Sustainable Water Resources Management (2023) 9:76
https://doi.org/10.1007/s40899-023-00854-x

ORIGINAL ARTICLE

Evaluation of farmers' adaptation capacity indicators with declining groundwater levels in Kazerun plain, Iran

Mehdi Ghorbani[1] · Najmeh Ganji[1] · Hassan Khosravi[1] · Amir Alambeigi[2] · Hossein Azadi[3]

Received: 9 April 2022 / Accepted: 1 April 2023 / Published online: 22 April 2023

Abstract

The aim of this study was to measure the main indicators of farmers' adaptation capacity response to the decreasing groundwater level in the Kazerun plain, Iran. For this purpose, 10 adaptation capacity indicators including local networks, confidence in government, interaction and mutual relation, labor and time, financial and infrastructure, inventing and innovation, adopting management, riskability, governance, knowledge and information have been measured and analyzed by the second-order confirmatory factor analysis model based on the 291 samples of farmers according to Cochran's formula. The results of factor analysis, prioritization of farmers' adaptation capacity indicators to cope with groundwater depletion, showed that the most important indicators were "adaptive management" (*T*-value = 5.51), "finance and infrastructure" (*T*-value = 3.94), and "local networks" (*T*-value = 3.38). The results also showed that most of the indicators for estimating adaptation capacity have a high impact on the adaptation of local stakeholders, except for the government confidence index (average extracted variance = 0.501). The findings suggested that human capital such as farmer reciprocity should be strengthened in the studied villages to enhance farmers' adaptive capacity to drought and water crises.

Keywords Adaptation strategies · Groundwater loss · Water governance · Local communities · Rural development services

Introduction

One of the main water reservoirs in the world is groundwater resources (Yapıcıoğlu and Demir 2020). However, many natural and human factors have caused critical conditions and reduced groundwater levels in most parts of the world, including Iran (Fallahati et al. 2020; Karamidehkordi 2010). Over recent years, the lack of efficient management of water resources due to increasing demand, on the one hand, and the reduction of surface and groundwater resources, on the other hand, have upset the natural balance of groundwater resources, especially in the agricultural sector (Yazdanparast et al. 2023; Youssef et al. 2020; Mortezapour et al. 2019).

The efficient regulation of water resources involves a complex process of human–water relations (Baharlooee et al. 2021; Jackson et al. 2012) and many researches argued about the necessity of changing the management of water resources. Especially, considering the significant effects of climate change, more flexible and adaptive management of water resources is necessary to better deal with the complexities and uncertainties (Hallaj et al. 2021).

Development and implementation of adaptive management approaches requires structural changes in water management regimes (Minhas et al. 2020). The issues in water resource management have resulted in rising water tensions, exacerbated disputes, and a lack of engagement among farmers due to the agricultural sector's significant reliance on water, the rapid expansion of human societies, and the slowness of the management process (Braga 2014). Due to the effects of groundwater loss, including social, economic, and infrastructural effects, it is necessary to analyze the effects of this phenomenon from a human and environmental perspective (Cole and Browne 2015; Teo et al. 2019).

This is an important part of responding to the issue of drought and water crisis (Muthelo et al. 2019; Khosravi et al. 2021; Chikwanha et al. 2021). During the drought incident, the livelihood capital of small holder farmers will be most vulnerable (Belay et al. 2017). Agricultural community

✉ Mehdi Ghorbani
mehghorbani@ut.ac.ir

[1] Faculty of Natural Resources, University of Tehran, Karaj, Iran

[2] Faculty of Agriculture, University of Tehran, Karaj, Iran

[3] Department of Economics and Rural Development, Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium

members organize and transform assets in diverse ways to escape climate-induced "poverty traps". Nowadays, interventions from external agencies (e.g., government, non-governmental organizations and market institutions) are an important key to livelihood sustainability for many households (Rahman et al. 2018; Muthelo 2018). Droughts and water shortages can threaten food security and lead to social unrest and land redistribution. Drought has also forced farmers in many areas to sell some of their livestock in order to buy fodder for the rest (Contreras et al. 2020). One pivotal concept in both the vulnerability and resilience literatures that bridges traditions is adaptive capacity, or adaptability; meaning the ability of a system to prepare for stresses and changes in advance or adjust and respond to the effects caused by the stresses (Ghorbani et al. 2021; Afkhami et al. 2021). It is the potential for species or populations to tolerate or adapt to climate change (Ofori et al. 2017). Agricultural systems with high adaptive capacity are more able to reconfigure without significant changes in crucial functions or declines in system services. Furthermore, improving smallholder farmers' adaptive capacity to tolerate drought and water crises requires reducing vulnerability (Shojaei-Miandoragh et al. 2019). However, it is not clear to what extent farmers' levels of vulnerability influence their decision to cope or increase their adaptive capacity (Azadi et al. 2019; Matewos 2020; Muthelo et al. 2019).

Crop and livelihood diversification, seasonal climate forecasting, community-based disaster risk reduction, famine early warning systems, insurance, water storage, supplementary irrigation, and other proactive measures are among them (Haile et al. 2019). Other examples of adaptive capacity used by farmers include increased use of traditional rainwater harvesting and water conservation techniques (Mucheru-Muna et al. 2017), building shelter-belts and windbreaks to enhance rangeland resilience, monitoring the number of grazing animals and cut trees (Campisano et al. 2017; Sanchez et al. 2018), offering credit funds, and national government programs to re-create natural habitats (Mucheru-Muna et al. 2017; Al-Abadi et al. 2017).

The capacity to adapt to climate change depends on social, economic, institutional, technical, and political factors, and the specific relationship that these factors have with each other depends largely on the scale of the study. In other words, adaptive capacity is a multidimensional concept (Vincent 2007). In many studies, researchers have examined the indicators of adaptive capacity of local communities and tried to identify the factors affecting the adaptive capacity (Ghorbani and Azadi 2021; Moghfeli et al. 2021). Adaptability capacity is examined in different ways. Therefore, the important point is that the adaptive capacity of a system cannot be fixed, and it is related to the scope of socio-economic variables (Ghorbani et al. 2019; Smit and Wandel 2006). In general, users who have more knowledge and understanding of the socio-economic harms have more capacity to adapt (Marshall et al. 2013). Human conditions and natural ecosystems are assessed using environmental, economic, and social indicators all over the world. For the indicators, two types of structures have been identified: the first category measures the system's conditions, and the second category measures causal relationships (Luers et al. 2003; Quinlan et al. 2016). Many of today's indicators are a combination of the two categories above, identifying current conditions and aggravating factors (Paavola 2008).

Kazerun County has been facing a severe drought and a decline in groundwater levels over recent decades (Maleksaeidi et al. 2016; Moghim 2020). Groundwater is certainly one of the world's most important natural commodities since it is used as the main water supply for agricultural, residential and industrial purposes (Berhanu et al. 2014). This is especially the case in the Middle East and Iran because the nation is known to be an arid and semi-arid country where deserts and wilderness cover more than two-thirds of its territory (Razandi et al. 2015). Iranian farming is strongly dependent on groundwater, and agricultural practices can be dramatically impacted by any water crisis. In recent years, water shortages have been the key force affecting economic and social processes because the main engagement in the rural communities of Iran is farming. In a study, Brandt et al. (2016) defined adaptive capacity as the general institutional, systemic, and individual measures to mitigate the risks of climate change. In adaptation studies, environmental threats can become appropriate management opportunities. Nevertheless, there have been surprisingly few reviews that give a deep insight into the material, structure, and relative importance of farmers' adaptive capacity, especially in Iran. Therefore, the main aim of this study is to measure the main indicators of farmers' adaptation capacity against the decrease in groundwater level in the Kazerun plain, Iran.

Materials and methods

This study attempts to investigate the material, composition, and relative significance of the farmers' adaptive capacity indicators and to identify their attitudes by answering the following hypothesis:

1. What is the attitude of farmers toward groundwater?
2. What are the main indicators of farmers' adaptation capacity to tolerate drought?
3. How should farmers' adaptation capacity indicators be assessed?

Study area

Kazerun plain is located in Fars province in the southwest of Iran. The plain is located between latitude 37° 29 and 30° 00 N and between longitude 30° 51 and 40° 51 E (Fig. 1) with the area of 4119 km2 and its height is 800 m above sea level. This region is limited to Shiraz city from the east, Farashband city from the southeast, Bushehr province from the west and south, and Mamsani city from the north. For the present study, several villages were selected which are prone to groundwater depletion. The economy of these villages is mainly based on agriculture, and the city's agricultural and horticultural products include wheat, barley, watermelon, melon, cucumber, tomato, eggplant, onion, cotton, citrus, palm, and alfalfa.

