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Adaptation of Water Resources to Climate Change (Case study: Cham Anjir watershed, Iran)

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ABSTRACT

Global warming, human activities, and increased water demand have led to a decrease in the resilience of the environment. Their effects in dry climates like Iran lead to the reduction of surface water and a water table drop. To evaluate the adaptation strategy for water resources with climate change, the Cham Anjir watershed was selected in the west of Iran. The geostatistical techniques are applied here. In this study, to detect climate change in the Cham Anjir watershed , hydrological-climatic data from 1991 to 2020 were used, and to adapt to climate change, a researcher-constructed questionnaire was employed. The results showed that annual temperature has increased. Long-term droughts have led to a decrease of available water. The local community has a correct understanding of climate change and its effects. Weak financial resources, lack of proper agricultural insurance support, weak training and technical consulting activities, lack of access to new technologies, and administrative bureaucracy are the most important obstacles to adaptation to climate change. Climate change adaptation programs include measures to meet essential needs, provide financial resources (short-term), improve irrigation and increase productivity (mid-term), and diversify economic activities (long-term) emphasized and accepted by the local community. The findings showed that the difference between local communities and technical experts with government experts is the most important obstacle in adapting strategies to climate change. Therefore, correcting the views of farmers and farm technicians with public sector experts is crucial for the success of climate change adaptation measures.

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1. Introduction

Water stress, wetland's dehydration, lake and river water table reduction, groundwater table drop, subsidence of plains, and limitations in drinking and agricultural water supply constitute the indicators of the vulnerability of water resources due to climatic changes (Pörtner *et al*., 2022). According to the regional patterns of climate change and social and economic scenarios, the evaluation of the effects of a 2 °C increase by 2100 indicates that between 0.9 and 3.9 billion people will be exposed to water stress (Koutroulise *et al*., 2019).

The findings indicate that climate change has increased heat waves, minimum temperature, increased the count of hot nights, a 1% increase in winter temperature, decreased agricultural production by 1.12% in North Africa and the Middle East, an increase in population pressure, and vulnerability to water resources and social unrest have intensified in these areas (Schelling *et al*., 2020). Due to climate change, 10% of the water volume of the world's rivers will decrease (Qin *et al*., 2019). The chronological data of 1971-2000 on water resources in urban areas at the global level reveal a 16-39% water shortage. These percentages of 36% would reach 63% if environmental aspects are added. This phenomenon necessitates the adoption of more proper restrictions in accessing fresh water sources and water supply for drinking, agriculture, and industry (Bijl *et al*., 2018; Hanasaki *et al*., 2018; Burk *et al*., 2020; Grasso, 2021; Pokhrel *et al*., 2021).

The prediction of water resources until 2050 indicates that 440 million people of the urban population in developed and more in developing countries would become vulnerable and face serious challenges in providing water resources (Flork *et al*., 2018; Mitlin *et al*., 2019).

Agriculture is one of the most susceptible industries and complex systems vulnerable to climate change. Considering the high sensitivity of agriculture to climatic elements and factors, the effect of climate change on its components like the growth and phenological stages of plants, water requirements, production efficiency, and plant diseases is inevitable (Chen *et al*., 2014; Feleke, 2015; Aksit *et al*., 2018; Clayton *et al*., 2020). More than 80% of freshwater resources in most regions of the world are in the agriculture industry, except for a few industrialized countries and countries with very humid climates.

The estimated water share consumption share by the agricultural industry in 2020 was: United States (41%), India (68%), China (86%), Pakistan (96%), Iran (92%), Egypt (86%), Japan (91%), and Russia (18%) (factbook, 2021). As to the agriculture industry's dependency on water resources and human activities' contribution to climate change and water resources, there exists an action-reaction model correlation among agricultural activities, the water cycle, and climate change. This fact necessitates optimal water consumption management in the agricultural industry to adapt to climate change technology. This process would affect livelihood instability, economic growth, and income sources of the agricultural industry (Madani, 2005; Imam *et al*., 2015; Rahimi and Zareei, 2019; Sourinejad, 2020; Ashraf *et al*., 2021). As the concentration of greenhouse gases increases, the balance of solar energy, temperature, rainfall, and phenological problems of agricultural products change. To diminish the effects of climate change, strategies for reducing greenhouse gas production (reduction strategy) and adapting to climate change technology have become of concern since the 1990s (Leman *et al*., 2008; Otitoju and Enete, 2016).

