of alternative strategies. This stage employs a single technique, the Quantitative Strategic Planning Matrix (QSPM), which involves the following six steps:

1. List strengths, opportunities, and threats in the first column.
2. Input weighted scores from the internal and external factor matrices in the second column.
3. Place the SWOT matrix at the top row of the QSPM.
4. Determine the attractiveness coefficient using a Likert scale (ranging from “should not be implemented” to “definitely should be implemented”).
5. Calculate scores by multiplying importance weights by attractiveness coefficients.
6. Sum scores for each column to indicate the attractiveness of each strategy (David & David, 2017).

Data were collected through document review, field surveys, and semi-structured interviews with key stakeholders, including government officials, private sector actors, and experienced farmers in the Zayandeh-Rud Basin. Purposive sampling with an expert approach was applied to select individuals with relevant expertise and experience regarding agricultural resilience and Climate change adaptation policies in the basin. The panel consisted of 29 experts from the Agricultural Jihad Organization and 20 producers and exporters of agricultural products, selected in collaboration with the provincial Agricultural Jihad, based on criteria such as a minimum of 10 years of related work experience and recognized academic qualifications. In other words, a credentialed approach was used for panel member selection, identifying individuals aware of specific policy issues.

A structured questionnaire, developed based on prior studies and expert consultation, covered internal and external factors influencing agricultural resilience and potential adaptation policies.

To enhance data validity and comprehensiveness, stakeholder and expert selection followed scientific and practical criteria. Agricultural Jihad experts were chosen for their key role in policymaking, implementation, and technology transfer; lead farmers and producers for their practical experience and field awareness; exporters as vital links in markets and production; and university professors and researchers for their specialized knowledge and analytical capability. This stakeholder combination was aimed at reflecting expert, experiential, and market-oriented perspectives, thus improving research quality and credibility.

An analysis of the power, influence, and interests of these groups showed farmers as the most vulnerable and influential stakeholders due to high livelihood dependence on water and soil resources and exposure to Climate change impacts. Agricultural Jihad experts, as main policymakers and executors, play a pivotal role in resource management and the success of adaptation policies. Exporters are key to economic sustainability and market development, while academics enhance policy credibility through scientific analysis and innovative solutions.

This approach, aligned with international standards and comparable studies, increased the precision, validity, and applicability of the research findings.

Table 1 provides the analysis of power, influence, and interests of the key stakeholders involved in the study.

Table 1 -Analysis of power, influence, and interests of key stakeholders participating in the study

Rationale for selection and role in the study	Key interests	Power/Influence in policy-making	Stakeholder group
Main policy-makers and implementers; possess regional expertise and executive experience	Enhancing agricultural resilience, safeguarding farmers'	High	Agricultural Jihad Organization Experts
Primary beneficiaries; practical and market experience; represent real field and market challenges	Securing water, income stability, production sustainability, market development, export sustainability	Moderate to High	Leading Farmers and Agricultural Product Exporters
Provide scientific solutions, policy analysis, and knowledge transfer	Sustainable development, technology transfer, education	Moderate	University Professors and Researchers

Source: Research results

Results and Discussion

This section analyzes the collected data to achieve the research objectives through three main stages: (1) determining the strategic position of agriculture in the Zayandeh-Rud Basin, (2) prioritizing adaptation policies to enhance resilience to climate change, and (3) formulating strategies for implementing these adaptive policies within the basin.

Stage One: Determining the Strategic Position of Agriculture in the Zayandeh-Rud Basin

Strategic positioning of agriculture is a process whereby agricultural planners and policymakers conduct a thorough analysis of internal factors (strengths and weaknesses) and external factors (opportunities and threats) to develop suitable strategies for improving agricultural productivity and performance.

Internal Factors Analysis (Strengths and Weaknesses)

In this stage, a total of 43 internal factors (strengths and weaknesses) were identified through documentary research. According to the aggregated perspectives of experts from the Agricultural Jihad Organization of Isfahan province and county (government agents) and agricultural stakeholders in the Zayandeh-Rud Basin, there are 20 identified strengths and 23 weaknesses in the basin's agriculture.

The prioritization of internal factors was based on final scoring. The primary strengths, in order of importance, include: the existence of markets, support services and transportation infrastructure, warehouses, reservoirs, cold storage facilities, and agro-processing industries within the basin's agricultural supply chain; crop diversity; and the degree of implementation of modern water and irrigation technologies.

The main weaknesses, ranked by significance, are: fragmented and small farm plots, low utilization of renewable energy sources, and inadequate transfer of agricultural technologies (such as robotics and smart farming) to farmers in the Zayandeh-Rud agricultural sector. These factors are listed in detail in Table 2.

External Factors Analysis (Opportunities and Threats)

In this stage, 28 external factors (opportunities and threats) were identified through documentary research. Based on the aggregated views of experts from the Agricultural Jihad Organization of Isfahan province and county (government agents), it was determined that agriculture in the Zayandeh-Rud Basin faces 9 opportunities and 19 threats related to Climate Change.

The most significant opportunities, in order of importance, include: integrated water resources management in the Zayandeh-Rud Basin, proximity to major national markets (due to the basin's central location in the country), guaranteed water rights for farmers, environmental protection, and the sustainability of the Zayandeh-Rud river flow (fair water distribution).

The major threats, ranked by their significance, comprise: water transfer to other basins and industrial development exceeding the basin's capacity, agricultural land subsidence, and intensified inter-sectoral and inter-provincial competition for water resources under changing climatic conditions. These factors are detailed in Table 3, where opportunities and threats were identified by experts and presented without alterations.