The rainfall (mean annual) in the region is 360 mm and the agriculture in the area relies on groundwater, which has declined over the recent years due to droughts and rainfall shortages (Ganji 2018).

Conceptual framework

We examine how individuals and communities respond to the recent severe water shortages and seek to understand the influences that are relevant in forming the adaptation to declining groundwater levels (Fig. 2).

Data sampling

This study benefits from a descriptive-analytical framework and the stratified sampling was used as the sampling method. The statistical population included farmers who have been exposed to groundwater depletion, and this study attempted to investigate their adaptive capacity to drought and water crisis. In other words, the statistical population of this study consist of 1200 rural households whose economy is based on agriculture. Due to the occurrence of groundwater decline in the Kazerun plain, six villages located in the same condition, in terms of groundwater shortage and drought status, but with different economic statuses, were selected. Various factors are involved in measuring farmers' adaptation capacity (Almaden et al. 2020; Goli et al. 2020) including the sensitivity of local people to available resources and their level of awareness and understanding about natural and unnatural disasters that may be important in their adaptation to climate changes such as drought.

The sample size according to Cochran's formula (Rezaii and Izadi 2015), and considering 0.1 error, was found to be 291 (Eq. 1). The questionnaire was distributed among the rural community and was then analyzed.

$$n = \frac{NZ^2pq}{Nd^2 + pqz^2}, \tag{1}$$

where N: sample volume; d: community amount error = 0.05; $z = 1.96$; $p = q = 0.05$

Then, 50 households from each of the villages were selected to estimate their adaptation capacity.

In this study, the data were collected by a self-designed questionnaire and a quantitative questionnaire was designed as the main research tool to answer the research questions and achieve the study's goals. The

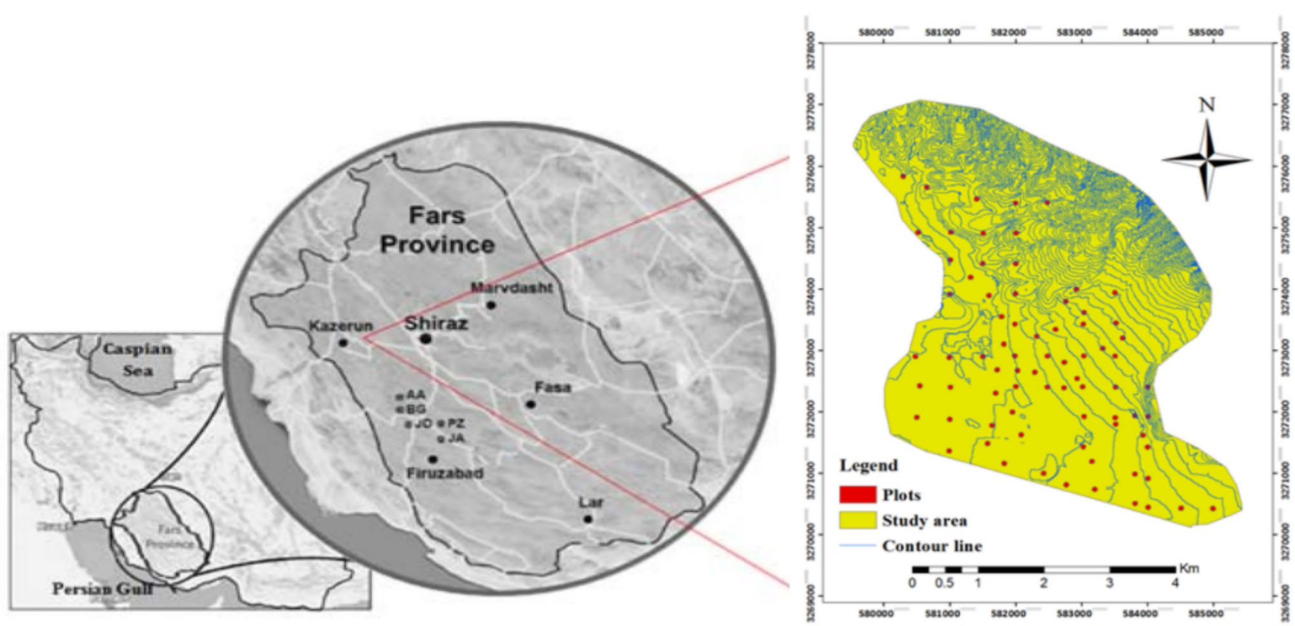


Fig. 1 Location of the study site in Iran

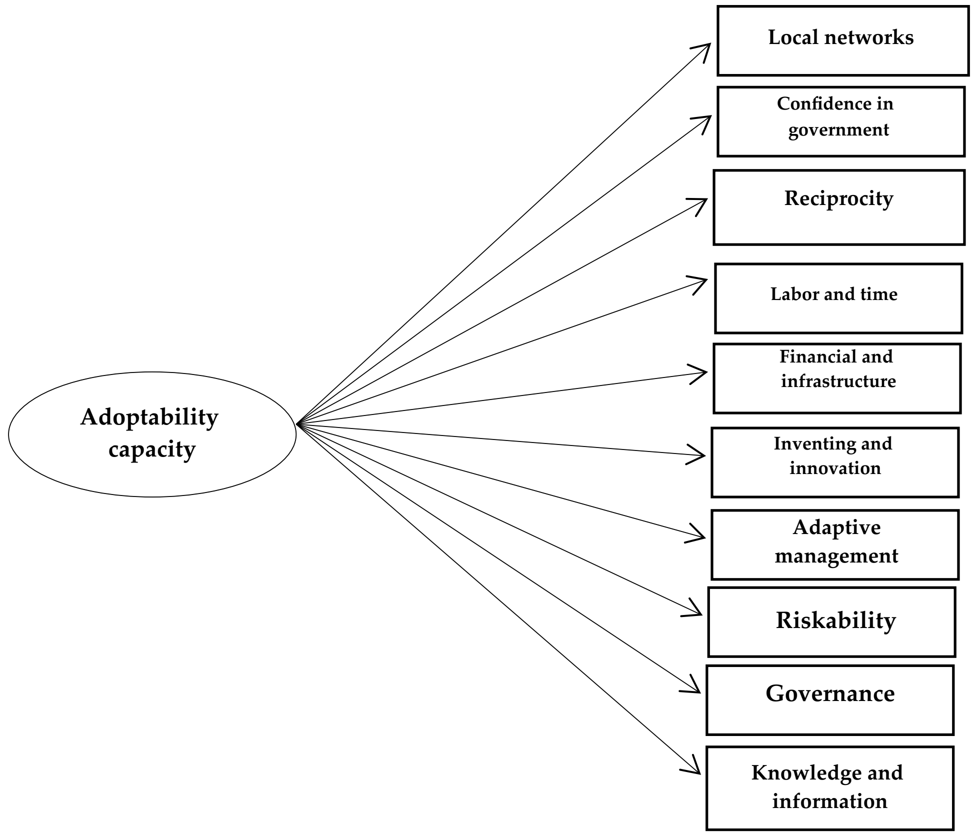


Fig. 2 Research conceptual model

initial questionnaire was prepared based on a review of resources and after field visits and corrections, the questionnaire of adaptive capacity was prepared in 10 categories (Lockwood et al. 2015), which included 3 questions (30 questions in total).

It is worth noting that various factors are involved in measuring the adaptation capacity of the farmers in this area. One of the factors that has been the criterion for the selection is the sensitivity of local people to the climatic stresses and their level of awareness and understanding about natural and unnatural disasters. The statistical population had the same experience in terms of groundwater shortage and drought situation. They were aware of these crises and had a high sensitivity to solve the problems caused by water shortage. Therefore, the subjects are almost homogeneous and have almost the same capacity for adaptation due to being in similar conditions. Therefore, the findings of this study can provide sufficient credibility and trust and will be able to be generalized to the whole community. To investigate the reliability of the compatibility capacity questionnaire, the combined reliability method was used, and to study its validity, the diagnostic validity method was considered by calculating the average extracted variance.

Data analysis

For data processing, the second-order confirmatory factor analysis model was used in the form of structural equation modeling. The second-order factor model is implemented when the first-order factors are explained by the higher-order factor form Coulacoglou and Saklofske (2017).

