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Research Paper

Determine the most appropriate strategy for groundwater management in arid and semi-arid regions, Abhar Plain, Iran

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Abstract: Due to growing demand and reduction of water resources and increasing pollution of water, driven by dramatic population and economic growth, arid and semi-arid land's imminent water problems are nowadays aggravating. This study aims to determine the most appropriate management strategies for balancing the Abhar plain aquifer using the SWOT coupled with AHP technique. The results indicate that weaknesses prevail over strengths as well as threats over opportunities. The placement in the quarter of weaknesses-threats with a defensive strategy indicates the critical condition of the Abhar plain aquifer. The most appropriate solutions to achieve the goal of balancing the groundwater were prioritized by AHP method. According to results, improper management of water consumption with a weight of 72.5% is the most destructive factor in reducing groundwater resources. Among the types of consumption, the effect of an agricultural factor carries a weight of 74.2%. The exploitation of illegal wells, overdraft of exploitation license provisions of wells, reduction of precipitation and traditional irrigation methods were selected as the destructive factors causing the deteriration of groundwater resources. Also, with filling the illegal wells, changing the type of cultivation and greenhouse crops cultivation, installing a smart water meter, observance the provisions of the water exploitation license, implementing integrated pressurized irrigation systems, benefiting from suitable climatic conditions and geographical location for cultivating and developing the low-water use species and industries and on the other hand, with implementing artificial recharge to control the surface water resources and reduce abstraction from groundwater aquifers, the adverse trend of Abhar Plain groundwater resources can be controlled.

Keywords: Groundwater balancing; Model; SWOT; AHP; Abhar Plain aquifer

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Introduction

Groundwater is almost available everywhere and although renewable, is not stable (Krishnamurthy et al. 2000). Groundwater management has become a significant component of water resources management and planning, particularly in the arid and semi-arid regions, because water resources distribution is very uneven both spatially and temporally in these regions such as Iran (Kardan et al. 2017). Improper use of groundwater resources regardless of their facilities will lead to irreparable damage such as the severe and irreversible drop in groundwater level, reduced discharge of wells and aqueducts, advancement of saline waterfronts and interference of saline and fresh water, the spread of pollution, vulnerability of plains to drought, land subsidence and endangerment of natural ecosystems (Izadi et al. 2008; The Department of Environment and Conservation, 2007).

This trend can be reversed with management decisions that consider several dimensions of

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groundwater. But there is no consensus on the importance of different criteria for the equitable and sustainable use of groundwater (Klein and Manda, 2019). Perceptions of groundwater resource management criteria have evolved over time and in numerous studies. Since not all the criteria on which groundwater management is based and affects the effective and sustainable use of groundwater are not of equal importance (Hajkowicz and Collins, 2007), the most important criteria for groundwater management are currently not specified. The choice of criteria and the assessment of the relative importance of those criteria are critical for new and innovative management options (Hajkowicz and Collins, 2007; Chen et al. 2010). The formulation of a strategy requires environmental scanning for internal and external factors that may affect performance.

A consistent study of the environment helps in forecasting trends and decision-making processes. Strengths, weaknesses, opportunities, and threats (SWOT) analysis is a commonly used tool for assessing internal strengths and weaknesses as well as probable opportunities and threats from the external environment. It is a foundation to formulate the strategies that best align internal and external factors (Singh and Singh, 2018). In the assessment of water management measures in the River Basin Districts of Crete, using SWOT as a decision-making tool to assess each measure show that reduction of irrigation water, control of fertilizers, exploitation of saline karstic springs, wastewater recycling and construction of small dams are recommended (Petousi et al. 2017).

Assessment studies have demonstrated that the SWOT method is an appropriate technique to determine the strategies. However, it neither accurately prioritizes the strategies nor does it reflect the sustainable development goals in finding the best strategy. Therefore, addressing these deficiencies is of great concern and the Analytic Hierarchy Process (AHP) method could be a proper solution to overcome this weakness (Bani et al. 2020). The use of the AHP method to determine the relative importance of criteria affecting groundwater resource management is a new application in groundwater research in arid and semi-arid regions. The AHP is one of the most comprehensive systems designed for decision making with multiple criteria and uses a pairwise comparison to compare the relative significance among criteria designed from the stakeholder's judgment (Saaty, 1994).

Determination of the most appropriate management strategy for groundwater balancing in the Abarkuh Plain Aquifer using the AHP, indicated that agriculture, compared to industry and drinking and sanitation water consumption is the most destructive sector in creating the aquifer imbalance. The most important activities in this sector were over-exploitation of the aquifer, competition in agricultural water utilization, irrigation systems, cultivation patterns, cultivated land area, exploitation of illegal agriculture water wells and development of industries with high water demand. Furthermore, the most important solutions for crisis management were irrigation system reform and cultivation pattern correction. To achieve these solutions, management strategies such as equipping the wells with the smart water meter, preventing illegal pumping, separating drinking from sanitation water and developing low water-consuming industries are suggested (Pourfallah et al. 2019). The combination of these two approaches (SWOT and AHP method) not only provides the possibility to develop the strategies but also ranks the strategies (Bani et al. 2020). In this paper, our approach is to develop a hierarchic structure to examine all the options and criteria affecting groundwater resources based on experts' opinions by SWOT analysis and to use the AHP analysis method for ranking and prioritizing these criteria in balancing the groundwater of Abhar plain aquifer. The aim of applying the combined method is to improve the quantitative side of strategic planning.

1 Study area

The study area of Abhar plain with an area of 1 964 km^2 is part of the catchment area of the Central Plateau of Iran (Latitude 35° 54′ N and 36° 31′ N, longitude 48° 50′ E and 49° 25′ E). Abhar watershed is limited to Tarom Mountains to the north and Soltanieh Mountains to the south and is connected to the Zanjan plain in the west and Qazvin plain in the east. About 60% of the area is covered by alluvial sediments and about 40% of the rest is covered by hard formations. The geographical location of the Abhar plain aquifer is shown in Fig. 1. According to the studies of Zanjan Regional Water Company on groundwater hydrograph by measuring the water level in exploratory and piezometric wells for the last thirty years, the groundwater level has decreased by an average of 1.4 m/a due to improper management of consumption and prolonged droughts, which may cause land subsidence, so the issue of managing these resources is very critical. Considering these conditions, it is obvious that the lack of rainfall,