Table 2- Internal factor evaluation (IFE) matrix

Code	Internal factors	(1-10) Importance	Weight	(1-4) Rating	Final score
	Strengths				
S_1	Existence of markets, support services, transportation, warehouses, silos, cold storages, and agro-processing industries in the Zayandeh-Rud Basin (agricultural supply chain)	6.76	0.025	3	0.075
S_2	Crop diversity	6.31	0.023	3	0.07
S_3	Deployment of modern water and irrigation systems and technologies in the basin	6.24	0.023	3	0.069
S_4	Efficiency of agricultural water storage, transfer, and distribution networks	6.14	0.023	3	0.068
S_5	Degree of alignment and compliance between adaptation policies and the national development plan	6.10	0.023	3	0.068
S_6	Profitability of agricultural products	6.03	0.022	3	0.067
S_7	Awareness and attitudes of officials, experts, and producers regarding climate change and resilience/adaptation strategies	6.03	0.022	3	0.067
S_8	Level of farmers' knowledge and awareness about climate change	6.03	0.022	3	0.067
S_9	Production of crops adapted to the basin's climatic conditions	5.93	0.022	3	0.066
S_{10}	Number of producers cultivating resilient and adapted plant species	5.92	0.022	3	0.066
S_{11}	Cultivation of halophyte (salt-tolerant) plants	5.90	0.022	3	0.065
S_{12}	Development and improvement of agricultural production units (poultry, livestock, etc.)	5.86	0.022	3	0.065
S_{13}	Level of interaction between management sectors and agricultural stakeholders	5.86	0.022	3	0.065
S_{14}	Existence of programs, regulations, and facilities for controlling and monitoring production resources	5.86	0.022	3	0.065
S_{15}	Pricing and guaranteed purchase of resilient and adapted products (e.g., safflower)	5.83	0.022	3	0.065
S_{16}	Technical and professional management capacities of individuals and institutions in the agricultural sector to address climate change	5.83	0.022	3	0.065
S_{17}	Utilization of public capacities and professional associations in achieving program objectives	5.76	0.021	3	0.064
S_{18}	High mechanization capacity	5.72	0.021	3	0.063
S_{19}	Controlled-environment agriculture (greenhouses, indoor, vertical, or protected farming)	5.61	0.021	3	0.062
S_{20}	Development of sustainable and climate-resilient agriculture	5.52	0.02	3	0.061
	Weaknesses				
W_1	Land fragmentation and small plot sizes	8.23	0.03	2	0.061
W_2	Lack of utilization of renewable energies	7.76	0.029	2	0.057
W_3	Lack of Transfer of agricultural technologies to farmers (robotics, smart farming, etc.)	7.55	0.028	2	0.056
W_4	Lack of Application of smart and precision agriculture	7.52	0.028	2	0.056
W_5	Lack of development of modern, smart, and precision agricultural technologies	6.45	0.024	2	0.048
W_6	Lack of Coordination and collaboration among responsible agencies in climate change adaptation, prioritizing objectives and resources	6.17	0.023	2	0.046
W_7	Low water use efficiency and weak protection of basin water resources	7.14	0.026	1	0.026
W_8	Limited Access to financial markets (e.g., farmer income stabilization funds)	6.86	0.025	1	0.025
W_9	Low Farmers' education and literacy level	6.79	0.025	1	0.025
W_{10}	Lack of Adoption of modern technologies by farmers	6.72	0.025	1	0.025
W_{11}	Poor Status of agricultural knowledge-based companies	6.55	0.024	1	0.024
W_{12}	Insufficient Cultivation of crops compatible with sustainable development and environmental protection	6.45	0.024	1	0.024
W_{13}	Insufficient Agricultural and retirement insurance coverage for farmers	6.38	0.024	1	0.024
W_{14}	Lack of Existence of a comprehensive agricultural information database in the basin	6.38	0.024	1	0.024
W_{15}	Low Level of best farming practices (quality and yield)	6.21	0.023	1	0.023
W_{16}	Low Degree of knowledge and information sharing on climate-smart agricultural technologies and methods by relevant institutions	6.17	0.023	1	0.023
W_{17}	Low Farmers' income diversification (integrated farming, home-based businesses, etc.)	6.14	0.023	1	0.023
W_{18}	Lack of Compliance with optimal cropping patterns	6.07	0.022	1	0.022
W_{19}	Land productivity	6.03	0.022	1	0.022
W_{20}	Lack of Existence of producer cooperatives, marketplaces, and direct sales stations in the basin	6.00	0.022	1	0.022
W_{21}	Lack of Optimal use of production resources	5.90	0.022	1	0.022
W_{22}	Inadequate Soil tillage methods and poor soil conservation practices	5.83	0.022	1	0.022
W_{23}	Lack of Access to agricultural infrastructure (technologies, etc.)	5.79	0.021	1	0.021
	Total Internal Factor Analysis Score	270.44	1		2.0437