The strategy of reducing greenhouse gases as an intersectoral solution (reduction of fossil fuel consumption, resorting to biofuel technology, and carbon market) has had no success on a global scale; consequently, adopting the climate change adaptation strategy as an appropriate and effective process in the agriculture industry becomes inevitable (Soleimani *et al*., 2021). Scientific and appropriate management and changes in irrigation systems, soil treatment, crop yield volume, and applying new technologies in crop cultivation can be effective in reducing the climate change effect on the growth and performance, thus, proper consumption of water resources. In this endeavor, adopting measures like reducing water consumption, water storage, optimizing irrigation efficiency, water trading, integrated management, changing water governance, diversifying agricultural activities and income sources, flood management and artificial feeding of underground aquifers, planting date change, planting density, increasing rainfed cultivation, crop diversity, drought-resistant cultivars, agricultural products' insurance and transfer of technical knowledge to beneficiaries, (Drogers and Aerts, 2005; Abbaspour *et al*., 2009; Madelin *et al*., 2009; Dhaka *et al*., 2010; Wilby and Dessai, 2010; Legesse *et al*., 2013; Akinnagbe and Iruhib, 2014; Abid *et al*., 2015; Somboonsuke *et al*., 2018; Kyani GhaleSard *et al*., 2019; Stringer *et al*., 2021; Tope, 2022) would contribute to water and food security.

Consecutive droughts, an increase in temperature next to more than the renewable capacity water harvesting of water resources, and low irrigation efficiency have increased the climate vulnerability index of water resources and the agriculture industry. This trend due to the exploitation of underground water resources, water transfer among the basins, unsustainable economic and social development, and projects with high water demand in areas with low rainfall and high population concentration has intensified since 2008 (Farmanbar *et al*., 2017; Ansari *et al*., 2022; Saleh *et al*., 2022). These conditions in river basins like Khorramabad plain with a semi-arid climate due to a low percentage of snowfall in the annual precipitation, long-term droughts, and rapid agricultural development are more susceptible to climate change (Derikvandi, 2012: 146).

The hypothesis is that climate change has threatened the security of water resources worldwide. Limitation of access to water sources, reduction in water quality, and drop in water table are among the effects of climate change. Strategies to reduce greenhouse gas emissions and adapt to climate change are effective in modulating these challenges. This study aimed to evaluate the adaptation strategies of water resources to climate change in local communities. The results of this study can help improve water security and the effectiveness of climate change adaptation strategies. To evaluate this strategy, the Cham Anjir watershed in the Karkheh Basin was selected.

2. Materials and Methods

2.1. Study area

Cham Anjir watershed is located in Karkheh catchment and western Iran. it is located between 48˚10 ′ E to 48˚40 ′ E and 33˚15′ N to 33˚35′ N (Fig. 1). This area is annual precipitation of 558.3 mm, annual temperature of 17.2˚c, and annual discharge of 9.2 m^3/s. Next to surface water, the extraction of 468.05 million m^3 of underground water is another source that meets the required water supply in this region (Sangab Consulting Engineers, Zagros, 2013).

2.2. Data

To assess the effects of climate change on hydroclimatic water elements and adapt to its consequences, the daily data of hydrometric-climatic stations recorded in the National Meteorological Organization and the Ministry of Energy: average rainfall, average minimum and maximum temperatures, surface and ground water discharge of 1991-2021 were used (Table 1 and Fig. 2). To evaluate climate change adaptation strategies, 215 questionnaires consisting of a statistical population of farmers and experts in agriculture and water resources were filled out using the snowball sampling method and randomly.