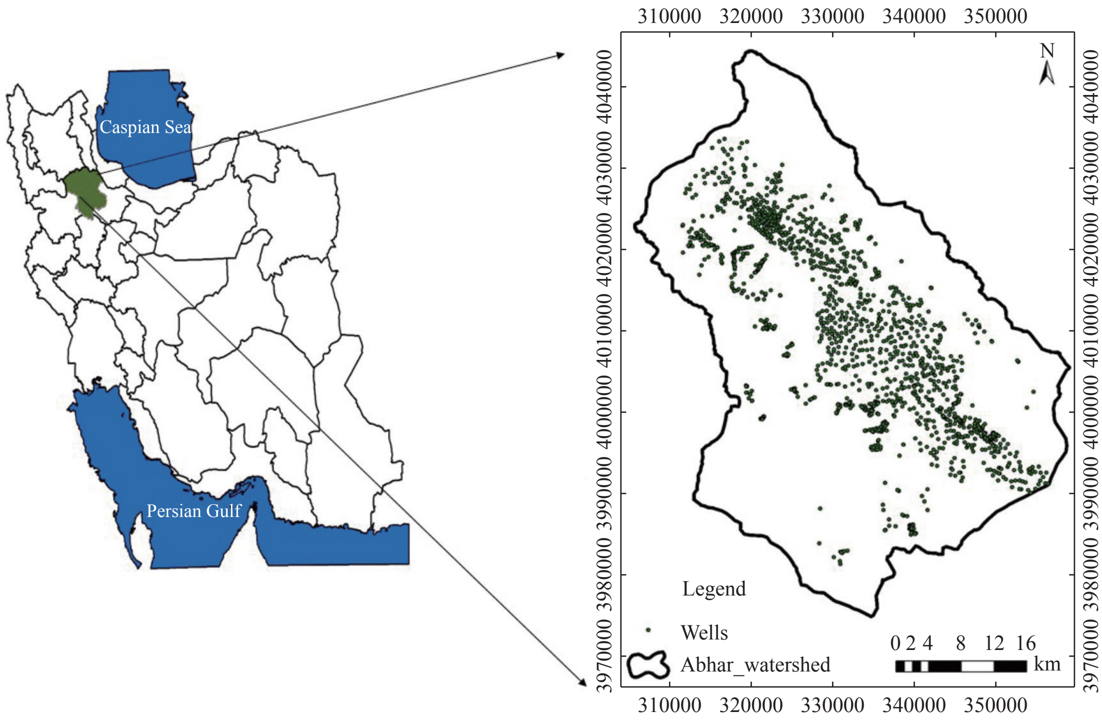

Fig. 1 Location of Abhar Plain in Iran

the groundwater overdraft, inadequate irrigation methods and failure to enforce the water sector laws and regulations are contributing to the water crisis. To address these issues, it is vital to develop the appropriate strategies regarding the characteristics of the study area. For this purpose, the expert committee including water engineers, academic professionals, water resources and agricultural authorities discussed the above features of the region in the brainstorming meeting to develop groundwater resources management strategies. Therefore, after using the SWOT model, the current state of water resources management in the study area was determined in terms of placement in four positions: Conservative, aggressive, defensive and competitive. Then, the factors that caused the current situation were identified and ranked in the AHP model and according to them, the strategies that will help to achieve the groundwater balance in the aquifer and improve the situation are rated.

2 Methods

2.1 SWOT analysis

SWOT stands for strength, weakness, opportunities, and threats. Strengths and weaknesses are internal factors, while opportunities and threats are external factors. SWOT is a useful tool for analyzing the situation as a whole. This approach seeks to maximize the strengths and opportunities and at the same time to minimize the weaknesses and threats (Martinez and Pina, 2015; Michailidis et al. 2015; Budi et al. 2016; Malgorzata, 2016; Sumiarsih et al. 2018). SWOT matrix analysis defines the strategies to achieve the goal by maximizing the driving factors and minimizing the inhibitory factors. The matrix consists of SO strategy (aggressive strategy) harnesses the power and seeks to take advantage of opportunities; ST strategies (diversification) uses force to avoid threats; WO strategies (turn around strategies) take advantage of opportunities to reduce weaknesses and WT strategies (defensive strategies) reduce weaknesses and move away from threats (Akbarpour and Tabibian, 2015; Aspan et al. 2015; Mousavizadeh et al. 2015; Adib and Habib, 2016).

In this study, to implement the SWOT analysis and formulate strategies, based on statistics and information collected from the region, the strengths, weaknesses, opportunities and threats were extracted. Then, in order to examine the SWOT matrix factors, questionnaires were designed and a decision-making group consisting of experts who are familiar with the study area was set up. A survey was conducted and relative importance was given on each factor, then the indicators and factors were ranked from 1 to 4 in terms of their value and the degree of compliance of the system with strengths, weaknesses, threats and opportunities. This score indicates the effectiveness of the system's current strategies in responding to these factors. The ranking of 4 indicates an excellent reaction while 1 indicates a very weak reaction of the relevant agent. Relative importance is calculated by the following equation:

$$RI = \frac{\sum_{s=1,2,\cdots,5} N \cdot S}{\sum \sum_{s=1,2,\cdots,5} N \cdot S} \quad (1)$$

Where: RI is the relative importance, N is the number of answers and S is the answers sensitivity. The sensitivity of criteria was assessed via a standard, Likert-type survey, with responses on a scale of one through five (where 1 = not important at all, 2 = slightly important, 3 = moderately important, 4 = very important, and 5 = extremely important) (Likert, 1932). Typically, Likert-type scales of 1–5 represent answer sensitivity, showing a relative strength of each response and avoiding extreme responses of "agree" or "disagree". The five-point scale is easy to understand, and accurately captures respondents' opinions (Alharbi and Sayed, 2017) without diminishing the response rate due to frustration (Babakus and Mangold, 1992). The final value of each factor was determined by multiplying the rank of the criterion by the relative importance. The overall rating in each of the strength, weakness, opportunities and threats factors is equal to the sum of the final value. The sum of the scores obtained from the evaluation of internal and external factors is placed in the horizontal and vertical axes of this matrix, to determine the position of the system. This matrix usually consists of a square that is created by the correspondence of internal and external factors. Based on the scores, the selected strategy is placed in one of the four positions SO, ST, WO and WT. If the sum of these scores is equal to 2.5, it indicates that the relevant factors are largely equal. More or less than this score will show the dominance of some factor (s) over other factor (s). By the comparative study, with the current situation and the selection of a superior strategic group from the SO, WO, ST and WT strategies, the SWOT matrix will be formed and the most important management strategies compatible with the region will be presented. The literature review of conventional SWOT analysis reveals that the importance of factors is not quantified to provide the effect of each factor on the formulated strategy (Chang and Huang, 2006; Masozera et al. 2006) and therefore needs to be utilized with other scientific techniques.

The application of the AHP method required a pairwise comparison of the different factors that make up the SWOT matrix. SWOT analysis focused on finding the strategies for water resources management, but did not rank the derived strategies. This research emphasizes the need for the integration of SWOT and AHP with the view to rank the groundwater management strategies to address the issue of groundwater decline and achieve the sustainable utilization of the resource in the aquifer.

2.2 AHP method

The analytic hierarchy process (AHP) is one of the most widely employed multi-criteria methods. The popularity of AHP stems from its simplicity, flexibility, intuitive appeal, and ability to mix quantitative and qualitative criteria in the same decision framework (Ramanathan, 2004). In this technique, the processes of rating alternatives and aggregating to find the most relevant alternatives are integrated. The ranking/selection is done concerning an overall goal, which is broken down into a set of criteria. The AHP method involves a set of judgments and evaluations logically, so on one hand, this method depends on personal perceptions and the hierarchical planning of an issue, on the other hand, it is related to logic, understanding and analysis of final decision and judgment (Ghodsipour, 2019). This method was first developed by Saaty (1980) in the 1970s to rank decision criteria and strategies. The advantage of the hierarchical analysis process is that it provides a structure and framework for collaboration and group participation in decision-making or problem-solving. It could be concluded that the AHP is an effective and powerful tool to analyze, structure and prioritize complex problems considering expert judgment on various aspects.