Source: Research results

Table 3- External Factor Evaluation (EFE) Matrix

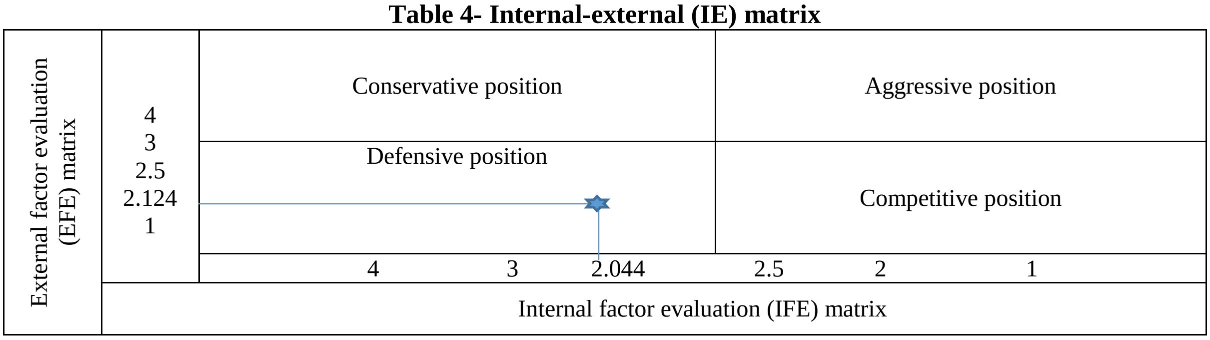
Code	External factors	(1-10) Importance	Weight	Rating	Final score
	Opportunities				
O_1	Integrated water resources management in the Zayandeh-Rud Basin	7.83	0.038	4	0.153
O_2	Proximity to major national markets (central location in the country)	7.62	0.037	4	0.149
O_3	Securing water rights for farmers, the environment, and the sustainability of the Zayandeh-Rud River (equitable water distribution)	7.6	0.037	4	0.148
O_4	Active human and social capital in the agricultural sector	7.31	0.036	4	0.143
O_5	Existence of programs, regulations, and facilities for controlling and monitoring basin resources	6.79	0.033	4	0.133
O_6	Natural and historical capital in the basin	7.46	0.036	3	0.109
O_7	Research and scientific infrastructure in the basin (universities, research centers, etc.)	6.21	0.03	3	0.091
O_8	Infrastructure and facilities for agricultural exports (customs, etc.)	6.17	0.03	3	0.09
O_9	Presence of unconventional water resources in the basin	6.1	0.03	3	0.089
	Threats				
T_1	Inter-basin water transfer and industrial development exceeding basin capacity	9.08	0.044	2	0.089
T_2	Land subsidence in agricultural areas	8.93	0.044	2	0.087
T_3	Intensified inter-sectoral and inter-provincial competition over water resources due to climate change	8.62	0.042	2	0.084
T_4	Decline in resources and increased pressure on basic resources under climate change	8.48	0.041	2	0.083
T_5	Intensified land use change and increased land value due to climate change	8.28	0.04	2	0.081
T_6	Escalation of conflicts, disputes, and social unrest among provinces in the Zayandeh-Rud Basin under climate change	8.24	0.04	2	0.08
T_7	Decrease in quantity (volume) and quality (standards and characteristics) of surface and groundwater due to climate change	7.93	0.039	2	0.077
T_8	Intensified soil erosion, dust storms, and increased soil salinity under climate change	7.28	0.036	2	0.071
T_9	Exit from agriculture and reduced investment in the sector	8.69	0.042	1	0.042
T_{10}	Reduced production, increased vulnerability, and economic difficulties for farmers under climate change	7.9	0.039	1	0.039
T_{11}	Increased frequency of natural disasters such as floods, fires, frost, droughts, heatwaves, hail, storms, dust storms, and untimely rains due to climate change	7.86	0.038	1	0.038
T_{12}	Declining resources, reduced productivity, and intensified price and market fluctuations under climate change (increased production costs in the basin)	7.5	0.037	1	0.037
T_{13}	Decline in quantity (amount of various elements) and quality (physical, chemical, and biological properties) of soil under climate change	7.31	0.036	1	0.036
T_{14}	Changes in rainfall timing, temperature fluctuations, and differences in precipitation patterns in the basin under climate change	6.97	0.034	1	0.034
T_{15}	Price fluctuations of agricultural products (food security, etc.)	6	0.029	1	0.029
T_{16}	Attention to agricultural biodiversity in the basin	5.9	0.029	1	0.029
T_{17}	Intensification of chemical fertilizer and pesticide use and Declining biodiversity by farmers	5.86	0.029	1	0.029
T_{18}	Outbreak of plant pests and diseases due to climate change	5.62	0.027	1	0.027
T_{19}	Balance between agricultural production and environmental protection	5.41	0.026	1	0.026
	Total External Factor Analysis Score	204	1		2.123

Source: Research results

Internal-External Factors Analysis (Strategic Position)

Based on the final scores of internal factors (2.04) and external factors (2.12) presented in Table 4, the strategic position of agriculture in the Zayandeh-Rud Basin was determined to be in a defensive (survival) posture .

Table 4- Internal-external (IE) matrix



Source: Research results

Stage Two: Prioritization of Adaptation Policies to Enhance Climate change Resilience

After designing the questionnaire based on Saaty's 9-point scale, weighting of resilience criteria was carried out by four professors from the Agricultural Economics Department at the University of Tehran and two experts from the Agricultural Jihad Organization of Isfahan province (government agents). Purposeful sampling was used to select the expert group for accurate and professional judgment in weighting the criteria. The experts were chosen based on their practical experience and theoretical knowledge relevant to the study.

The Analytic Hierarchy Process (AHP) and Expert Choice software were employed to assign weights to the resilience criteria. The inconsistency ratio for each pairwise comparison set, obtained via Expert Choice software, was 0.091, indicating an acceptable level of consistency in the findings.

According to the results of the criteria comparisons shown in Table 5, the redundancy dimension received the highest weight with 33%, as rated by the experts. It was followed by the responsiveness dimension (reaction capacity) with 31%, the self-organization dimension with 20%, the governance dimension with 12%, and finally, the robustness dimension with 4%, ranking them respectively in terms of their contribution to enhancing the resilience of adaptation policies.

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Table 5- Percentage importance of resilience criteria

Rank	Percentage importance	Criterion
2	0.309	Response
1	0.33	Redundancy
3	0.198	Recovery
4	0.119	Resourcefulness
5	0.044	Robustness

Source: Research results

In the context of formulating Climate change adaptation policies for the agricultural sector in the Zayandeh-Rud Basin, a comprehensive set of strategies, general policies, and adaptation tools were designed and implemented. Their main foundation was Iran’s Climate change Strategic Plan (2017) and the international Sendai Framework for Disaster Risk Reduction (SFDRR). These policies were developed using an integrated approach aimed at aligning climate strategies with the region’s socio-economic structures, structured around four strategic axes:

Strategy One: Revision and Development of Macro Agricultural Policies with an Integrated and Climate-Adaptation Approach

This includes two core policies:

Development of the policy-making and decision-making process,

Advancement of agricultural input management and production programs tailored toward adaptation and high efficiency.

Strategy Two: Technical, Economic, Social, and Cultural Empowerment Compatible with Climate change Effects

This includes two core policies:

Enhancement of economic, social, and cultural capacities,

Revision and development of education, technical, and research programs to improve farmers’ adaptive capacity.