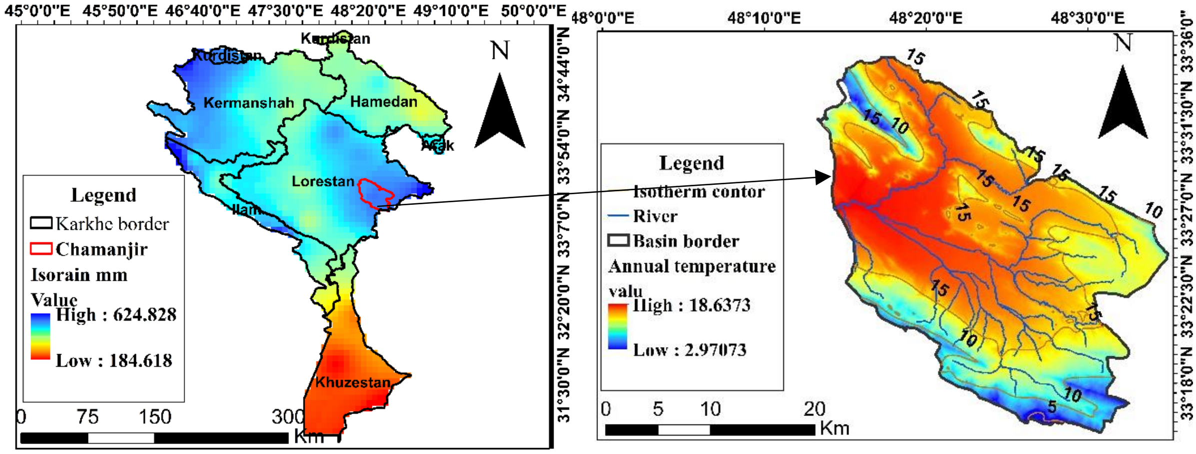
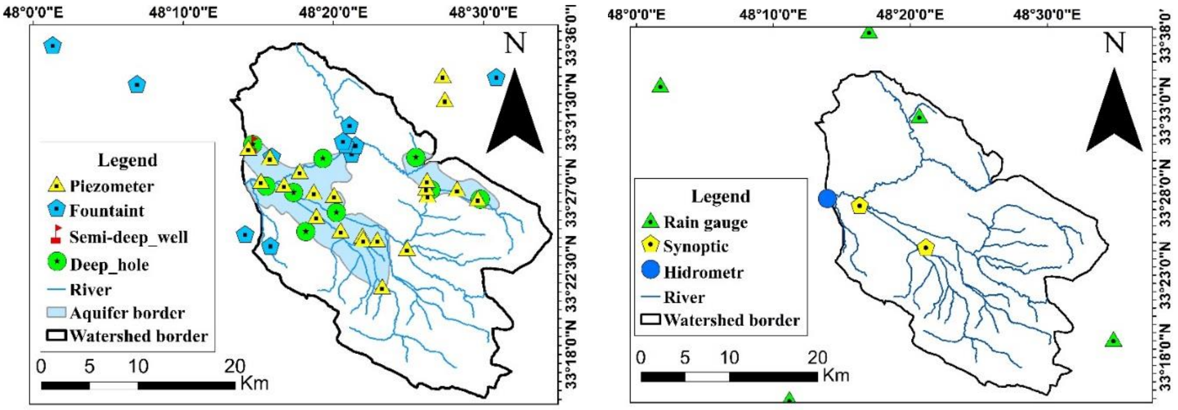


Fig. 1. Geographical location of the Cham Anjir watershed in the Karkheh catchment