2.2.1 Determining and ranking factors and strategies for groundwater management in the AHP method

The criteria for assessing groundwater management are drawn from national guidelines and results of research in the field of water resources by public and private organizations and researchers that were adopted by the International Law Association (ILA) in 2004 and the conditions of the study area. These factors served as a starting point for developing the major factors affecting groundwater resources evaluation in this study. The selected criteria are given in Table 1 and Table 2. These criteria are practical and appropriate to the society, economy, geography and aquifer condi-

Table 1 The most important problems of groundwater resources destruction and imbalance in the Abhar Plain aquifer

Main criteria	Sub-criteria	Alternatives
Climate change	Decrease of precipitation	-
	Increase of temperature	-
	Changes in the precipitation pattern	-
Improper management of water consumption	Agriculture	Increase of cultivation area
		Drilling and exploitation of illegal wells
		Overdraft of exploitation license provisions for agricultural water wells
		Implementation of traditional irrigation methods
		Improper cultivation pattern
		Low price of water in the agricultural sector
		Lack of awareness and problems of agricultural promotion
	Industry	Non-industrial consumption of water in the shadow of industry (change the type of unauthorized consumption)
		Overdraft of exploitation license provisions for industrial water wells
		Development of high water-consuming mines
		Establishment of high water-consuming industries that do not comply with the water capacity of the region
		Low price of water in the industry sector
		No recycle of industrial effluents in water circulation
	Drinking and sanitation	Water consumption in agriculture and green space under the shadow of drinking and sanitation water
		Water consumption in the industrial sector under the shadow of drinking and sanitation water
		Water and sewage transmission network wear
		Uniformity of drinking water distribution network with green space
		Low price of water in the drinking and sanitation sector
		Cultural and promotional problems and lack of attention to proper water consumption and waste of household water

tions because most of Iran is located in arid and semi-arid regions, which are often occupied by rural communities. In addition, due to limited resources, the life, economy and sustainability of these communities depend on groundwater resources. Moreover, global and regional climate change has also contributed to the instability of the groundwater system.

2.2.2 Survey Instrument in AHP Method

The application of the methodology consists of establishing the weights associated with the criteria in defining the overall goal. This is done by comparing the criteria pairwise. Considering two criteria, C_j and C_k, The DM is asked to express a graded comparative judgment about the pair in terms of the relative importance of C_j over C_k with respect to the goal. The comparative judgment is captured on a semantic scale (equally important/ moderately more important/strongly important and so on) and is converted into a numerical integer value a_{jk}. The relative importance of C_k over C_j is defined as its reciprocal, i.e. $a_{kj}=1/a_{jk}$. A reciprocal pairwise comparison matrix A is then formed using a_{jk}, for all j and k. Note that $a_{jj}=1$. It has been generally agreed that the weights of criteria can be estimated by finding the principal eigenvector w of the matrix A:

$$AW = \lambda_{max} w \tag{2}$$

Where: A is the pairwise comparison matrix of criteria/strategies, W is the weight vector, and λ is the eigenvalue. When the vector w is normalized, it becomes the vector of priorities of the criteria with respect to the goal; λ_{max} is the largest eigenvalue of the matrix A and the corresponding eigenvector w contains only positive entries. The methodology also incorporates established procedures for checking the consistency of the judgments provided by the decision maker. Using similar procedures, the weights of alternatives with respect to each criterion are computed. Then, the overall weights of alternatives are computed using the weighted summation (Ramanathan, 2004).

$$FWS = \sum_{j=1}^{n} P_{ij} \cdot W_j \tag{3}$$

Table 2 The best ways to protect groundwater resources and balance in the Abhar Plain aquifer

Main criteria	Sub-criteria
Irrigation method	Flood or surface irrigation method
	Drip irrigation method
	Subcortical irrigation method
	Injectable irrigation method
	Pressurized irrigation method
Type of cultivation	Greenhouse crops cultivation
	Plastic cultivation
	Free (outdoors) cultivation
Pattern of cultivation	Almond and walnut trees
	Apricot, pear, peach, cherry trees
	Low-water demand cereals (wheat and barley)
	High-water demand cereals and fodder (corn, alfalfa, clover)
	Oil seeds (sunflower, rapeseed)
	Vegetable cultivation
Consumption management	Installation of the smart water meter
	Filling the illegal wells
	Observance of the provisions of the water exploitation license
	Blackout of water wells
	Reformation and insulation of irrigation system and water transfer
	Increasing the stairs rate of water price
	Water pricing in different sections
Reducing the development of water-intensive industries	Reducing the development of the production of polymer and fiberglass sanitary pipes and tubes
	Reducing the development of the steel industry
	Reducing the development of the petrochemical and chemical industry
	Reducing the development of the textile industry
	Reducing the development of the electronic and technology industry
	Reducing the development of the food industry
	Reducing the development of wood production industries
Reducing the development of water-intensive mines	Reducing the development of sand and gravel mines
	Reducing the development of building stone mines
	Reducing the development of copper mines
	Reducing the development of industrial stone mines
Reducing the non-industrial consumption	Reducing industrial water consumption in the non-industrial sector
	Strengthen water recycling in the industry
	Separation of industrial water and drinking water
	Reducing evaporation from recirculation ponds
	Use of recycled water for irrigation of green spaces
Drinking and sanitation and green space water consumption	Separation of drinking water and sanitation pipelines
	Construction of the station’s water card pump in different parts of the city
	Distribution of gallons of drinking water throughout the city
	Gradual increase in water prices for the drinking and sanitation sector
	Separation of green space water from drinking water

Where: *FWS* is the final weight of a strategy or overall weight of alternative *i*, P_{ij} is the weight of alternative *i* with respect to C_j and W_j is the weight of C_j with respect to the goal.

The hierarchy was designed for effective criteria, sub-criteria and alternatives in the solutions and problems of the region. Then, a questionnaire is prepared to compare the criteria, sub-criteria and alternatives in pairs and experts are asked about the importance of these questions in the form of a binary comparison matrix. Survey questions targeted practicing water professionals working in different locations and work sectors such as Zanjan Regional Water Organization, Natural Resources and Watershed Management Department, Agriculture Jihad office and sample farmers. The reason for selecting these experts was because of their awareness of technical, economic and social issues of Abhar plain, and their complete knowledge of the environmental conditions of the plain and their professionalism in water resources management. Twenty-three experts were then asked to evaluate the importance of each criterion. The consistency ratio between the expert's opinions was evaluated using the pairwise comparison method and the final weight was computed for each criterion. Surveys were circulated using a random sampling approach via paper and online avenues. The geometric instruments used in this questionnaire were rated with a "Saaty intensity scale". The Saaty intensity scale (Table 3) represents the relative importance between any two criteria on a nine-point scale.