Strategy Three: Adaptation-Driven Development in Crop and Horticultural Planning

This includes three core policies:

Climate-adaptive soil management,

Climate-adaptive agricultural water resources management,

Climate-driven organization of research and development in crop and horticulture sectors.

Strategy Four: Strengthening Sectoral Management Structures and Institutionalizing Cross-Sector Collaboration

This includes one core policy:

Creation and enhancement of legal and institutional capacities to align structures with climate change conditions.

This policy framework seeks to integrate institutional, technical, and social actions based on national and international frameworks to enhance the region's agricultural resilience.

In total, based on documentary analyses and expert opinions, 52 adaptation policies and implementation tools were developed for the agricultural sector in the Zayandeh-Rud Basin. To prioritize these policies, the PROMETHEE multi-criteria decision-making method was employed, providing a systematic, precise, and comparable evaluation of policy options.

Table 6 presents the PROMETHEE Flow Table generated by the Visual PROMETHEE software. According to Table 6, the top three priorities based on PROMETHEE flow values (ϕ) are:

Considering the ecological needs of the Gavkhouni Wetland and ensuring sustainable flow of the Zayandeh-Rud River (fair water distribution) with ϕ=0.901,

Basin-level water resource development planning with a holistic approach that enhances flexibility in meeting variable consumption needs (ϕ=0.722),

Amending laws and regulations related to land fragmentation (such as inheritance law) aimed at land consolidation, improving farmers' efficiency, and establishing a land bank (ϕ=0.594).

These policies ranked highest in the PROMETHEE Flow Table, highlighting their priority for enhancing agricultural resilience under climate change.

Table 6- Prioritization of climate change adaptation policies to enhance resilience using the PROMETHEE method

Rank	Code	Adaptation policies and tools	Phi	Phi+	Phi-
1	A_{19}	Considering the ecological needs of Gavkhouni Wetland and the sustainability of Zayandeh-Rud River flow (equitable water distribution)	0,9018	0,9418	0,0400
2	A_{21}	Basin-based water resources development planning with a holistic approach that provides flexibility in meeting variable consumption needs	0,7224	0,7351	0,0127
3	A_1	Reforming laws and regulations related to land fragmentation (such as inheritance law) to consolidate lands, increase farmers' efficiency, and establish a land bank	0,5947	0,6318	0,0371
4	A_8	Establishment of a groundwater level monitoring system and implementation of early warning systems	0,5947	0,6318	0,0371
5	A_{25}	Promoting and allocating facilities to encourage and facilitate income diversification among farmers (integrated agriculture, home-based businesses, etc.)	0,5947	0,6318	0,0371
6	A_{26}	Allocating technical and credit support to producer cooperatives and establishing weekly markets and direct sales stations for agricultural products	0,5947	0,6318	0,0371
7	A_{28}	Development of ancillary industries (processing and packaging of products), improvement of infrastructure, and economic diversification (home-based businesses, rural tourism, etc.)	0,5947	0,6318	0,0371
8	A_{31}	Establishment of regional support funds to protect farmers against price fluctuations of agricultural products or to provide facilities and credits	0,5947	0,6318	0,0371
9	A_{35}	Promoting the use of renewable energies	0,5947	0,6318	0,0371
10	A_{24}	Development of agricultural insurance adapted to climate change (such as weather index insurance) and farmers' retirement insurance	0,5147	0,5941	0,0794
11	A_{13}	Updating and completing the optimal water consumption pattern and water loss reduction program in the agricultural sector and implementing it	0,5024	0,6316	0,1292
12	A_{32}	Research and planning for the breeding of field and horticultural crops to produce varieties resistant to drought, aridity, and salinity	0,4457	0,5533	0,1076
13	A_{33}	Zoning of agricultural systems and production planning based on climatic capacity	0,4457	0,5533	0,1076
14	A_{23}	Development of farmer income stabilization funds against the effects of climate change	0,4124	0,5527	0,1404
15	A_{40}	Promoting heat- and drought-tolerant varieties and developing new adaptation inputs and technologies	0,3825	0,5410	0,1584
16	A_{27}	Providing educational and extension services to farmers to maintain and improve performance and optimal productivity	0,3359	0,5039	0,1680