Reliability and validity of the questionnaire

To determine the face validity of the questionnaire, the expert including the researchers and agricultural organization panel's opinions were used. After applying the necessary corrections in the questionnaire, the validity of the questions was confirmed by the panel. In this regard, Cronbach's initial test and alpha coefficient were applied for testing the reliability of the questionnaire. In the first visit for the initial test of the questionnaire, 30 rural people were randomly interviewed in two villages (Fig. 5). The alpha parameter was estimated at 0.76, and it was determined that the questionnaire has the necessary reliability and standard (Table 5).

To investigate the validity of the questionnaire structure, both convergent validity and diagnostic validity indices were used, which are based on the average extracted variance (AVE). To determine the validity of the structure, the adaptive capacity indicators and the average extracted variance index were used (Gefen 2000). This index shows what percentage of the variance of the studied structure has been affected by its indicators, and researchers consider a *T*-value of 0.5 and above for the suitability of this index (Table 1). The overall research process is shown in Fig. 6.

Results

Validation of the research model (confirmatory measurement or analysis model)

Confirmatory factor analysis (CFA) has been used to validate the questionnaire. In this way, the operating load of each indicator with its structure has a *T*-value higher than 1.96. In this case, this indicator has the required validity to measure the specific latent structure or attribute. Therefore, to investigate to what extent each structure of the research model was consistent with the selected indicators for measuring them, a confirmative component analysis was used. This model was implemented by SPSS and LISREL software packages, and its marker relationships were drawn. Based on the results of the initial model, the markers next to each other correctly confirmed the relevant structures because the present model has been properly implemented using the confirmatory factor analysis method (Fig. 3).

Secondary factor analysis results

According to the results of Table 2, the research model has a good fit and the model shows the measurement of adaptive capacity factors in relation to groundwater loss in the Kazerun plain (Fig. 5). According to the LISREL output, the calculated X^2 value is 1.00671. The low level of this indicator indicates a slight difference among the findings, which indicates that the fit is appropriate.

Table 1 Combined reliability value of the research variables

Latent variables	Combined reliability	Average extracted variance
Local networks	0.891	0.680
Confidence in government	0.815	0.501
Interaction and mutual relation	0.840	0.610
Labor and time	0.869	0.580
Financial and infrastructure	0.857	0.501
Inventing and innovation	0.801	0.610
Adopting management	0.892	0.705
Riskability	0.789	0.501
Governance	0.913	0.710
Knowledge and information	0.824	0.610

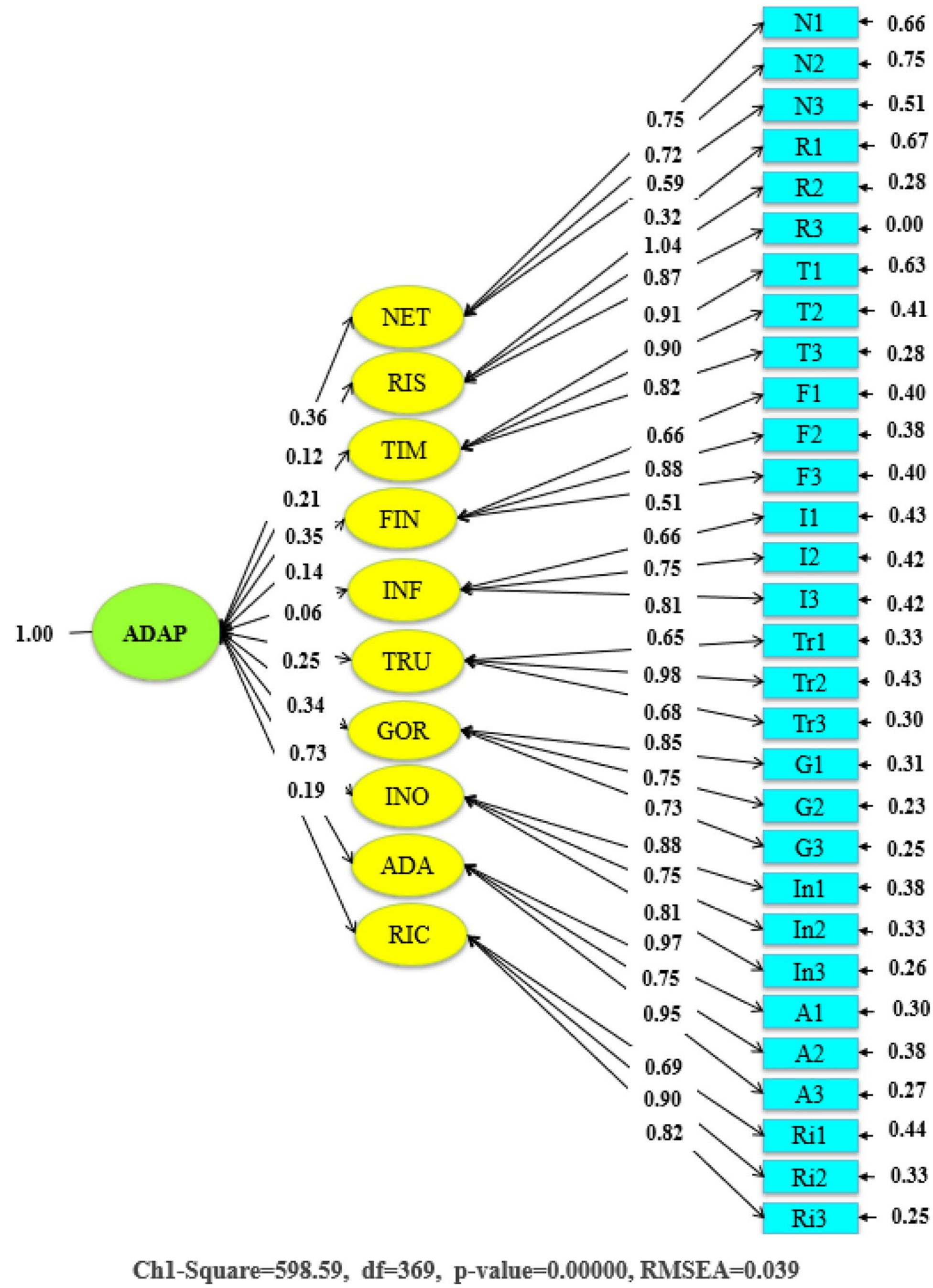
Based on the findings of the model, it is possible to determine the appropriateness of the researcher's chosen questions to measure the structures and discard the irrelevant questions belonging to the more precise structure than the original model. In addition to the goodness of fit index (GFI), the *T*-value of the second root of the RMSEA approximation error variance estimate is 0.039, which is acceptable (Wiktorowicz 2016). Therefore, the estimated parameters can be statistically confirmed and used to make the indicators compatible with the studied structures. The comparative fit indicators all show the model's excellent fit (Fig. 4). It is also a measure of the absolute decay *T*-values, i.e., the measurement of the relative *T*-value of the variances and correlations, which is justifiably justified by the model. The closer it is to the *T*-value, the better the data fit the model (Wiktorowicz 2016). The absolute fit values in this study are 0.93 and 0.91, which are appropriate. The markers next to each other apparently confirmed their respective structures according to the research's intended structure because the present model has been properly implemented using the confirmatory factor analysis method, and no significant interference is observed.

Since the *T*-value of second root estimation of RMSEA approximation error variable for the modified model was 0.039, it is therefore possible to make decisions based on the findings of the model on the suitability of the research's selected questions. The estimated parameters in the model are statistically acceptable and the indicators are consistent with the studied structures. The output also shows the significant part of the coefficients and the obtained parameters of the compatibility capacity measurement model. If the significance number is greater than 1.96 or less than −1.96, the relationship in the research model will be significant (Surastina and Dedi 2018). Meanwhile, the calculated *T*-values for each of the factor loads of the indicators (along with its latent structure or variable) are above 1.96, so the questions were appropriate to measure the adaptive capacity of the farmers. In fact, the results show that the relationships between the structures and the latent variables are significant and the model has a good fit; thus, all the assumptions are confirmed (Table 3).

To show to what extent these obtained *T*-values correspond to the realities of the model, the fitness indices were studied. Furthermore, it is possible to decide on the importance of each of the indicators according to the factor loads in each of the dimensions (Table 4).