In this scale, the numbers used to compare pairs are from 1 to 9, which is a standard measure. A value of 9 or 1/9 signifies that one criterion is nine times more important than the other. All the required data were extracted from questionnaires based on the Saaty intensity scale and were converted to a ratio scale using the AHP to allow for a comparison of the intensity of each criterion and expert's opinions evaluated and inconsistency rate obtained. The AHP is useful for assigning priorities by using pairwise comparisons of criteria to assess the relationships between those criteria (Saaty, 1980; Saaty, 1990; Saaty, 2008; Saaty and Vargas, 1991). Control of the judgment's inconsistency index was done, after determining the relative weight of the criteria based on the pairwise comparison. The accuracy of binary comparison matrices is determined using the consistency index. The *CI* indicates the consistency of judgment in the pairwise matrix and is given by:

$$CI = (\lambda - n) / (n - 1) \tag{4}$$

$$CR = CI / RI \tag{5}$$

Where: λ is the product of the reciprocal of the normalized values for each criterion in the matrix and the average of each row in the matrix (Saaty, 1990), and n is the number of criteria. The consistency ratio (*CR*) is obtained by forming the ratio of *CI* and the appropriate one of the following set of numbers shown in Table 4, each of which is an average random consistency index computed for $n \leq 10$ very large samples. They create randomly generated reciprocal matrices using the scale 1/9, 1/8, ⋯, 1/2, 1, 2, ⋯, 8, 9 and calculated the average of their eigenvalues. This average is used to form the random consistency index *RI*.

It is recommended that a consistency index

Table 3 The fundamental scale of values representing the intensities of judgments between two groundwater management criteria

Intensity of importance	Definition	Description
1, 1/1	Equal importance	Two criteria are of equal importance
2, 1/2	Weak importance	
3, 1/3	Moderate importance	Moderate importance of one criterion over the other
4, 1/4	Moderate plus importance	
5, 1/5	Strong importance	Strong importance of one criterion over the other
6, 1/6	Strong plus importance	
7, 1/7	Very strong importance	Very strong importance of one criterion over the other, evidence based
8, 1/8	More, more strong importance	
9, 1/9	Extreme importance	Unquestionable or demonstrated support of the importance of one criterion over the other

Notes: From Saaty and Vargas (2006).

Table 4 Random index for matrix (Reproduced from Saaty, 1994)

Order of matrix	1	2	3	4	5	6	7	8	9	10
Random index (RI)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

should be less than 0.1, indicating that a desired level of compatibility exists in binary comparisons. Otherwise, this rate represents inconsistent judgment (Saaty, 2002; Oswald, 2004; Malczewski, 2006; Ghodsipour, 2019; Ishizaka and Labib, 2009; Ataee, 2010; Hatefi and Ekhtesasi, 2016).

3 Results

To separate the internal and external environment to determine the SWOT model factors, the basin boundary was determined as the range under the management of Abhar plain. The strengths and weaknesses were summarized from the characteristics and potentials within the basin as the internal factors, and everything outside the basin was considered as external factors (threats and opportunities). The relative importance and rankings in the tables are obtained from the opinions presented by the participants in the brainstorming session and then the indicators and factors, based on the amount of value, were ranked 1 to 4. Finally, the final value of each factor was calculated by multiplying the relative importance with the rank.

The internal and external factors of the evaluation matrix are described in Table 5, Table 6, Table 7 and Table 8. According to these tables, overall, 19 strengths and opportunities were identified as advantages and 21 weaknesses and threats were identified as the limitations or bottlenecks of the water resources management of Abhar plain. Among them, the most important strengths include climate conditions, appropriate geographical location for the cultivation of plant species, the development of industries with low-water demand, and communication with the three metropolises of Tehran, Tabriz and Qazvin. The traditional irrigation system, low irrigation efficiency, productivity and performance at high cost, water harvesting of unauthorized wells were the most important weaknesses according to the expert

Table 5 Analysis of internal factors (Strengths)

No	Strengths	Relative importance	Rank	Final value
1	Participation of exploiters in groundwater management (management, protection, utilization)	0.120	3	0.359
2	Promoting the public awareness of proper water use to reduce water consumption	0.115	3	0.346
3	Use of mineral potentials instead of water-loving agriculture	0.081	1	0.081
4	Suitable climatic conditions for the cultivation of low-water demand species	0.123	3	0.368
5	Participation and cooperation of the people with the relevant authorities	0.105	2	0.210
6	Cohesion and solidarity between different organizations and social communities	0.114	3	0.342
7	Replacement of consumption water from groundwater resources with runoff extraction	0.093	1	0.093
8	Suitable geographical location and connection with the three metropolises of Tehran, Tabriz, the Qazvin to develop low-water demand industries	0.145	4	0.580
9	Increase the quality of consumption water	0.104	2	0.207
Overall strength rating		2.590		

Table 6 Analysis of internal factors (Weaknesses)

No	Weaknesses	Relative importance	Rank	Final value
1	Insufficient income, lack of productive employment and strong dependence of the rural economy on agricultural products and activities	0.113	4	0.450
2	Lack of sufficient information and knowledge among farmers and exploiters and their old age	0.102	3	0.305
3	Change of hydraulic gradient and influx of saline water to fresh water	0.064	1	0.064
4	Increased salinity in soil resources	0.065	1	0.065
5	Lack of attention to the coherent organizational structure in water resources management	0.098	3	0.294
6	Existence of traditional irrigation systems, low irrigation efficiency, productivity of production factors (water and soil) and performance at the level and high production costs	0.126	4	0.504
7	Lack of intellectual space to raise awareness about water crisis issue	0.093	2	0.186
8	Over-exploitation of permitted wells	0.118	4	0.470
9	The exploitation of illegal wells	0.124	4	0.494
10	Lack of construction and completion of the wastewater treatment plant to benefit from treated water in agriculture, industry and green space	0.099	3	0.297
Overall weaknesses rating		3.130		

Table 7 Analysis of external factors (Opportunities)

No	Opportunities	Relative importance	Rank	Final value
1	Ability to provide information to strengthen culture in groundwater reclamation and balancing	0.093	1	0.093
2	Possibility of implementing the Danab Comprehensive Plan (National Student Water Rescue Plan) from which the concepts of quantity and quality of water, virtual water, intrinsic and economic value of water could be raised	0.087	1	0.087
3	Possibility to increase the value of agricultural products by improving the quality and proper processing	0.102	2	0.204
4	Participation of clerics and involving them to promote knowledge related to water resources	0.088	1	0.088
5	Equipping water wells with smart water meters to control consumption	0.111	4	0.443
6	Watershed management and aquifer artificial recharge measures to prevent floods and loss of water resources and surface runoff extraction	0.118	4	0.472
7	Establishment of various cooperatives to create local markets for buying and selling water	0.091	1	0.091
8	Optimize the distribution network to reduce water loss	0.093	1	0.093
9	Land consolidation and prevention of land fragmentation through integrated pressurized irrigation systems	0.112	4	0.447
10	Amend and facilitate upstream laws to change the type of agricultural water consumption to other uses	0.105	3	0.316
Overall rating of opportunities		2.330		

Table 8 Analysis of external factors (Threats)