17	A_{10}	Developing executive programs for water resource management by farmers and water user associations and establishing regional water markets	0,3324	0,5151	0,1827
18	A_{37}	Implementing infrastructure and training for the use of smart agriculture and precision agriculture	0,2947	0,4906	0,1959
19	A_{38}	Providing climate adaptation technologies	0,2947	0,4906	0,1959
20	A_{36}	Providing low-interest credits and facilities to farmers for purchasing technologies compatible with the basin's climatic conditions	0,2335	0,4625	0,2290
21	A_{30}	Planning and preparing operational programs to expand alternative agricultural incomes with the aim of reducing pressure and reliance on basic resources (planning for farmers' livelihood diversification)	0,1535	0,4249	0,2714
22	A_{42}	Planning for the cultivation of halophyte (salt-tolerant) or xerophyte field and horticultural crops in dry and saline areas and implementing in pilot regions	0,1457	0,4122	0,2665
23	A_{18}	Allocating low-interest technical and credit support for implementing modern and smart water systems and irrigation technologies (monitoring technologies such as sensors)	0,1175	0,4075	0,2900
24	A_{2}	Increasing farmers' climate change-related information through enhanced in-person and virtual extension services	0,0825	0,3998	0,3173
25	A_{9}	Developing research and planning to improve agricultural irrigation efficiency according to hydrological unit capacity	0,0465	0,3824	0,3359
26	A_{17}	Allocating low-interest technical and credit support for expanding agriculture in controlled environments such as greenhouses, indoor, vertical, protected agriculture, etc.	0,0465	0,3824	0,3359
27	A_{34}	Allocating technical and credit support to farmers for the use of renewable energies	0,0433	0,3708	0,3275
28	A_{11}	Implementing small-scale water supply projects (water management measures and technologies)	0,0233	0,3573	0,3339
29	A_{3}	Establishment of an integrated spatial, descriptive, and market information system and creating an appropriate structure for sharing climate change-related information	-0,0665	0,3214	0,3878
30	A_{7}	Allocating subsidies to farmers for implementing on-farm water efficiency projects such as modern irrigation systems	-0,0665	0,3214	0,3878
31	A_{41}	Financial and technical support for producers of resilient and adapted crops in the basin	0,0665-	0,3214	0,3878
32	A_{43}	Policies related to best farming practices for field and horticultural production (priority for vulnerable areas)	0,0665-	0,3214	0,3878
33	A_{12}	Improvement of public irrigation canals, covering ditches, and reducing water losses in the agricultural sector	0,0904-	0,3220	0,4124
34	A_{16}	Developing, implementing, and operating programs for the reuse of return flows and treated wastewater in agriculture, considering ecological issues and piloting them	0,1294-	0,2963	0,4257
35	A_{29}	Compensation by the government for farmers' losses due to climate change	0,1375-	0,3541	0,4916
36	A_{39}	Providing credits and facilities to innovative projects and agricultural knowledge-based companies in the field of climate change	0,1825-	0,2663	0,4488
37	A_{47}	Policies for best farming practices with emphasis on conservation agriculture	0,2412-	0,2502	0,4914
38	A_{46}	Developing biological and environmental management programs to address climate change (such as biodiversity programs, sustainable agriculture, greenhouse gas reduction, etc.)	0,3118-	0,2173	0,5290
39	A_{4}	Creating, designing, and integrating knowledge management for the dissemination of climate-smart agricultural technologies and methods	0,3573-	0,1951	0,5524
40	A_{6}	Regulations for the conservation and use of agricultural lands	0,4186-	0,1761	0,5947
41	A_{14}	Balancing and protecting surface and groundwater resources in view of climate change	0,4576-	0,1504	0,6080
42	A_{45}	Comprehensive soil fertility and plant nutrition program (monitoring the quality of agricultural lands and soil fertility)	0,4576-	0,1504	0,6080
43	A_{20}	Transparency and avoidance of arbitrary interpretation of laws and upstream documents regarding climate change management	0,5008-	0,1480	0,6488
44	A_{5}	Implementation of leading agricultural projects	0,5933-	0,1049	0,6982
45	A_{44}	Supplementary planning and implementation of conservation tillage programs according to climatic potential and biological capacity	0,5933-	0,1049	0,6982
46	A_{22}	Implementation of watershed management programs in the region	0,7427-	0,0553	0,7980

47	A_{15}	Volumetric water delivery to farmers, such as installation of smart meters on agricultural wells	0,8127-	0,0235	0,8363
48	A_{48}	Integration of responsible organizations and agencies or assigning climate change management to a relevant institution or organization in the agricultural sector	0,8127-	0,0235	0,8363
49	A_{49}	Revision of laws and regulations for the protection of surface and groundwater resources in light of climate change	0,8637-	0,0078	0,8716
50	A_{51}	Economic valuation of water (determining the economic value of water) and allocation management for agricultural uses	0,8637-	0,0078	0,8716
51	A_{52}	Limiting water abstraction through penalties for high-consumption actors	0,9037-	0,0008	0,9045
52	A_{50}	Familiarizing farmers with the principles of optimal product production (cropping pattern) considering land use planning and restrictions or prohibitions based on the basin's climatic conditions	0,9037-	0,0008	0,9045

Source: Research results

Following the prioritization of adaptation policies based on resilience criteria from the World Economic Forum with expert participation, the strategic analysis phase (SWOT) was carried out by intersecting internal factors (strengths and weaknesses), external factors (opportunities and threats), and 24 prioritized policies. This process led to the extraction of four major strategy types:

- Defensive Strategies: Focused on reducing threats by mitigating weaknesses.
- Conservative Strategies: Aimed at exploiting opportunities while addressing weaknesses.
- Aggressive Strategies: Targeted at leveraging strengths to capitalize on opportunities.
- Competitive Strategies: Designed to reduce threats by utilizing strengths.

Within this framework, each policy or implementation tool is explicitly linked to one or more of the four SWOT elements and purposefully designed to reduce vulnerability and enhance the resilience of the agricultural sector. The structure and outcomes of this intersection and strategic categorization are detailed in Table 7.

Table 7- SWOT matrix

External factors / **Internal factors**	**Opportunities** **O1، O2،O3،O4،O5، O6**	**Threats** **T1، T2،T3،T4،T5، T6**
Strengths S1، S2،S3،S3،S4، S5،S6	SO Strategies -A25(S1،S6،O2،O4،O6) -A26(S1،S6،O2،O4،O6) -A28(S1،S6،O2،O4،O6) -A31(S1،S6،O2،O4،O6) -A24(S5،S6، O4،O6) -A23(S1،S6،O2،O4،O6)	ST Strategies -A32(S2،S6،T2،T3،T4،T6) -A33(S2،S6،T1،T2،T3،T4،T6) -A27 (S4،S6،T2،T4) -A30(S4،S6،T2،T4،T6) -A42(S2،S6،T2،T4،T6) -A2(S4،S5،T1،T2،T3،T4،T5،T6)
Weaknesses W1، W2،W3،W4،W5، W6	WO Strategies -A35(W2،W3،W4،W5،O4،O6) -A40(W3،W4،W5،O1،O3) -A37(W3،W4،W5،O1،O3،O6) -A38(W3،W4،W5،O1،O3،O6) -A36(W3،W4،W5،O1،O3،O6) -A18(W3،W4،W5،O1،O3،O6)	WT Strategies -A19(W6،T1،T2،T3،T4،T6) -A21(W6،T1،T2،T3،T4،T6) -A1(W1،W6،T2،T4،T5) -A8(W6،T1،T2،T3،T4،T6) -A13(W6، T1،T2،T3،T4،T6) -A10(W6، T1،T2،T3،T4،T6)

Source: Research results

Stage Three: Formulation of Adaptation Policy Strategies to Enhance Resilience to Climate change in the Zayandeh-Rud Basin

The objective of this stage is to develop adaptation policy strategies that are sustainable and feasible in the face of climate change, with flexibility to allow strategy substitution in unforeseen circumstances.