Table 1. Location of weather and hydrometric stations of Cham-Anjir

Name station	Time-Series	lat	Lon	Elevation	Station-Type
Khorramabad	1991-2021	33.44	48.28	1147.8	Synoptic station
Imanabad	2006-2021	33.40	48.37	1500.0	Synoptic station
Poldokhtar	1998-2021	33.15	47.72	713.5	Synoptic station
Alashtar	1976-2021	33.83	48.25	1567.1	Synoptic station
Norabad	2000-2021	34.05	48.00	1859.0	Synoptic station
Robate Dolatshahi	1998-2021	33.62	48.28	1364.0	Rain gauge
Sarab CHenar Oliya	1998-2021	33.68	48.15	1540.0	Rain gauge
SarabeDoreh(Dorechegini)	1994-2021	33.55	48.03	1138.0	Rain gauge
Chameshk	1995-2021	33.23	48.21	1475.0	Rain gauge
Champelk	1995-2021	33.70	47.80	1123.0	Rain gauge
Chenar Kol	2003-2021	33.32	48.60	1756.0	Rain gauge
Daregarm	1997-2021	33.53	48.35	1233.0	Rain gauge
Shirvan(Lorestan)	1998-2021	33.77	47.82	1152.0	Rain gauge
Cham Angir	1991-2021	48.25	33.44	1127.0	Hydromeric



A. Location of piezometric stations B. Weather and Hydrometric stations

Fig. 2. Location of hydrometric and weather stations of the Cham-Anjir watershad

2.3. Methodology

The method adopted in this study is experimental-analytical. Different geostatistical and spatial analysis methods are adopted to analyze the meteorological data.

This research revealed trending climate change, increased drought, and reduced access to water resources in the Cham Anjir watershed . Then, residents' opinions were gathered through field methods in the form of four categories of questions (climate change events, understanding its effects, adaptation strategies to climate change, and their barriers to adapting to changes). It has been compared with the opinions of specialists and experts in water resources and agriculture (Fig. 3).

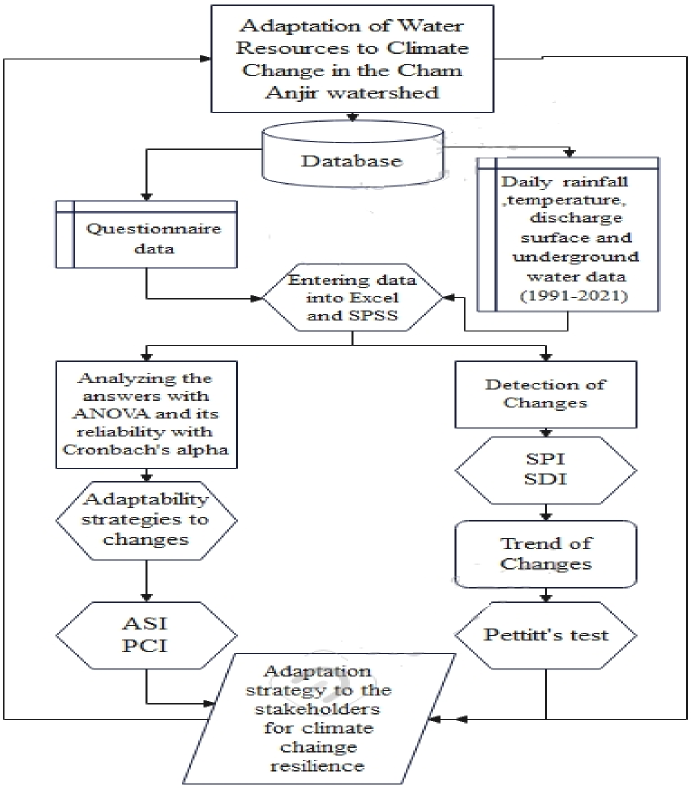


Fig. 3. Conceptual model of the research method

To assess the climate data trend, the data anomalies from the Z-score method, Eq. (1), is applied: And based on this test, meteorological (SPI) and hydrological (SDI) drought indices were investigated (Saberi *et al*., 2021).

$$\text{Z-value} =(x_i - \overline{X}\,)/\delta_i \qquad (1)$$

where x_i = value for annual, $\overline{X}$ = Average , δ = SD (Saberi *et al*., 2021)