No	Threats	Relative importance	Rank	Final value
1	Occurrence of migration phenomenon and increase of population and exploitation in the region	0.061	1	0.061
2	Occurrence of drought and climate change (scarcity and improper distribution of temporal and spatial precipitation)	0.106	4	0.425
3	Insufficient funds and facilities	0.100	3	0.299
4	Lack of proper cultivation pattern	0.093	3	0.279
5	Lack of active and legal supervision from the Ministry of Energy and Agricultural Jihad in water consumption in the agricultural sector	0.093	3	0.279
6	Expansion of industries with high-water demand in the plain	0.040	3	0.283
7	Lack of stock market for agricultural products	0.078	2	0.156
8	Impossibility and cost of intra-basin and extra-basin water transfer projects to the region	0.088	2	0.175
9	Absence of beneficiaries in the top-down planning and decision-making sector	0.103	4	0.412
10	Uncertainty about the true value of water in agriculture, industry, drinking and health	0.107	4	0.429
11	Existence of upstream rules in issuing exploitation licenses and the existence of rent	0.077	2	0.153
Overall rating of threats		2.950		

opinions. Also, watershed management and artificial recharge measures to prevent floods and loss of water resources, extracting surface runoff, integrating lands and preventing crushing land through integrated irrigation systems under pressure are the most important opportunities in the water resource management of the plain. The lack of real value of water in the agricultural, industry, drinking and health sectors and the occurrence of drought and climate change (inappropriate time and spatial distribution) are the most important threats that the water resources management of Abhar plain faces.

According to the results of Table 5, the most important strength in the groundwater resources management of Abhar plain from the perspective of experts and elites is the appropriate geographical location and relationship with the three metropolises of Tehran, Tabriz and Qazvin to develop low-water demand industries, with a final value of 0.58.

Considering the analysis in Table 6, the weaknesses of the region are classified into 10 categories, in which the existence of traditional irrigation system, low irrigation efficiency, and productivity and performance at high cost of production with final value 0.504 is the most prominent weakness in the management of water resources in the region.

Based on the results of Table 7, the greatest opportunities in the region are grouped into 10 categories, in which watershed management and artificial recharge of the aquifer to prevent floods and loss of water resources and surface runoff with a final value of 0.472 is the most important factor and if it is properly considered, it will play an important role in preventing the loss of surface water resources and preventing the occurrence of floods and reducing its destructive effects, and finally recharging the aquifer.

The results of Table 8 show the factors that threaten the groundwater resources of Abhar plain, classified into 11 groups, in which the lack of real value of water in agriculture, industry, drinking and health is the biggest threat to water resources. For strategic planning, SWOT analysis is a good tool and can be the basis for identifying the best opportunities for future planning. The SWOT matrix also includes internal strengths and weaknesses and external opportunities and threats to extract future strategies. By comparing these factors, four strategies SO, ST, WO and WT can be presented. According to the internal factor identification in Table 5 and Table 6, the relative weight of the strengths (2.59) was deducted from the relative weight of the weaknesses (3.13) to get the internal factors score (−0.54). Its negative sign indicates that the groundwater management weaknesses in Abhar plain outnumber the strengths. According to the analysis of external factor identification in Table 7 and Table 8, the relative weight (overall strength rating) of the opportunities (2.33) was deducted from the relative weight of the threats (2.95) to yield the external factor score (−0.62). The negative sign indicates that groundwater management threats in Abhar plain outnumber opportunities. Fig. 2 shows the schematic and position of the current situation of the evaluated strategies in Abhar plain in terms of water resources management.

Using the AHP model, two goals were achieved, the most important problems of groundwater imbalance in Abhar plain and determining a solution to solve it.

3.1 Model of water resources degradation and groundwater imbalance

After determining the location of Abhar Plain in the SWOT matrix, the strategies for improving the groundwater situation in Abhar Plain could be ranked. In AHP, pairwise comparisons of decision elements at each cluster are performed with respect to their importance toward their control criteria, and between clusters with respect to the objective of the study. To identify the relative importance of criteria and sub-criteria, the decision-makers and experts from the related field were asked to approve the effect of each criterion on the other criteria with respect to criterion 1, criterion 2, criterion 3, etc. Also, the relative importance of the sub-criterion of each criterion, with respect to every other sub-criterion is provided sequentially. To evaluate the preference intensity between two elements, fundamental Saaty's scale with the verbal terms of 1–9 was used, where equal importance between two elements is represented by the score of 1 and the extreme importance of one element (row cluster in the matrix) compared with the other (column cluster in the matrix) is denoted by a score of 9. A reciprocal value of the element (i, j) shows that the criterion in the j^{th} row is better than the criterion in the i^{th} row. AHP performs pairwise

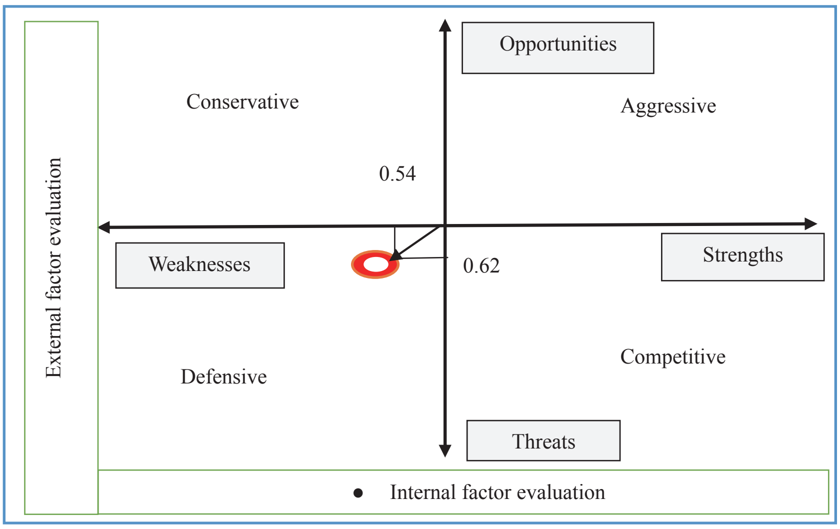

Fig. 2 Matrix of internal and external evaluation factors in SWOT

comparisons in the framework of a matrix, and w is obtained by normalizing the vectors in each column of the matrix and then by computing the average of the resulting matrix rows. Table 9 shows an example of pairwise comparison between criteria and their calculated relative importance values in the AHP model.

The results from the survey show that in the AHP model, two main criteria were defined, including water consumption management and climate change, while the former was assigned a higher weight of 72.5%. In order to investigate the climate change criterion, three sub-criteria, i.e. precipitation decrease, temperature increase and change in the precipitation pattern (snow and rain) were considered with wights of 61.1%, 17.8% and 21.1%, respectively. Furthermore, an incompatibility rate of 0.003 91 was allocated.