This stage incorporates participatory governance, engaging farmers and agricultural exporters (private sector actors) as key agents to overcome climate change challenges. Accordingly, using a political Delphi method, a homogeneous sample of 20 agricultural producers and exporters—knowledgeable and actively involved in the basin's agricultural issues—was selected with the assistance of the Isfahan Provincial Agricultural Jihad.

Considering the basin's strategic position and the results of the Quantitative Strategic Planning Matrix (QSPM), the defensive, competitive, conservative, and aggressive strategies were ranked by attractiveness. Due to the basin's defensive strategic position, the defensive strategy was the primary focus.

For the defensive strategy, the highest attractiveness was assigned to addressing the ecological needs of the Gavkhouni Wetland and maintaining sustainable flow of the Zayandeh-Rud River (fair water distribution) (A19) with a score of 1.462. The second priority was basin-level water resource development planning with a holistic approach providing flexibility to meet variable demands (A21), scoring 1.383. The third-ranked priority was updating and completing the optimized water consumption pattern and implementing water loss reduction programs in agriculture (A13) with a score of 1.359.

The Quantitative Strategic Planning Matrix for the defensive strategy is presented in Table 8.

Table 8- Quantitative strategic planning matrix (QSPM) for defensive strategy

Factors	Weight	Strategy (WT)											
		A_{19}		A_{21}		A_1		A_8		A_{13}		A_{10}	
Threats (T)		AS	TAS	AS	TAS	AS	TAS	AS	TAS	AS	TAS	AS	TAS
T_1	0.0443	4	0.177	4	0.177	2	0.089	4	0.177	3	0.133	3	0.133
T_2	0.0435	4	0.174	4	0.174	3	0.131	4	0.174	4	0.174	3	0.131
T_3	0.042	4	0.168	4	0.168	2	0.084	3	0.126	4	0.168	4	0.168
T_4	0.0413	4	0.165	4	0.165	2	0.083	4	0.165	4	0.165	4	0.165
T_5	0.0404	4	0.162	4	0.162	4	0.162	3	0.121	3	0.121	3	0.121
T_6	0.0402	4	0.161	4	0.161	3	0.121	3	0.121	3	0.121	3	0.121
Weaknesses(W)													
W_1	0.0304	3	0.091	3	0.091	4	0.122	2	0.061	2	0.061	2	0.061
W_2	0.0287	3	0.086	2	0.057	3	0.086	2	0.057	2	0.057	2	0.057
W_3	0.0279	3	0.084	2	0.056	3	0.084	2	0.056	3	0.084	2	0.056
W_4	0.0278	2	0.056	2	0.056	3	0.083	2	0.056	4	0.111	2	0.056
W_5	0.0238	2	0.048	2	0.048	3	0.071	2	0.048	4	0.095	2	0.048
W_6	0.0228	4	0.091	3	0.068	3	0.068	3	0.068	3	0.068	2	0.046
TOTALS TAS			1.462		1.383		1.183		1.23		1.359		1.161
Priorities			1		2		5		4		3		6

Source: Research results

The QSPM results confirmed the PROMETHEE ranking; in other words, the adaptation policies prioritized by experts were validated by farmers and agricultural exporters and corresponded respectively to the defensive, competitive, conservative, and aggressive strategies. The defensive strategies emphasized fair water distribution, development-oriented water resource planning, optimization of consumption and reduction of water losses, groundwater level control, reform of laws related to land fragmentation, and farmer participation in water resource management. This matrix demonstrated the relative attractiveness of each policy, providing a solid basis for decision-making.

Based on the research findings, a comprehensive set of policies and implementation actions was developed to enhance agricultural resilience in the Zayandeh-Rud Basin. The operational program for these strategies is presented in Table 9, which can serve as a practical roadmap for policymakers and agricultural sector managers.

Table 9- Action plan for policy strategies consistent with increasing agricultural resilience in the Zayandeh-Rud Basin

Strategy type	Selected policies (Code)	Time priority	Targeted resilience capacity	Operational actions	Required resources	Evaluation indicators
Defensive (Survival)	A19, A21, A13, A8, A1, A10	Short-term	(Absorptive)	-Developing and implementing water distribution regulations -Establishing monitoring and warning systems -Training farmers -Implementing land consolidation projects -Establishing regional water markets -Reforming inheritance laws	Government budget, water and legal experts, monitoring systems, local organizations	Percentage of equitable water distribution, reduction in water conflicts, number of consolidated lands, reduction in water losses
Competitive	A33, A32, A42, A27, A30, A2	Mid-term	(Adaptive)	-Developing zoning and production plans based on climate -Implementing breeding projects -Piloting cultivation of resilient crops -Organizing training and extension courses -Supporting alternative livelihoods	Research budget, research centers, extension experts, educational resources	Number of resilient crops produced, number of trained farmers, increase in alternative incomes, increased climate awareness
Conservative	A18, A37, A40, A36, A35, A38	Long-term	(Transformative)	Providing low-interest loans and facilities -Installing smart water systems -Training in precision agriculture -Promoting renewable energy in farms -Delivering innovative technologies to farmers	Bank credits, technology equipment, specialized training, government incentives	Number of smart systems installed, increased use of renewable energy, increased water and energy efficiency
Aggressive	A25, A28, A26, A31, A34, A23	Long-term	(Transformative)	-Providing facilities for home-based and integrated farming jobs -Establishing and equipping processing and packaging industries -Launching agricultural markets -Establishing regional support funds -Supporting renewable energy adoption	Government and bank credits, industrial infrastructure, cooperatives and NGO support	Number of alternative jobs created, increase in value-added products, number of active support funds, increased farmers' income

Source: Research results

The results of this study demonstrated that defensive strategies, particularly those related to integrated water resources management, reform of land fragmentation laws, and technological advancement, hold the highest priority for enhancing agricultural resilience in the Zayandeh-Rud Basin. These findings align with previous studies (Safavi *et al*., 2015; Sadeghi *et al*., 2019) that emphasize the importance of water governance and institutional structure reform. However, this study advances by employing multi-criteria decision-making approaches and integrating international frameworks, thus offering more localized adaptation policies.