To evaluate the confirmatory factor analysis model, the mean of RMR residual averaging, GFI index, NFI softening

Fig. 3 Model of adaptive capacity measurement in standard mode (second-order factor analysis)



index, NNFI softening index, IFI index, CFI index, and the second root of the RMSEA approximation error variance estimate have been used. The reported GFI value for this model is 0.93, which is near to a reasonable model fit with more details. The second average residual square root of the RMR value (0.06) in this study (which is closer to zero) indicates the proper explanation of covariance. The value of SRMR is 0.036, which is smaller than 0.05 and is more practical to model the data (Surastina and Dedi 2018). To analyze how well a particular model performs relative to other potential models in terms of describing the data collection observed, the values of the softened softness index (NFI), the non-softened drop index (NNFI), the increasing drop index (IFI), and the adaptive decline index (CFI) are used. High values of 0.9 in these indicators show a very

Table 2 Models of fit of the model of measurement of adaptive capacity to the groundwater level depletion (modified model)

Indexing of indicators	Index	The value of the reported index	Acceptable level
Absolute fit indicators	GFI	0.93	More than 90.0
	AGF	0.92	More than 90.0
Comparative fit indicators	NNFI	0.97	More than 90.0
	NFI	0.91	More than 90.0
	CFI	0.99	More than 90.0
	IFI	0.99	More than 90.0
Suitable fit indicators	PNFI	0.77	More than 50.0
	RMSEA	0.039	Less than 0.08
	X^2/df	1.00671	Less than 3

good fit of the model. Furthermore, the RMSEA index in the model was 0.41, which indicates that the model fits well).

The data of this study are well suited to the factor structure and theoretical foundation of the research, and this indicates that the questions are consistent with the desired structures (Tables 4, 5). In this study, farmers' adaptive capacity indicators were validated in the face of groundwater depletion in the Kazerun plain. According to the information obtained from the structural model of the LISREL software, most of the indicators considered in this study to estimate the adaptive capacity have a very high impact on the adaptive capacity of local operators. Compatibility capacity indicators, in the order of their effectiveness, are as follows.

(1) Adaptive management indicators; (2) local area networks; (3) farmers' initiative and innovation; (4) financial ability and rural infrastructure; (5) governance, labor, and time; (6) interaction between farmers; (7) farmers' information and awareness; (8) farmers' risk-taking; and (9) trust in government.

One of the most effective approaches to the shared resource management is a compatibility-based participatory management. Local networks are the second priority, showing that local farmers in the Kazerun plain are able to operate in groups and engage in efficient groundwater management, and that the human and social aspects are critical in enhancing farmers' adaptive capacity, which is consistent with the effective. Human capital, led by physical, social, financial, and natural capital, is closely linked to adaptive capability, according to the findings. Furthermore, farmers' initiative and innovation were the third priority, and financial capability and infrastructure indicators are the fourth priority. Based on the results, water resources governance was ranked fifth, and the farmers' interaction and interaction index were ranked sixth. Whereas, the labor and time indices are the seventh priority and farmers' information and awareness were the eighth priority.

According to the flinging, farmers' risk index and GCI in the Kazerun plain have the least effect on the adaptive capacity of the local farmers. Moreover, an agricultural risk index was built based on modeled data on the estimated losses of chosen farm activities.

Discussion

Adaptive management index

According to the findings, the main adaptive management coping strategies include adaptive management indicators, local area networks, farmers' initiative and innovation, financial ability and rural infrastructure, governance, labor and time, interaction between farmers, farmers' information and awareness, farmers' risk-taking, and trust in government. Overall, the main barriers to farmers' capacity to adapt to groundwater depletion are weak management, lack of financial and physical resources, information and education, strong communication between social networks at the village level, and farmers' lack of trust in government networks. It should be noted that limited physical resources, communication tools, and logistics facilities often limit the farmers' activities at the farm level. On the other hand, the lack of support from the public sector may be due to the limited budget for climate risk management. These results are consistent with and confirmed by the findings of Abid et al. (2015) and Khan et al. (2020).

Adaptive management coping strategies were given the first priority, showing that consistent management and development of groundwater resources to achieve sustainable agriculture in areas facing water shortages are necessary. These results are also consistent with the findings of Tringali et al. (2017) and Azemzi and Erraoui (2021). As shown by Ausiku et al. (2020), water and nitrogen adaptive management can improve crop performance and enhance sustainable agriculture. Other similar studies (Bodin and Prell 2011; Ghorbani 2018) suggest that one of the most effective approaches to manage shared resources, including water resources, is a compatibility-based participatory management approach that is consistent with the results of the present study. According to Tang et al. (2020), the participatory management approach is positively associated with a high level of adaptive capacity. This approach is based on involving farmers in decision-making, problem-solving, and empowerment, as well as supporting their high autonomy, initiative, and creativity. According to Azarnivand et al. (2015), human capital management and the promotion of stakeholder participation are necessary prerequisites for developing practical strategies to support sustainable groundwater management. It is also a robust tool for decision-making in comprehensive water problems.

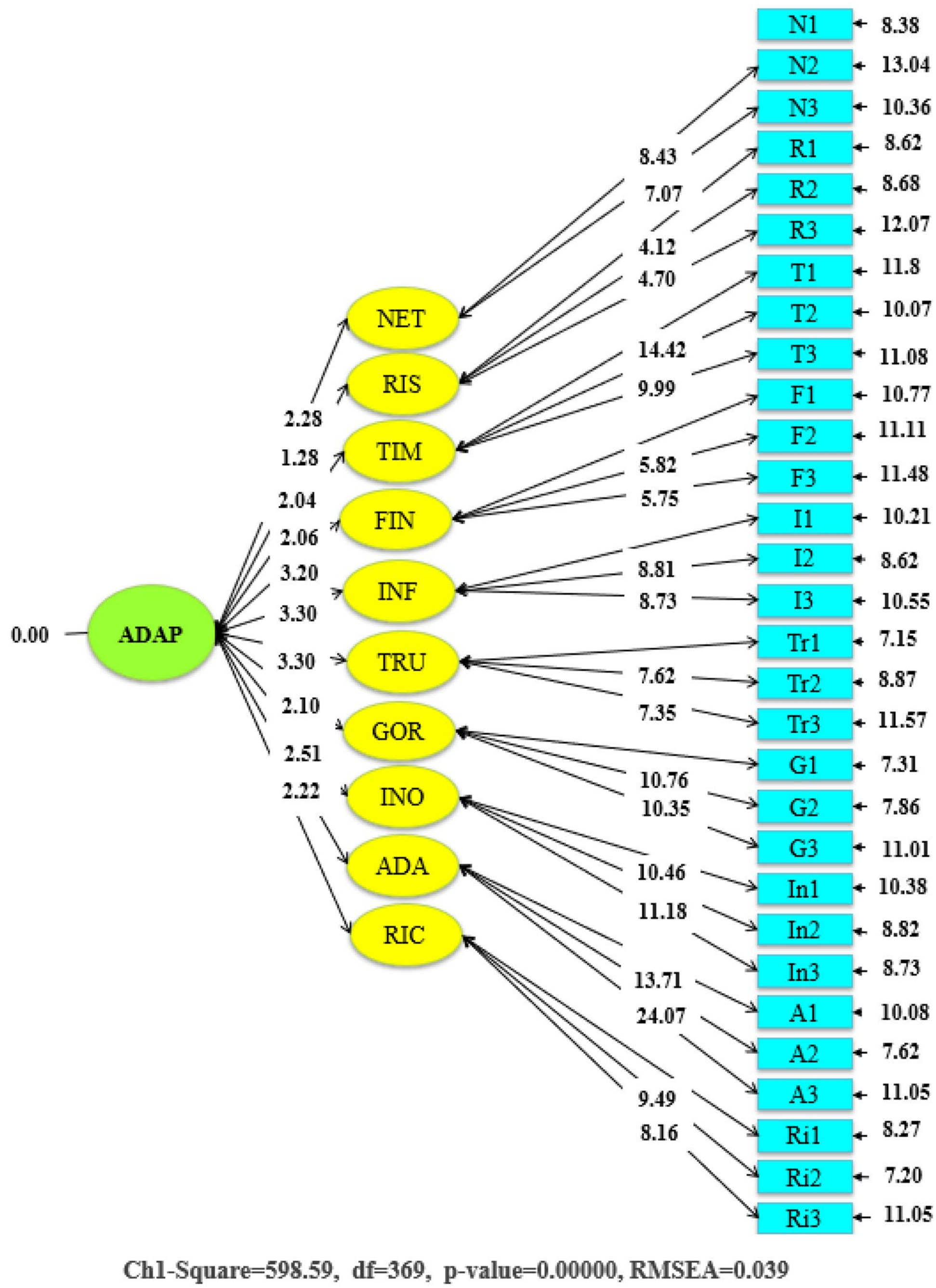


Fig. 4 Compatibility capacity measuring model in meaningful state (factor analysis of the second order)