To manage groundwater consumption, sub-criteria of agriculture, industry, drinking and sanitation were identified in the AHP model with an inconsistency rate of 0.02. In the pairwise comparisons, agriculture with a weight of 74.2% has a much higher impact in the groundwater imbalance of the Abhar plain aquifer. Considering the extent of agricultural activities in the Abhar plain, the above results are consistent with the condition of the region and therefore acceptable. Other agricultural sub-criteria with an inconsistency rate of 0.007 45 included the drilling and exploitation of illegal wells (32.9%), over-exploitation of license provisions for agricultural water wells (17.3%), implementation of traditional irrigation methods (13.8%), low price of water in the agricultural sector (10.9%), increase the area under cultivation (10.3%), improper cultivation pattern (8.7%) and lack of awareness and problems of agricultural promotion (6.3%).

Industry sub-criteria with an inconsistency rate of 0.008 06 included overdraft of exploitation license provisions in industrial water wells (21.7%), non-industrial consumption in the shadow of industry (change the type of unauthorized consumption) (20.6%), the establishment of water-loving industries that do not comply with the region (20%), no use of industrial effluents in water circulation (14.5%), development of high water demand mines (12.2%), low price of water in the industry sector (11%).

Drinking and sanitation sub-criteria with an inconsistency rate of 0.02 included water consumption in agriculture and green space under the shadow of drinking and sanitation (21.5%), drinking water distribution network with green space (18.7%), cultural and promotional problems and lack of attention to proper water consumption and waste of household water (16.4%), water consumption in the industrial sector under drinking and sanitation (15.2%), low price of water in drinking and sanitation sector (14.7%) and water and sewage transmission network (13.5%).

The criterion of improper management of water consumption with a weight of 72.5% had the greatest role in groundwater imbalance in the Abhar plain aquifer. Improper Water consumption in the agriculture sector is the biggest cause of imbalance in this aquifer below the consumption criterion with a weight of 74.2%. In the agricultural sector, the drilling and exploitation of illegal wells, as well as the excessive and improper exploitation of authorized and legal agricultural water wells without monitoring and control for decades has had a devastating effect on groundwater resources, resulting in a sharp water level decline in aquifers and an imbalance between recharge and discharge. The weakest criteria in destruction of groundwater resources are related to the drinking and sanitation sector. In general, the factors causing the destruction of groundwater resources in the Abhar Plain aquifer with relative weight are listed in Table 10.

3.2 Model of determining the best strategies for balancing in the groundwater

After identifying the key problems causing the groundwater imbalance in the region, the best management solution to solve these problems was prepared. Eight main criteria were selected to run the model for the best solution. After entering the criterion into the AHP model, their weighting with an inconsistency rate of 0.09 was allocated. Consumption management (34.2%), irrigation system modification (21.4%), cultivation type modification (15.5%), cultivation pattern modifica-

Table 9 The framework of pairwise comparison of the problem ofaquifer imbalance in Abhar Plain

Criteria	Water consumption management	Climate change	Standardized weights /%
Water consumption management		2.634 48	72.5
Climate change			27.5
Inconsistency rate: 0.00			

Table 10 The general framework of factors causing degradation and groundwater imbalance in the Abhar Plain aquifer

Criteria	Standardized weights /%	Criteria	Standardized weights /%
Drilling and exploitation of illegal wells	18.2	Change the precipitation pattern	3.2
Overdraft of exploitation license provisions for agricultural water wells	9.6	Increase in the temperature	2.7
Reduction of precipitation	9.3	Water consumption in agriculture and green space under the shadow of drinking and sanitation	2.6
Implementation of traditional irrigation methods	7.6	No use of industrial effluents in water circulation	2.5
Low price of water in the agriculture sector	6.1	Identity of drinking water distribution network with green space	2.2
Increase the area under cultivation	5.7	Development of the mines with high-water consumption	2.1
Improper cultivation pattern	4.8	Cultural and promotional problems and lack of attention to proper water consumption and waste of household water	2.0
Overdraft of exploitation license provisions in industrial water wells	3.8	Low price of water in the industry sector	1.9
Non-industrial consumption in the shadow of industry	3.6	Water consumption in the industrial sector under the shadow of drinking and sanitation	1.8
Establishment of water-intensive industries that do not comply with the region	3.5	Low price of water in the drinking and sanitation sector	1.8
Lack of awareness and problems of agricultural promotion	3.4	Water and sewage transmission network wear	1.6

tion (11.2%), reducing non-industrial water consumption in the shadow of industry activity (6.8%), managing water consumption in drinking and sanitation and green space (3.8%), reducing the development of mines with high-water demand (3.6%), and reducing the development of industries with high-water demand (3.5%) are the best solutions to balance the Abhar plain aquifer. In order to clarify the problem and to achieve the best solution, for each of the selected criteria, sub-criteria were selected and ranked by the AHP model.

Under the criteria of modification of irrigation system, the sub-criteria with an inconsistency rate of 0.03 was prioritized as a drip (28.2%), pressurized (27.9%), subcortical (18.9%), injectable (14.3%) and finally flood or surface irrigation method (10.8%).

Under the criteria of cultivation type modification, the sub-criteria with an inconsistency rate of 0.05 were identified in the following order, i.e. greenhouse crops cultivation with a weight of 48.7%, plastic cultivation (cultivation with plastic mulch) with a weight of 31.2%, and free (outdoors) cultivation weighs 20.1%.

Under the criteria of cultivation pattern modification, according to the purpose, the following sub-criteria were identified with inconsistency rate 0.09, cultivation of low-water demand cereals (wheat and barley) cultivation (34.7%), almond and walnut trees cultivation (24.1%), apricot, pear, cherry trees cultivation (16.7%), oil seeds (sunflower, rapeseed) cultivation (9.4%), vegetable cultivation (9.3%) and cereals and fodder (corn, alfalfa, clover) cultivation with high-water demand (5.8%) .

Under the criteria of water consumption management, sub-criteria with an inconsistency rate of 0.10 included filling the illegal wells, installing smart water meters, observance of the provisions of the water exploitation license, pricing of water in different sections, increasing the stairs rate of water price, reformation and insulation of irrigation system and water transfer and blackout of agriculture water wells.

Under the criteria of reducing water-intensive industries, sub-criteria with an inconsistency rate of 0.09 were selected such as reducing the development of the steel industry (31%), reducing the development of the textile industry (19.5%), reducing the development of the food industry (15.3%), reducing the development of the petrochemical and chemical industry (13.2%), reducing the development of the electronic and technology industry (8.8%), reducing the development of production of polymer and fiberglass sanitary pipes and tubes (7%) and reducing the development of wood production industries (5.2%).

The steel industry is one of the most water-intensive industries, which, has a great impact on the quantity and quality of water resources due to the large volume of groundwater in this region. Therefore, when proposing the construction of industries, it is necessary to pay attention to the critical situation of groundwater resources in the region and to select industries that are compatible with the water condition in that region, which should have low water requirement ideally. The relative weight of 5.2% for the wood products industry indicates that, due to low water consumption, this type of industry can be developed according to the existing potentials in the Abhar plain aquifer. Sub-criteria for reducing water-intensive mines with an inconsistency rate of 0.08 include reducing the sand and gravel mines (47.8%), reducing the copper mines (27.4%), reducing the building stone mines (14.6%) and reducing the industrial stone mines (10.2%), respectively.