From a practical perspective, the implementation of prioritized policies requires strengthening stakeholder participation, investing in modern technologies, and reforming governance processes. Research limitations include the lack of field data in some regions and difficulties in engaging all stakeholders. It is recommended that future studies incorporate scenario-based approaches and long-term policy impact assessments.

Considering the unique climatic, environmental, and social conditions of each watershed in the country, it is essential that the results and proposed strategies be independently tailored and localized based on each area's specific characteristics. Nevertheless, because this study is grounded in recognized international frameworks such as the Sendai Framework for Disaster Risk Reduction and the World Economic Forum's resilience criteria, and utilizes standard analytical tools (SWOT, IFE, EFE, AHP, PROMETHEE, and QSPM), along with the fact that many of the key challenges—including water scarcity, infrastructural weakness, and governance issues—are common across other watersheds, the proposed model and identified adaptation policies have relative generalizability and applicability to other regions. Therefore, the findings can serve as a reference framework for designing and developing agricultural resilience policies in other watersheds in the country, provided that local adaptation processes and active stakeholder participation are taken into account.

Conclusion and Recommendations

The findings of this study highlight the fundamental challenges and opportunities for agricultural resilience in the Zayandeh-Rud Basin under the pressures of climate change. The defensive position of the agricultural sector in the IE matrix indicates significant vulnerability, primarily due to water transfer and scarcity, land fragmentation and subsidence, and weaknesses in infrastructure and modern technologies. These challenges align with prior studies in arid and semi-arid regions, where climate change exacerbates resource limitations (Safavi *et al*., 2015; Teymouri *et al*., 2023).

Integrated and basin-scale water resources management was identified as the most critical resilience criterion, consistent with global research emphasizing the key role of water management in agricultural adaptation (Talashi & Kafash, 2019; Srivastav *et al*., 2021). The high priority for modern technology development underscores the necessity of investing in efficient technologies like monitoring systems and sensors to reduce water waste and increase water use efficiency.

Reforming laws and regulations related to land fragmentation, including inheritance laws, for land consolidation and enhanced farmer efficiency ranked as the second most important factor. This corresponds with previous research indicating land fragmentation as a major barrier to agricultural productivity and sustainable rural development (Golmohammadi, 2021; Hadi Pour *et al*., 2019). Furthermore, designing and implementing water resource management programs by farmers and water user associations, alongside establishing regional water markets, ranked third in importance. These play a pivotal role in local participation and improving water governance, aligning with previous findings that stress strengthening local capacities and participatory mechanisms for optimal water resource management (Islamy & Rahimi, 2019; Taleshi, 2018).

The integration of various tools in a comprehensive strategic management model—including IFE, EFE, IE, SWOT, AHP, PROMETHEE, and QSPM—provided a clear and robust framework for evaluating complex adaptation options, combining quantitative and qualitative data simultaneously. This participatory approach notably enhances analytical precision, legitimacy, and applicability of findings for policymakers and implementers.

Overall, the study's results indicate that to enhance agricultural resilience in the Zayandeh-Rud Basin, policies and strategies must be designed and implemented comprehensively, collaboratively, and based on optimal water resource management and modern technologies. Legal structure reforms and strengthening local capacities are also key factors for success.

Policy and Operational Recommendations

A. National and Provincial Policy-Level Recommendations

Based on the study's findings pointing to the defensive status of agriculture in the Zayandeh-Rud Basin and key challenges such as water scarcity, land fragmentation, weak infrastructure, and the need for integrated governance, it is recommended to:

- Develop a climate adaptation strategic document for the Zayandeh-Rud Basin with collaboration from the Ministry of Agriculture Jihad, Environmental Protection Organization, and Ministry of Energy.
- Integrate adaptation policies into Isfahan province's budgetary programs, particularly in agriculture, natural resources, and water.
- Establish a Climate and Agricultural Resilience Integrated Management Task Force, comprising government, private sector, and regional agricultural association representatives.

B. Operational and Local-Level Recommendations

Aligned with priority policies emphasizing water use efficiency, livelihood diversification, and technology development, it is suggested to:

- Revise cropping patterns emphasizing drought and temperature-resistant crops such as medicinal plants and dryland farming.
- Enhance livelihood diversification for farmers by supporting supplementary occupations (e.g., rural tourism, handicrafts, fisheries, and semi-industrial livestock).
- Develop climate monitoring and early warning systems via mobile applications and field training for farmers.
- Promote climate-indexed agricultural insurance supported by the government to reduce farmers' financial risks.

Additionally, considering the study's findings and focusing on the defensive (WT) strategy to reduce threats and overcome weaknesses for agricultural survival against climate change, the following steps are proposed:

- Step 1: Current Situation Analysis and Regional Action Planning

Identify priority crisis areas in upstream, midstream, and downstream parts of the basin.

Create an integrated database on farmers, water resources, cropping patterns, and climatic indices.

Monitor climatic changes and analyze long-term trends in temperature, precipitation, and water resources. Responsible bodies: Isfahan Governorate, Agricultural Jihad, Meteorological Organization.

- Step 2: Water Demand Management and Agricultural Water Use Efficiency

Assign precise volumetric water quotas for each farm and record in smart systems.

Install smart meters on authorized wells for real-time monitoring.

Promote low-water crops such as saffron, medicinal plants, and dryland wheat.

Responsible bodies: Regional Water Company, Agricultural Jihad, Agricultural Guilds.

- Step 3: Enhance Economic Resilience and Reduce Income Dependency on a Single Source

Provide low-interest loans to develop complementary occupations (dryland orchards, light livestock, solar greenhouses).