Local networks

Local networks are the second priority, indicating that in the Kazerun plain, local farmers are willing to work in groups and participate in the optimal management of groundwater, and the human and social dimensions are very important in improving farmers' adaptive capacity. It can be especially useful for effective grassroots engagement in monitoring, managing and recharging groundwater as a common water resource (Jadeja et al. 2018). Group management by municipal joint action is a method of reacting successfully to critical groundwater management challenges. It can also create adequate confidence for members to agree with discussing and ultimately introducing new opportunities for the use and control of water sources. The results showed that human capital is most closely related to adaptive capacity, followed by physical, social, financial, and natural capital. Our findings are in line with existing studies, such as Ghorbani et al. (2022);

Table 3 Prioritization of farmers' adaptation capacity indicators in the face of groundwater decline

Rank	Second-order variable measurement	ƛ	T	sig
1	Adaptive management	0.73	5.51	0.1
2	Local networks	0.36	3.38	0.1
3	Financial and infrastructure	0.35	3.94	0.1
4	Creation and innovation	0.34	3.20	0.1
5	Governance	0.25	2.29	0.1
6	Labor and time	0.21	0.21	0.1
7	Reciprocity	0.19	1.84	0.1
8	Knowledge and information	0.14	1.60	0.1
9	Riskability	0.12	1.28	0.1
10	Trust in government	0.06	0.61	0.1

Table 4 Results of the second-order variable measurement model

Variable	Symbol	Factor loading	T	Status
Local networks	Net1	0.75	–	–
	Net2	0.73	8.43	Accepted
	Net3	0.59	8.50	Accepted
Trust in government	Tr1	0.65	–	–
	Tr2	0.98	7.68	Accepted
	Tr3	0.68	8.16	Accepted
Reciprocity	RI1	0.69	–	–
	RI2	0.90	9.49	Accepted
	RI3	0.82	8.16	Accepted
Labor and time	TI1	0.91	–	–
	TI2	0.90	14.42	Accepted
	TI3	0.82	9.99	Accepted
Governance	GO1	0.85	–	–
	GO2	0.75	10.76	Accepted
	GO3	0.73	10.35	Accepted
Creation and innovation	IN1	0.88	–	–
	IN2	0.75	10.46	Accepted
	IN3	0.81	11.18	Accepted
Financial and infrastructure	FI1	0.66	–	–
	FI2	0.88	5.82	Accepted
	FI3	0.51	5.75	Accepted
Adaptive management	AD1	0.91	–	–
	AD2	0.75	13.71	Accepted
	AD3	0.95	12.44	Accepted
Riskability	Ri1	0.32	–	–
	Ri2	0.39	5.44	Accepted
	Ri3	0.87	4.70	Accepted
	RI3	0.13	3.70	Accepted
Knowledge and information	IN1	0.66	–	–
	IN2	0.82	8.81	Accepted
	IN3	0.86	8.73	Accepted

Shalsi et al. (2019) and Velis et al. (2017), and are confirmed by them.

Farmers' initiative and innovation

Farmers' initiative and innovation were the third priority, showing that in the study area, farmers welcome new ideas and advanced technology in the field of agriculture which means the index is very important in measuring adaptive capacity. Furthermore, Mousavi (2017), by measuring adaptation capacity in Neishabour plain, Iran, concluded that the indicators of initiative and localization of local stakeholders and financial ability of farmers have the greatest impact on measuring adaptive capacity, while farmers' risk-taking has the least effect on adaptive capacity. Brown et al. (2010) found that in rural Australian communities, the greatest weakness for rural adaptive capacity is the lack of information and technology, and this should be reinforced in rural Australian communities. According to Cinner et al. (2018), creativity is directly related to innovation capability and partly connected to population size, income level, and educational backgrounds of water decision-makers. The visualizations also show that some cities have excess capacity for adaptation, while others have been able to turn capacity into water management innovations more efficiently. Monitoring the success and failure of water governance in social groups allows citizens and planners to learn how to adapt water infrastructure for long-term sustainability.

Financial capability and infrastructure

Financial capability and infrastructure indicators are the fourth priority and must be carefully planned because they play an important role in quick and timely reactions to preserve local communities. In rural areas, natural, economic, and social phenomena are generally closely related, and any disruption of natural capital will lead to economic turmoil in the countryside because poor, illiterate, and elderly communities are less able to adapt (Campbell et al. 2001). Salam et al. (2021) show that one way to improve current adaptive capacity constructs is to explicitly account for the adaptive capacity of economic systems. Scale, diversity, the relative mix of the private and public sectors, innovation, organizational/managerial capital, substitutability of inputs, factor mobility, asset liquidity, and other characteristics of economic systems will influence their ability to adapt.

Water resources governance

In the present study, water resources governance was ranked fifth. Therefore, to improve adaptive capacity, it is important to implement proper management of groundwater resources. In such a way, governmental and non-governmental farmers' associations and local communities should share a common vision and act in parallel. In fact, the goal of water governance is to achieve participatory management of water management with a view to preserving the conditions of the environment and, at the same time, gaining social and economic gains. Accordingly, to achieve sustainable water resource management, participatory governance and management approach must be developed (Lockwood et al. 2015; Rejeski and Michelson 2014; Reed 2008). These results are also consistent with the findings of the research of Rahimi et al (2022) at the basin in Iran with water crisis challenges. They stated that this region has a weak and unstable structure of the water governance network and as a result, it has low level of collaboration and coordination among the institutions and high power centralization. Salari et al. (2015) by using the analysis of the network of social ties of trust and the participation of local stakeholders in Kermanshah city of Iran, conclude that the weakness of social capital and the lack of unity in the studied area reduce the speed of circulation of trust and participation and as a result good governance of water resources has been challenged. Also, in the results obtained by Ghorbani et al. (2015) in the analysis of the social network of local stakeholders in the action plan of cooperative management of water resources in the Latian watershed of Iran, they point out that cohesion and high social capital among local stakeholders is one of the requirements of the action plan. Participatory management of water resources is aimed at achieving water security and sustainable development. Sehrsweeney (2021) found that adaptive capacity was shaped by four socio-political conditions including political and legal power, institutional support, and the extent of protected land. Recent research also shows that adaptation capacity, in addition to technological advancement and economic development, depends on social factors such as social capital and government structure (Adger et al. 2003; Smith et al. 2011; Brooks and Adger 2005).

Farmers' interaction and interaction

In this study, the farmers' interaction and interaction index were ranked sixth, so it is suggested that human capital such as farmer reciprocity should be strengthened in the studied villages to enhance farmers' adaptive capacity to drought and water crisis. The desire to work in groups and participate among farmers can pave the way for economic movements to village development. In this regard, encouraging operators and stakeholders to participate in participatory activities can be the key to resolve water disputes in each region (Verburg et al. 2013).

The labor and time indices are the seventh priority, so it is critical for farmers to improve their adaptive capacity when spending efficient time and energy on groundwater management practices. Farmers' awareness were the eighth priority, which should be strengthened in the study area. Operators who have more knowledge and understanding about the upcoming crisis also have more capacity to adapt. Therefore, it is important to conduct training and extension classes relevant to the optimal use of water resources among operators to provide them with the necessary knowledge. There should be more access to available resources, proper crop cultivation, and other issues, and it can make timely and appropriate decision-making possible. Emphasizing capacity building through educational and promotional tools can also be effective. Furthermore, farmers' knowledge will play an important role in increasing their adaptation capacity. Therefore, we should try to increase the adaptation of farmers while providing proper training, familiarizing them with new global technologies, and combining indigenous knowledge and modern sciences. Nowadays, many regions in Iran, and even in the world, face the problem of lack of surface and groundwater and the management of these valuable resources (Jafary and Bradley 2018). Therefore, the findings of this research can help planners to provide better solutions for water resources management and increase the adaptive capacity of farmers in Iran and other parts of the world.

Farmers' risk and government confidence

Farmers' risk index and GCI in the Kazerun plain have the least impact on the adaptive capacity of local farmers. There is a growing understanding of the detrimental impacts of farming activities on the quality of microbial water, contributing to improved demands for farmers to mitigate environmental impacts on water quality (Mucheru-Muna et al. 2017). Farmers also need a mechanism to help them prioritize conservation steps aimed at reducing fecal pollution of surface water. An agricultural risk index was built based on modeled data on the estimated losses of chosen farm activities. This solution to the farm risk index can be integrated into current decision support tools to help farmers control the effect of their farming activities on water (Benbrook and Davis 2020). The GCI shows that the ideals of the government, such as high standards of transparency, justice, and systemic accountability, are good predictors of public confidence. Similarly, the competence of the government (its responsiveness and effectiveness in providing public services and addressing emerging demands) is critical to raising confidence in the institutions (Xiao et al. 2020).