Sub-criteria of non-industrial consumption reduction in the shadow of the industry with inconsistency rate of 0.10, include the control and reduction of industrial water consumption in the non-industrial sector (39%), strengthen water recycling in the industry (23.5%), irrigation of green space with water from recycling (19.4%), separation of industrial and drinking water (11.4%) and reduce evaporation from recirculation ponds (6.8%).

Sub-criteria for drinking, sanitary and green space uses with an inconsistency rate of 0.10 include distribution of gallons of drinking water throughout the city (32.9%), construction of station card pumps in different parts of the city (32.8%), separation of green space water from drinking water (17.5%), separation of drinking water and sanitation pipelines (10.4%) and gradual increase in the price of water for drinking and sanitation (6.4%).

In general, all the sub-criteria with their respective priority to improve the groundwater balance in Abhar plain aquifer have been extracted from the AHP model, as indicated in Table 11.

4 Discussions

As the available groundwater resources are limited in arid and semi-arid regions, and the implementation of groundwater balancing and reclamation projects are costly and time-consuming, so the selected methods and tools in decision-making to develop groundwater management strategies must be strong, equitable and effective. Groundwater resource management requires a comprehensive and integrated approach that addresses countless physical and socio-economic dimensions. Conscious and enforceable strategies are compatible with the long-term sustainability of groundwater. However, it is not clear how to assess the weight of the criteria properly. There is a consensus on the most important criteria for groundwater resource management and the degree of importance of these criteria is relative and varies (Hajkowicz and Collins, 2007; Hajkowicz and Higgins, 2008).

4.1 Determine the current state of groundwater management of Abhar Plain by SWOT

According to the score obtained from the final sum of the matrix of internal factors, it is concluded that in the Abhar plain, the weaknesses of water resources management are more than its strengths (Fig. 2). Also, according to the final sum of the scores of the matrix of external factors, it is concluded that the threats to water resources management in the Abhar plain are more than opportunities. After forming the matrix of internal and external factors and before formulating management strategies, according to the type of reaction, how each internal and external factor interacts, based on the values obtained from the SWOT matrix, from the perspective of experts presented at the brainstorming meeting, WT strategy was the most deployed among other strategies. This strategy seeks to minimize the damage caused by the identified threats and weaknesses.

According to the current situation of Abhar Plain, to control the trend of groundwater level decline and for better management, defensive strategies should be prioritized. In other critical plains of the country such as Abarkooh Plain, Songhar Plain and Bushehr Plain, according to the results of Pourfallah et al. (2019), Rahmatipour and Maroufi (2017) and Mousavizadeh et al. (2015), the weaknesses and threats of the region have greatly exceeded its strengths and opportunities, and the situation of water resources is in an extremely critical state, which should be prevented as soon as possible through the implementation of defensive strategies. Their experience should be learned by Abhar Plain, combined with the most important weaknesses and main threats in this plain from the results of the SWOT analytical model, it is suggested that the research results from Hashemi and Bani (2014) could be adopted, which was to focus on land consolidation and prevent their fragmentation through integrated pressurized irrigation systems.

4.2 Importance of coupling two models of SWOT and AHP

The combined use of the AHP and SWOT analysis

Table 11 Prioritized solutions for strengthening groundwater resources and balance in the Abhar plain aquifer

Priority	Sub-criteria
10.1	Filling the illegal wells
7.6	Greenhouse crops cultivation
7.6	Install the smart water meter
7.1	Observance of the provisions of the water exploitation license
6.3	Water pricing in different sections
6.0	Drip irrigation method
6.0	Pressurized irrigation method
4.9	Plastic cultivation method
4.0	Subcortical irrigation method
3.9	Low-water demand cereals (wheat and barley) cultivation
3.1	Injectable irrigation method
3.1	Free (outdoors) cultivation method
2.7	Almond and walnut trees cultivation
2.7	Control and reduction of industrial water consumption in the non-industrial sector
2.3	Flood or surface irrigation method
1.9	Apricot, pear, peach, and cherry trees cultivation
1.7	Reducing the development of sand and gravel mines
1.6	Strengthen water recycling in the industry
1.5	Gradual increase in water prices
1.3	Irrigation of green space with water from recycling
1.2	Construction of station card pumps in different parts of the city
1.2	Distribution of gallons of drinking water throughout the city
1.1	Oil seeds (sunflower, rapeseed) cultivation
1.1	Reducing the development of the steel industry
1.0	Vegetable cultivation
1.0	Reducing the copper mines
0.8	Reformation and insulation of irrigation system and water transfer
0.8	Separation of industrial water and drinking water
0.7	Blackout of water wells
0.7	Reducing the development of the textile industry
0.7	Separation of green space water from drinking water
0.6	Cereals and fodder (corn, alfalfa, clover) cultivation with high-water demand
0.5	Reducing the development of the petrochemical and chemical industry
0.5	Reducing the development of the food industry
0.5	Reducing the development of building stone mines
0.5	Reducing evaporation from recirculation ponds
0.4	Reducing the development of industrial stone mines
0.4	Separation of drinking water and sanitation pipelines
0.3	Reducing the development of the electronic and technology industry
0.2	Reducing the development of polymer and fiberglass sanitary pipes and the production of the tubes industry
0.2	Reducing the development of wood production industries
0.2	Gradual increase in the price of water for drinking and sanitation

has been widely used to support strategic decision-making processes. Utilizing AHP in SWOT analysis yields analytical priorities for the factors included in SWOT analysis and makes them commensurable. While SWOT analysis supports the decision situation, AHP measures the relative importance of the SWOT factors (Kandakoglu et al. 2007; Kurttila et al. 2000). Making pairwise comparisons forces the decision–makers to consider the weights of the SWOT factors and to analyze the situation more precisely and insightfully than the standard SWOT model does. By integrating SWOT with AHP, not only the mutual weighting of SWOT factors but also the evaluation of alternative strategic decisions can be integrated with ordinary SWOT analyses. In this way, the most crucial weakness of SWOT can be avoided (Kangas et al. 2001; Kangas et al. 2003). Therefore, due to the location of Abhar plain in WT zone from the SWAT model, it is necessary to take immediate action to protect the aquifer and to prevent the aquifer from these weaknesses and threats using the strategies which are proposed and weighted in the AHP model. The results show that combining the two models can effectively help to determine the desired strategies.

4.3 Ranking and role of destructive factors causing groundwater decline and depletion in Abhar Plain Aquifer

Based on AHP model results, the inconsistency rate of all criteria and sub-criteria was less than 0.1 and the consistency of the judgments was confirmed. Extracted information from questionnaires and surveys conducted by water experts reflect their understanding of the relative importance of physical, social and economic criteria impacting groundwater resource management and allocation. Improper management of water resources carries the highest weight of 72.5% which is much higher than that of climate change. Most experts believe that lack of precipitation and drought are inherent features of these areas, although climate change such as the decrease in precipitation, increase in temperature and change in precipitation pattern and long-term droughts affect the water situation in the region, but compared with improper management of available water resources, its relative importance is only 27.5%. They also believe that changes in precipitation characteristics are a costly, time-consuming process that requires technical knowledge and the cost-effectiveness and availability of water storage infrastructure in the region. Therefore, water resources deterioration in this plain is closely related to water consumption management, which should be regarded as the best way to alleviate the groundwater stress in the plain. Increasing precipitation, artificial water recharge and storage have proved to be illogical and technically impossible considering the situation in the region, such as change of precipitation patterns, reduced permeability of the soil cover and loss of vegetation due to prolonged drought.