Establish multifunctional local cooperatives for marketing and selling diverse products.

Train young farmers in business skills.

Responsible bodies: Agricultural Jihad, Cooperatives Office, Agricultural Bank.

- Step 4: Institutionalize Climate Index Insurance and Risk Management

Design agricultural insurance based on climatic indices.

Create climate damage funds with government support and private sector participation.

Promote insurance culture through education and financial incentives.

Responsible bodies: Central Insurance, Agricultural Products Insurance Fund.

- Step 5: Local Empowerment and Education

Conduct workshops on smart farming, climate change, and resilience.

Utilize lead farmers' experience to transfer knowledge.

Set up local "Agricultural Resilience Centers" for consultation and promotion.

Responsible bodies: Agricultural and Natural Resources Research Center, Vocational Training Centers, Universities.

- Step 6: Institutionalize Participatory Water and Agricultural Governance

Establish Basin Climate and Agricultural Management Council with farmer representatives.

Enhance transparency in water allocation and provide online complaint systems.

Draft a legal charter for water and farmers' rights in Zayandeh-Rud.

Responsible bodies: Ministry of Energy, Islamic Parliament, Governorate.

Expected Outputs

- Preservation of employment levels and sustainable livelihoods for farmers.
- Reduction of social conflicts stemming from water issues.
- Increased efficiency and reduced dependency on groundwater.
- Enhanced social and economic resilience of the region against climate change.

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تدوین راهبرد سیاست‌های سازگار با افزایش تاب‌آوری ناشی از تغییر اقلیم (مطالعه موردی: کشاورزی حوضه زاینده‌رود)

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چکیده

تغییرات اقلیمی با تأثیرگذاری تدریجی و پیچیده، خسارات فزاینده‌ای را به بخش کشاورزی مناطق خشک و نیمه‌خشک ایران از جمله حوضه زاینده‌رود تحمیل کرده است. این پژوهش با هدف تدوین راهبرد سیاست‌های سازگاری به‌منظور افزایش تاب‌آوری کشاورزی در مواجهه با تغییر اقلیم این حوضه، بر اساس سند چارچوب کاهش ریسک بلایا (SFDRR)، و معیارهای تاب‌آوری مجمع جهانی اقتصاد (۲۰۱۳) انجام شد. روش تحقیق توصیفی-تحلیلی و مبتنی بر ترکیب مطالعات اسنادی، پیمایش میدانی و روش دلفی سیاستی برای اخذ اجماع خبرگان و جمع‌آوری داده‌ها انجام گرفت. نمونه‌گیری به‌صورت هدفمند و از میان اساتید دانشگاهی، کارشناسان جهاد کشاورزی و تولیدکنندگان و صادرکنندگان محصولات کشاورزی که شناخت مناسبی از مباحث تغییر اقلیم، سیاست‌های سازگاری و تاب‌آوری داشتند، صورت پذیرفت. ابزار گردآوری داده‌ها شامل چهار پرسشنامه ساختاریافته (برای شناسایی نقاط قوت و ضعف، وزن‌دهی معیارهای تاب‌آوری، اولویت‌بندی سیاست‌ها و انتخاب راهبردها) و مصاحبه‌های نیمه‌ساختاریافته بود. در گام نخست، برای تعیین موقعیت راهبردی کشاورزی حوضه زاینده‌رود، از ماتریس‌های ارزیابی عوامل داخلی (IFE)، عوامل خارجی (EFE) و ماتریس موقعیت داخلی-خارجی (IE) استفاده شد. سپس به‌منظور اولویت‌بندی سیاست‌های سازگار با افزایش تاب‌آوری ناشی از تغییر اقلیم، از فرآیند تحلیل سلسله‌مراتبی (AHP) و روش تصمیم‌گیری چندمعیاره PROMETHEE بهره گرفته شد. راهبردهای مناسب نیز با استفاده از تحلیل SWOT توسعه و استخراج گردید و در نهایت، با به‌کارگیری ماتریس برنامه‌ریزی راهبردی کمّی (QSPM)، جذابیت نسبی و قابلیت اجرای هر راهبرد ارزیابی و سیاست‌های نهایی قابل‌اجرا انتخاب شد. یافته‌ها نشان داد که کشاورزی حوضه زاینده‌رود با امتیاز نهایی عوامل داخلی ۲.۰۴ و عوامل خارجی ۲.۱۲ در وضعیت تدافعی (بقا) قرار دارد و تاب‌آوری آن به‌دلیل انتقال و کمبود آب، خردشدگی و فرونشست اراضی و ضعف زیرساخت‌های نوین، پایین است. جذاب‌ترین سیاست‌های سازگاری شناسایی‌شده در راهبرد تدافعی، شامل توزیع عادلانه آب (TAS=1.46)، برنامه‌ریزی توسعه‌محور منابع آب (TAS=1.38)، بهینه‌سازی مصرف و کاهش تلفات آب (TAS=1.35)، کنترل سطح آب‌های زیرزمینی (TAS=1.23)، اصلاح قوانین مرتبط با خردشدگی اراضی (TAS=1.18) و مشارکت کشاورزان در مدیریت منابع آب (TAS=1.16) می‌باشد. راهکارهای پیشنهادی این پژوهش عبارت‌اند از: تقویت حکمرانی یکپارچه و حوضه‌محور منابع آب، اجرای مدل مدیریت راهبردی مشارکتی، سرمایه‌گذاری در فناوری‌های نوین و نرم، بازنگری تدریجی در قوانین و مقررات آب و گسترش تحقیقات و تدوین راهبرد ملی. نتایج این پژوهش، راهکارهای عملی و مبتنی بر مشارکت ذی‌نفعان را برای سیاست‌گذاران جهت ارتقای پایداری و تاب‌آوری کشاورزی در مناطق آسیب‌پذیر را پیشنهاد می‌نماید.

واژه‌های کلیدی: برنامه‌ریزی راهبردی، حکمرانی مشارکتی، راهبردهای تاب‌آوری کشاورزی، سیاست‌گذاری سازگار

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