According to the results in the studied villages, farmers have little confidence in government experts and believe that government agencies often do not take appropriate actions, and the government does not provide sufficient facilities and loans, as well as agricultural insurance. Therefore, this index cannot be considered as a positive factor in strengthening the adaptive capacity because it has the lowest value among the ten indicators. Accordingly, in this plain, farmers may be vulnerable to groundwater depletion. This result shows that the government should look for rational solutions in areas that are facing water shortages and are prone to drought and try to manage water resources with proper planning. In general, adaptive capacity in the face of declining groundwater aquifers is a multidimensional phenomenon. Analysis of the adaptive capacity of social systems is a scientific measure to provide appropriate information infrastructure due to the occurrence of natural hazards. Therefore, analyzing and explaining the adaptive capacity by providing the appropriate information for adjustment and control can directly affect the degree and extent of damage caused by the accident and prevent its transformation into a catastrophe (Ranjbar et al. 2013).

Furthermore, by creating new job opportunities in the studied villages and structural and institutional coordination in the distribution of tasks related to compatibility in the agricultural sector between related agencies and ministries, it is possible to increase farmers' adaptive capacity to natural hazards. In addition, one of the most successful approaches in natural resource management is the adaptive participatory management approach. Social capital is one of the most important criteria for establishing participatory management based on compatibility. However, in rural areas, social interaction is high and networks of agriculture and water governance have a significant weight that is very effective in strengthening the adaptive capacity of social systems, therefore, social capital (i.e., participation in underground water resources exploitation mechanisms) is the most important and fundamental factor. The criterion for improving the adaptive capacity of the social system in the face of threats is the biological environment, including the decline in groundwater and arid waters. The approach also emphasizes the involvement of local stakeholders in the decision-making, planning, and implementation of management projects in each region according to its specific social and ecological context (Bodin and Prell 2011; Ghorbani 2018).

Conclusion and implication

The results showed that most of the indicators to estimate adaptation capacity have a very high impact on the adaptation of local stakeholders, with the exception of the GCI. The findings also show that most farmers in the Kazerun plain are looking for consistent management of groundwater depletion, which is important for policymakers and rural development service providers.

Farmers who have more knowledge and understanding of the upcoming crisis in this case have more capacity to adapt. Also, local farmers are willing to work in groups and participate in the optimal management of groundwater, and the human and social dimensions are very important in improving farmers' adaptive capacity, so it is suggested that in the villages under study, human capital, which includes reciprocity between farmers, be strengthened to protect the village from dangers.

In addition, programmatic changes that enable farming populations to improve the productivity of agricultural water and energy usage must be introduced with the ultimate aim of mitigating the drop in the groundwater table and/or restoring the aquifer water balance in the Kazerun plain. Such reforms include the facilitation of agricultural sector transformation through technology transfer and extension projects, as well as the implementation of supplementary policies and regulations to enhance the control and management of groundwater through a stronger system of governance. Failure to do so would intensify the adverse effects on freshwater supplies in the region and will result in the loss of multiple agricultural jobs in the future as a result of excessive groundwater stress and depletion in vulnerable areas. Finally, based on the results, the following suggestions are presented:

- Training and extension classes related to the issue of optimal use of water resources among operators be held so that in case of a crisis, the necessary knowledge is provided.
- Increasing farmers' technical knowledge as is crucial in increasing their adaptation capacity at the farm level.
- Availability of rural development services is essential.
- There is an urgent need to provide physical infrastructure to meet the needs of farmers. It is recommended that the government establishes irrigation consulting services, purchases farm wells, determines serious restrictions on harvesting wells and irrigated agricultural areas, exchanges treated wastewater with groundwater, and considers measures to increase the efficiency of urban and industrial water use for better water management.
- Strengthening social interactions between local networks in rural areas is essential for better management of water resources. The government plays a key role in building social capital.
- Irrigation management strategies must also focus on the role of local networks in better water resource sharing,

sustainable policies, and the protection and improvement of livelihoods, including human capital.

- It is also emphasized to hold regional and international training workshops for leading farmers, in order to increase new knowledge and transfer it to other farmers.
- Granting of financial and technical assistance by international organizations be considered in order to increase the adaptive capacity of farmers in water resources management with an emphasis on supporting developing countries.

This paper contributed to evaluating the farmers' attitudes toward groundwater and investigated the content, structure, and relative importance of farmers' adaptive capacity indicators which is crucial for policymakers, planners, and rural development service providers and will lead to the identification and enhancement of adaptation capacities among rural communities. Many of the problems and challenges that water supply managers and planners are encountering with these days are close to those that managers and planners faced with in the past. Most of the recent ones are the outcomes of two trends: (a) an increased awareness of the necessity for a bottom-up participation approach to non-governance planning and politics, decision-making and management, and (b) an increasing concern about protecting the environments.

In general, it can be said that the inter-sectoral cooperation of the networks of all related institutions to control and manage water resources in Kazerun plain can increases productivity. In this regard, public acceptance and society's attention to natural resource protection approaches are essential for its implementation. Thus, we presented a range of adaptation categories to inform future research, compare adaptation capacity elsewhere, and assist policymakers in designing effective policy measures.

Appendix

Figures 5, 6 and Tables 5, 6.

Fig. 5 Field interviews with farmers

Fig. 6 Research process

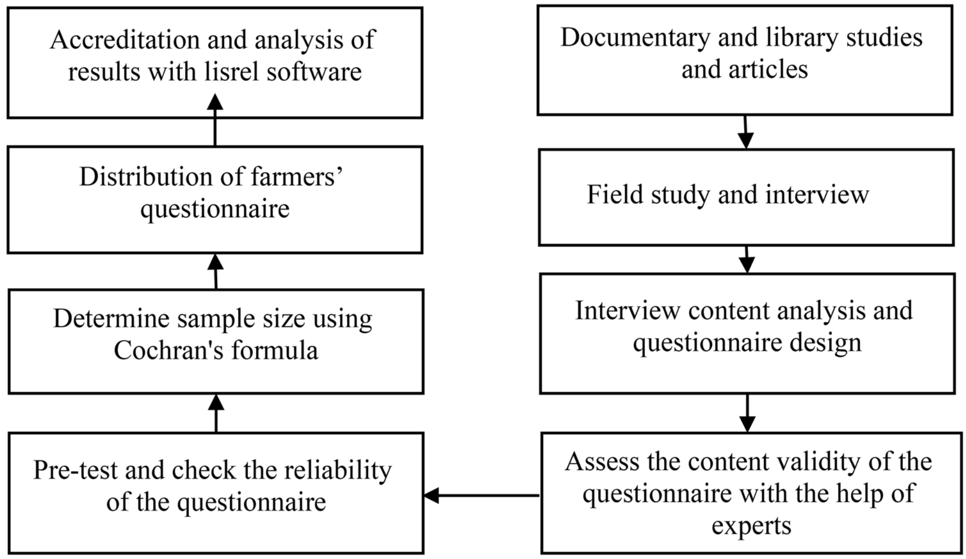


Table 5 Cronbach's alpha value of the research variables

Dimension	Items	Cronbach alpha
Local networks	As a result of connecting with local groups, I have a greater ability to achieve optimal groundwater consumption	0.76
	As a result of connecting with local groups, I better understand that social, economic, and environmental factors affect my interests	
	As a result of connecting with local groups, I can better understand how my irrigation system affects groundwater	
Trust the government	As a result of communication with local groups, more trust is established in government experts (institutional trust)	0.71
	To control groundwater levels, I believe it is possible to trust government agencies that often do the right activities	
	To control groundwater levels, I believe it is wrong to partner with government programs because they are constantly changing	
Reciprocity	I feel responsible for helping the community in which I live	0.73
	If there is a serious problem in this society, people should unite to solve it	
	The people in this village generally support each other	
Labor and time	I have enough time to manage groundwater in the area	0.83
	I don't have free time and I can't really help with water issues in the area	
	Although I don't have much time, water management in the village is a priority for me	
Finance and infrastructure	Due to financial difficulties, it is difficult for me to decide on irrigation issues	0.86
	I'm interested in experiencing new things, but it's hard to find money to do them	
	I have the equipment and infrastructure needed to manage irrigation methods	
Innovation	I don't like to experiment with new things	0.85
	It is important for me to be aware of new technologies and methods	
	I welcome new ideas for new irrigation methods	
Adaptive management	I have properly planned for optimal groundwater management	0.79
	In my mind, I can imagine how I could get where I want to manage my farm	
	I use my past experiences for the future	
Riskability	I can take risks and use new ideas and new technology	0.83
	I am able to manage environmental hazards	
	I am able to manage economic risks	

Table 5 (contined)

Dimension	Items	Cronbach alpha
Governance	I believe that the government's environmental programs are fair to everyone in terms of the use of groundwater (wells)	0.84
	I believe I have the opportunity to make decisions about the government's environmental programs	
	I believe that the government has cooperated well in the insurance sector of agricultural products	
	I believe that there is good coordination between governmental and non-governmental organizations and local groups	
Knowledge and information	Over the past 5 years, have you used newspapers related to the optimal use of groundwater in agriculture? And how useful was that information?	0.70
	Have you used the recommendations of a consultant or water resources expert in the last 5 years? And how useful was the information?	
	Have you participated in training workshops related to modern agricultural methods during the last 5 years? And how useful was the information?	