On the other hand, the results showed that improper management of water consumption in the agricultural sector has a weight of 74.2%, which is much higher than industrial, drinking and sanitation consumption. Improper management of water consumption in the agricultural sector not only in Abhar plain but also in other parts of the world has led to the decline of groundwater levels (Bejar-Pizarro, 2017; Pal and Karnam, 2019). The biggest problems in the agricultural sector are related to the drilling and use of illegal wells, overdraft of exploitation licenses for agricultural water wells, implementation of traditional irrigation methods, low price of water in the agricultural sector, increase in the area under cultivation, improper cultivation pattern and lack of awareness and problems of agricultural promotion.

The main income, livelihood and employment in the social and economic sectors in this plain are related to agriculture (irrigated agriculture) and horticulture (vineyards), which use traditional irrigation methods causing wastage and evaporation of water. Also, very low production efficiency per unit area and lack of modern and mechanized methods in the processes of planting, holding and harvesting, irrigation and observing technical principles, has led to the cultivation of more land and increased stress on water resources. Furthermore, the cultivation patterns are not compatible with the arid conditions of the region and most of the plants have high water consumption. These have all contributed to the pressure on water resources.

According to the conditions in the region and its comparison with the agricultural situation in the region, the results from AHP are confirmed. Among the factors causing the water resource deterioration in the plain aquifer, all sub-criteria of the agricultural sector has the highest ranks. In other sectors, such as industry, drinking and sanitation, the main issues are over-exploitation of licenses, non-industrial consumption in the shadow of industry (such as agriculture) and the establishment of water-intensive industries or industries that are not compatible with the water situation in the region. In this plain, in most cases of water violations is the change in the type of illegal consumption and use of water allocated to industrial activities in the form of agriculture, which has also done damages to the aquifer. In the drinking and sanitation sector, changing the type of water consumption, its use in the agricultural sector, and the same drinking water and sanitation network with green space have been identified. In general, it can be said that the main activities are related to agricultural consumption, whether in agriculture, industrial sectors, or drinking and sanitation, which has a change in the type of illegal consumption and use in the agricultural sector.

The results obtained in this section are similar to the research of Pourfallah et al. (2019) which showed that the factors of cultivation pattern, over-exploitation of license, incorrect consumption of agricultural and drinking water are considered important factors in creating an environmental crisis and sinking in Abhar Plain. After identifying the problems and determining the contribution of different sectors, appropriate solutions to control the crisis were reviewed and ranked by hierarchical analysis. The results showed that in determining the main strategies, water consumption management, irrigation systems improvement, cultivation type improvement and cultivation pattern modification criteria with a wight of 34.2%, 21.4%, 15.5% and 11.2%, respectively, would play the greatest role in the improvement groundwater resources in the plain. The results of the research by Kazemi et al. (2016) and Ghobadian et al. (2016), Pourfallah et al (2019) are also similar and close to the prioritized solutions in the present study.

4.4 Ranking and role of strategies to improve the condition of Abhar plain groundwater

In the ranking of stragies for creating balance in the Abhar plain aquifer, filling the illegal wells, developing greenhouse crops cultivation, installing smart water meters, preventing over-exploitation of license provisions for legal water wells, water pricing in different sections and developing drip and pressurized irrigation methods prioritized. In general, it can be concluded that if in the employment and livelihood sector, conversion and processing industries and the type of greenhouse crops that have high production per unit of area with low water consumption are developed, while improving the living standards, employment and economy of the stakeholders in Abhar Plain, we can think positively about the proper management of groundwater resources in Abhar Plain, especially in the agricultural sector.

5 Conclusion

In this study, to sustainably manage water resources and to address the challenge of water scarcity in the arid and semi-arid regions, SWOT analysis and AHP were combined to rank water resources management strategies based on criteria on destruction of groundwater resource. The novelty and value of this research are that it addresses questions on how groundwater management criteria in arid and semi-arid regions should be analyzed, how the perceptions vary by water professionals, and how the degree of importance varies among the criteria. Strengths, weaknesses, opportunities and threats were extracted for the study area during brainstorming meetings. The findings show the ranking of each SWOT group as following: Weaknesses (group weight 28.5%), Threats (26.8%), Strengths (23.5%) and Opportunities (21.2%). According to the analysis, the most important factor in SWOT is "suitable geographical location and connection with the three metropolises of Tehran, Tabriz, the Qazvin to develop low-water demand industries" from the group of Strengths with a priority value of 0.580. Other considerable factors are ranked as follows according to priority: Existence of traditional irrigation systems and low irrigation efficiency and productivity of production at high production costs (0.504), The exploitation of illegal wells (0.494), watershed management and aquifer artificial recharge measures to prevent floods and loss of water resources and surface runoff extraction (0.472) and insufficient income, lack of productive employment and strong dependence of the rural economy on agricultural products and activities (0.450). Using calculated priorities of SWOT factors could help to develop a management approach or support critical decisions. Additionally, the study results can be used for constitute of appropriate strategy alternatives for organization.

In general, arid and semi-arid regions are complex and interconnected, groundwater can be effectively managed when strategies are adapted to the appropriate spatial and temporal scales. Also, the use of AHP in establishing weights of groundwater management criteria is also a innovative contribution. When given a common set of criteria for groundwater management, water professionals agree on the most and least important criteria. In this study, the main strategies were developed using SWOT analysis, and they were ranked based on criteria including degradation and improvement of groundwater resources using the AHP model. The results show that the continuous improvement strategies such as drilling and exploitation of illegal wells, overdraft of exploitation license provisions for agricultural water wells and reduction of precipitation in degradation of groundwater resources and filling the illegal wells, greenhouse crops cultivation and installing smart water meters in the improvement of groundwater resources were ranked 1th, 2nd and 3rd, respectively. Furthermore, the AHP approach could prioritize factors or criteria at each level of the hierarchy process using the eigenvalue calculation for pairwise comparisons. The methodological framework includes the combined use of AHP and SWOT in developing groundwater resources management strategies, tallying SWOT factors, and prioritizing them with the pairwise comparison technique available with AHP. AHP-SWOT combined approach i) provides a simple, transparent and rapid decision-making process, ii) provides some insights on what can be done to enhance the groundwater management success, and iii) provides a mechanism to reach an agreement on the most important groundwater management strategy. Based on the analysis done in this research, two topics are suggested to create synergy in future research: i) Using fuzzy logic framework with the AHP method to more effectively analyze cases with uncertainty, ii) Due to the independent and hierarchical structure of AHP, groundwater resources management strategies are considered to be independent and the connections among the strategies as well as the strengths, weaknesses, opportunities and threats cannot be evaluated. In order to highlight the interaction and dependence among the strategies, the combined use of ANP (Analytic Network Process) and SWOT can be applied in future studies.

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