Table 6 Latent variables of farmers' adaptation capacity to cope with groundwater depletion

Latent variables	Local networks	Reciprocity	Financial and infrastructure	Adaptive management	Information
Measurement model variables					
Symbol	NET	RIC	FIN	ADAP	INF
Latent variables	Trust in government	Labor and time	Creation and innovation	Riskability	Governance
Symbol	TR	TIM	INNO	RISK	GOV

Funding This study received no findings from any organizations.

Availability of data and materials Raw data were generated at University of Tehran. We confirm that the data, models, or methodology used in the research are proprietary, and derived data supporting the findings of this study are available from the first author on request.

Declarations

Conflict of interest We have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abid M, Scheffran J, Schneider UA, Ashfaq M (2015) 'Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab Province, Pakistan. Earth Syst Dyn 6:225–243

Adger WN, Huq S, Brown K, Conwa D, Hulme M (2003) Adaptation to climate change in the developing world. Prog Dev Stud 3(3):179–195

Afkhami M, Ghorbani M, Zahraee B, Azadi H (2021) Role of social network measurements in improving adaptive capacity: the case of agricultural water users in rural areas of western Iran. J Soc Nat Res 34(7):1–20

Al-Abadi AM, Shahid S, Ghalib HB, Handhal AM (2017) A GIS-based integrated fuzzy logic and analytic hierarchy process model for assessing water-harvesting zones in Northeastern Maysan Governorate, Iraq. Arab J Sci Eng 42(6):2487–2499

Almaden CRC, Diep TT, Rola AC et al (2020) Factors influencing measure-based adaptation of rice farmers for slow-onset hazard: the case of saltwater inundation in the Philippines and Vietnam. Environ Manag 66: 629–643

Ausiku AP, Annandale JG, Steyn JM, Sanewe AJ (2020) Improving Pearl Millet (*Pennisetum glaucum*) productivity through adaptive management of water and nitrogen. Water 12(2):422

Azadi Y, Yazdanpanah M, Mahmoudi H (2019) 'Understanding smallholder farmers' adaptation behaviors through climate change beliefs, risk perception, trust, and psychological distance: evidence from wheat growers in Iran. J Environ Manag 250:109456

Azarnivand A, Hashemi-Madani FS, Banihabib ME (2015) Extended fuzzy analytic hierarchy process approach in water and environmental management (case study: Lake Urmia Basin, Iran). Environ Earth Sci 73:13–26

Azemzi H, Erraoui EH (2021) Irrigation water management and collective action: understanding the shift from community management to participatory management in Souss-Massa (Morocco). Euromediterr J Environ Integr 6(1):1

Baharlooee D, Zohrabi N, Shabanlou S, Saremi A (2021) Climate change impact on optimal reservoir operation and agricultural water allocation. Int J Global Warm 23(3):296–310

Belay A, Recha JW, Woldeamanuel T, Morton JF (2017) Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agric Food Sec 6(1):1–13

Benbrook CM, Davis DR (2020) The dietary risk index system: a tool to track pesticide dietary risks. Environ Health 19(103):1

Berhanu B, Seleshi Y, Melesse A (2014) Surface water and groundwater resources of ethiopia: potentials and challenges of water resources development. https://doi.org/10.1007/978-3-319-02720-36

Bodin O, Prell C (2011) Social network in natural resources management. Cambridge University Press, Cambridge, p 560

Brandt L, Lewis AD, Fahey R, Scott L, Darling L, Swanston C (2016) A framework for adapting urban forests to climate change. Environ Sci Policy 66:393–402

Brooks N, Adger WN (2005) Assessing and enhancing adaptive capacity. Adaptation policy frameworks for climate change. Dev Strat Polic Meas 2005:165–181
Brown PR, Nelson R, Jacobs B, Kokic P, Tracey J, Ahmed M, DeVoil P (2010) Enabling natural resource managers to self-assess their adaptive capacity. Agric Sys 103:562–568
Campbell B, Sayer AJ, Frost P, Vermeulen S, Pérez RM, Cunningham A, Prabhu R (2001) Assessing the performance of natural resources systems. Ecol Soc 5:267–292
Campisano A, Butler D, Ward S, Burns MJ, Friedler E, DeBusk K, Han M (2017) Urban rainwater harvesting systems: research, implementation and future perspectives. Water Res 115:195–209
Chikwanha OC, Mupfiga S, Olagbegi BR, Katiyatiya CL, Molotsi AH, Abiodun BJ, Mapiye C (2021) Impact of water scarcity on dryland sheep meat production and quality: key recovery and resilience strategies. J Arid Environ 190:104511
Cinner JE, Adger WN, Allison EH, Barnes ML, Brown K, Cohen PJ, Morrison TH (2018) Building adaptive capacity to climate change in tropical coastal communities. Nat Clim Change 8(2):117–123
Cole S, Browne M (2015) Tourism and water inequity in bali: a social-ecological systems analysis. Hum Ecol 43:439–450
Contreras D, Voets A, Junghardt J, Bhamidipati S, Contreras S (2020) The drivers of child mortality during the 2012–2016 drought in La Guajira, Colombia. Int J Disast Risk Sci 11(1):87–104
Coulacoglou C, Saklofske DH (2017) Chapter 4—Advances in latent variable measurement modeling. Psychomet Psychol Assess Princ Appl 2017:67–88
Fallahati A, Soleimani H, Alimohammadi M et al (2020) Impacts of drought phenomenon on the chemical quality of groundwater resources in the central part of Iran-application of GIS technique. Environ Monit Assess 192(64):1
Ganji N (2018) Presenting an optimal groundwater use model by integrating humanenvironmental systems to combat desertification (Case Study: Kazeroon plain-Fars province). MSc thesis. University of Tehran, Tehran, Iran, p 133 (**in Persian**)
Ghorbani M, Azadi A (2021) A social-relational approach for analyzing trust and collaboration networks as preconditions for rangeland co-management. Rang Ecol Manag 75:170–184
Ghorbani M, Taghipour M, Khalighi Sigaroudi S, Alambeygi A (2019) Assessing and prioritizing the components of the capacity of local communities in the face of climate change (Study area: Gonabad city). J Range Water 72:543–556 (**in Persian**)
Ghorbani M, Javadi A, Rasekhi S, Yazdanparast M, Azadi H (2022) Bonding social capital of rural women in southwest Iran: application of social network analysis. J Rural Soc. https://doi.org/10.1111/ruso.12430
Ghorbani M, Ebrahimi F, Salajegheh A, Mohsenisaravi M (2015) Social network analysis, social power and the key stakeholders in action plan for water resources co-management (Case study: Jajrood River in Latian watershed, Darbandsar village). JWMSEIR 9(28):21–32. http://jwmsei.ir/article-1-502-fa.html
Ghorbani M, Azadi H, Janečková K, Sklenička P, Witlox F (2021) Sustainable co-management of arid regions in southeastern Iran: social network analysis approach. J Arid Environ. https://doi.org/10.1016/j.jaridenv.2021.104540
Ghorbani M (2018) Adapting institutions, 2nd edn. Tehran University Press, Tehran, p 274 (**in Persian**)
Goli I, Omidi Najafabadi M, Lashgarara F (2020) Where are we standing and where should we be going? Gender and climate change adaptation behavior. J Agric Environ Ethics 33:187–218
Haile GG, Tang Q, Sun S, Huang Z, Zhang X, Liu X (2019) Droughts in East Africa: causes, impacts and resilience. Earth-Sci Rev 193:146–161
Hallaj Z, Sadighi H, Farhadian H, Bijani M (2021) Human ecological analysis of farmers' pro-environmental behaviour in the face of drought: application of norm activation theory. Water Environ J 35(4):1337–1347
Jackson S, Finn M, Featherston P (2012) Aquatic resource use by indigenous australians in two tropical river catchments: the fitzroy river and daly river. Hum Ecol 40:893–908
Jadeja Y, Maheshwari B, Packham R et al (2018) Managing aquifer recharge and sustaining groundwater use: developing a capacity building program for creating local groundwater champions. Sustain Water Resour Manag 4:317–329
Jafary F, Bradley C (2018) Groundwater irrigation management and the existing challenges from the farmers, perspective in central Iran. Land 7(1):15
Karamidehkordi E (2010) A country report: challenges facing Iranian agriculture and natural resource management in the twenty-first century. Hum Ecol 38:295–303
Khan NA, Gao Q, Abid M (2020) Public institutions' capacities regarding climate change adaptation and risk management support in agriculture: the case of Punjab Province, Pakistan. Sci Rep 10:14111
Khosravi F, Taylor A, Siu YL (2021) Chinese water managers' long-term climate information needs. Sci Total Environ 750:141637
Lockwood M, Raymond C, Oczkowski E, Morrison M (2015) Measuring the dimensions of adaptive capacity: a psychometric approach. Ecol Soc 20(37):1
Luers AL, Lobell DB, Sklar LS, Addams CL, Matson PA (2003) A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Global Environ Change 13(4):255–267
Marshall NA, Park S, Howden SM, Dowd AB, Jakku ES (2013) Climate change awareness is associated with enhanced adaptive capacity. Agric Sys 117:30–34
Matewos T (2020) The state of local adaptive capacity to climate change in drought-prone districts of rural Sidama, southern Ethiopia. Climate Risk Manag 27:100209
Minhas PS, Ramos TB, Ben-Gal A, Pereira LS (2020) Coping with salinity in irrigated agriculture: crop evapotranspiration and water management issues. Agri Water Manag 227:105832
Moghfeli Z, Ghorbani M, Rezvani MR, Khorasani MA, Azadi H, Scheffran J (2021) Social capital and farmers' leadership in Iranian rural communities: application of social network analysis. J Environ Plan Manag. https://doi.org/10.1080/09640568.2021.2008329
Mortezapour MR, Shahnazari A, Khaledian MR (2019) Water governance in the sefidrud basin using the theory of games approach. J Water Manag Res 10:13–21 (**in Persian**)
Mousavi H (2017) The role of social capital in increasing of local stakeholders' adaptive capacity faced with groundwater level decrease (case study: Neyshabur plain-Khorasan province). MSc thesis. University of Tehran, Tehran, Iran, p 134 (**in Persian**)
Mucheru-Muna M, Waswa F, Mairura FS (2017) Socio-economic factors influencing utilisation of rain water harvesting and saving technologies in Tharaka South, Eastern Kenya. Agric Water Manag 194:150–159
Muthelo D, Owusu-Sekyere E, Ogundeji AA (2019) Smallholder farmers' adaptation to drought: identifying effective adaptive strategies and measures. Water 11(10):2069
Muthelo D (2018) Perception and adaptation strategies of smallholder farmers to drought in the Free State Province, South Africa. Doctoral dissertation. University of the Free State
Ofori BY, Stow AJ, Baumgartner JB, Beaumont LJ (2017) Influence of adaptive capacity on the outcome of climate change vulnerability assessment. Sci Rep 7(1):1–12
Paavola J (2008) Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. Environ Sci Policy 11:642–654
Quinlan AE, Berbés-Blázquez M, Haider LJ, Peterson GD (2016) Measuring and assessing resilience: broadening understanding

through multiple disciplinary perspectives. J Appl Ecol 53(3):677–687
Rahimi M, Ghorbani M, Azadi H (2022) Structural characteristics of governmental and non-governmental institutions network: case of water governance system in Kor River basin in Iran. Environ Dev Sustain. https://doi.org/10.1007/s10668-022-02346-y
Rahman HT, Robinson BE, Ford JD, Hickey GM (2018) How do capital asset interactions affect livelihood sensitivity to climatic stresses? Insights from the Northeastern Floodplains of Bangladesh. Ecol Econ 150:165–176
Razandi Y, Pourghasemi HR, Neisani NS et al (2015) Application of analytical hierarchy process, frequency ratio, and certainty factor models for groundwater potential mapping using GIS. Earth Sci Inform 8:867–883
Rejeski D, Michelson E (2014) International governance perspectives on nanotechnology water innovation. Nano App Clean Water 2014:573–582
Rezaii A, Izadi S (2015) The social causes of illiteracy in Iran. J Soc Behav Sci 46:5631–5634
Salam R, Islam ARMT, Shill BK, Alam GM, Hasanuzzaman M, Hasan MM, Shouse RC (2021) Nexus between vulnerability and adaptive capacity of drought-prone rural households in northern Bangladesh. Nat Hazards 106(1):509–527
Salari F, Ghorbani M, Malekian A (2015) Social monitoring in local stakeholders network to water resources local governance (case study: Razin Watershed, Kermanshah City). J Range Watershed Manag 68(2):287–305. https://doi.org/10.22059/jrwm.2015.54931
Sanchez C, Gamez M, Burguillo FJ, Garay J, Cabello T (2018) Comparison of predator-parasitoid-prey interaction models for different host plant qualities. J Commun Ecol 19(2):125–132. https://doi.org/10.1556/168.2018.19.2.4
Sehrsweeney M (2021) Governing resilient ecosystems: an investigation of governance network level adaptive capacity. Doctoral dissertation
Shalsi S, Ordens CM, Curtis A et al (2019) Can collective action address the "tragedy of the commons" in groundwater management? Insights from an Australian case study. Hydrogeol J 27:2471–2483
Shojaei-Miandoragh M, Bijani M, Abbasi E (2019) Farmers' resilience behaviour in the face of water scarcity in the eastern part of Lake Urmia, Iran: an environmental psychological analysis. Water Environ J 34(4):611–622
Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Global Environ Change 16(3):282–292
Surastina S, Dedi FSO (2018) Examining academic writing motivation of prospective Indonesian language teachers using exploratory factor analysis. Int J Instr 11:15–24
Tang M, Liao H, Herrera-Viedma E, Chen CP, Pedrycz W (2020) A dynamic adaptive subgroup-to-subgroup compatibility-based conflict detection and resolution model for multicriteria large-scale group decision making. IEEE Trans Cybern 1:1
Teo HC, Lechner AM, Walton GW, Chan FKS, Cheshmehzangi A, Tan-Mullins M, Chan HK, Sternberg T, Campos-Arceiz A (2019) Environmental impacts of infrastructure development under the belt and road initiative. Environ 6(72):1
Tringali C, Re V, Siciliano G et al (2017) Insights and participatory actions driven by a socio-hydrogeological approach for groundwater management: the Grombalia Basin case study (Tunisia). Hydrogeol J 25:1241–1255
Velis M, Conti KI, Biermann F (2017) Groundwater and human development: synergies and trade-offs within the context of the sustainable development goals. Sustain Sci 12:1007–1017
Verburg P, Parker DC, Stannard CA (2013) Spatial agent-based models for socio-ecological systems: challenges and prospects. Environ Model Soft 45:1–7
Vincent K (2007) Uncertainty in adaptive capacity and the importance of scale. Global Environ Change 17:12
Wiktorowicz J (2016) Exploratory factor analysis in the measurement of the competencies of older people. J Econ Lit 54:48–60
Xiao H, Gong T, Yu C et al (2020) Citizens' confidence in government control of corruption: an empirical analysis. Soc Indic Res 152:877–897
Yapıcıoğlu P, Demir Ö (2020) Environmental performances of the wastewater treatment plants: Green Index. Int J Glob Warm 21(1):1–19
Yazdanparast M, Ghorbani M, Salajegheh A, Kerachian R (2023) Development of a water security conceptual model by combining human-environmental system (HES) and system dynamic approach. Water Resour Manag. https://doi.org/10.1007/s11269-023-03449-5
Youssef AM, Zabramwi YA, Gutiérrez F, Bahamil AM, Otaibi ZA, Zahrani AJ (2020) Sinkholes induced by uncontrolled groundwater withdrawal for agriculture in arid Saudi Arabia. Integration of remote-sensing and geophysical (ERT) techniques. J Arid Environ 177:104132

Table 5 continued