The statistical Pettitt-Test is run in the trend analysis, turning points, and the homogenization test of different data series. A monotonic ascending/descending trend indicates the variables' consistent ascending/descending. If the computed z ≥ + 1.96, there exists an ascending trend at $\alpha \leq 0.05$; if not, there exists a descending trend at $\alpha \leq 0.05$. The Pettitt Test, a non-parametric test that requires no assumption about data distribution, is run to detect changes in the variables throught (Pettitt, 1979) Eq. (2):

$$K_T max\left| U_{t,T}\right|,\ \ U_{t,T} = \sum_{i=1}^{t}\sum_{j=t+1}^{T} sgn\,(X_i - X_j) \qquad p \simeq 2\,exp(-6\,K_T^2/T^3 + T^2\,) \qquad (2)$$

where $U_{t,T}$ is the Turning point, and K_T is the Significance level (Pettitt, 1979))

To assess the barriers to economic and social conditions and provide a solution to climate change adaptation, the PCI index and the adaptation factor (ASI) index (Eqs. 3 and 4) are applied:

$$ASI = AS_n \times P_i + AS_t \times P_i + AS_m \times P_i + AS_h \times P_i + AS_v \times P_i \quad (3)$$

where ASI is the adaptation strategy index (Uddin *et al.*, 2014).

$$PCI = PC_n \times P_i + PC_t \times P_i + PC_m \times P_i + PC_h \times P_i + PC_v \times P_i \quad (4)$$

where PCI is the problem-coping index

and in both the equations: Pi is the percentage of the frequency of questions, and *v*, *h*, *m*, *t*, and *n* indicators symbolize the very low, low, medium, high, and very high values of these indicators (Uddin *et al.*, 2014).

Questionnaires are completed based on Morgan's table. The samples are randomly filled by adopting the snowball method, and Cronbach's alpha is applied in assessing them, Eq. (5), and ANOVA is applied to compare the communities (respondents).

$$\alpha = k/k - 1\,(1 - \textstyle\sum_{i=1}^{k} \sigma_i^2 / \sigma^2) \quad (5)$$

where K is the items and question count, σ_i^2 is the variance of each question, and σ^2 is the variance of all questions (Ghasemi, 2005).

3. Results

To analyze the adaptability to water resources due to climate change in the Cham Anjir watershed, meteorological and hydrological drought indices have been evaluated to demonstrate the occurrence of climate change and the timing of changes. It is sought to determine the strategies and solutions to increase the resilience of the beneficiary community against climate change and facing risks.

3.1. Revelation and trend of changes

To analyze the trends of hydrological and climatic variables, the changes in average annual rainfall, average annual maximum and minimum temperature, surface and groundwater discharge are assessed.

3.1.1. Surface water

The annual discharge of the Cham Anjir watershed is 9.2 m³/s with a 60.5% variability coefficient, which indicates the severe changes in the river surface waters. The survey of river flow anomalies and hydrological droughts standard discharge index (SDI) indicates that the periodic changes of this watershed are 8 years that have occurred in the (1991-2020) statistical period (Fig. 4). The frequency of droughts indicates that 12 years of annual discharge in the statistical period was more than average and 18 years was less than the long-term average. Notably, the period of hydrological drought continuity and flow discharge anomaly is greater than its positive continuity values. The data trend analysis at the 95% confidence level obtained through P-Test indicates that the river discharge follows a significant descending trend, that is, the average annual discharge in the first period (1991-2006) decreased by 10 m³/s to 7.8 m³/s in the second period (2007-2020), with a rotation time recorded in 2006 (Fig. 5).

3.1.2.Ground water

During the years 1995–2021, the water table in the Cham Anjir watershed has not indicated a significant trend. However, the Standardized Discharge Index (SDI) indicates that the water table in this watershed has been negative for 18 years and positive for 7 years. The periods below the average are more frequent. This basin (1998) faced the most severe drop in the water table (-1.6 m) (Fig. 6).

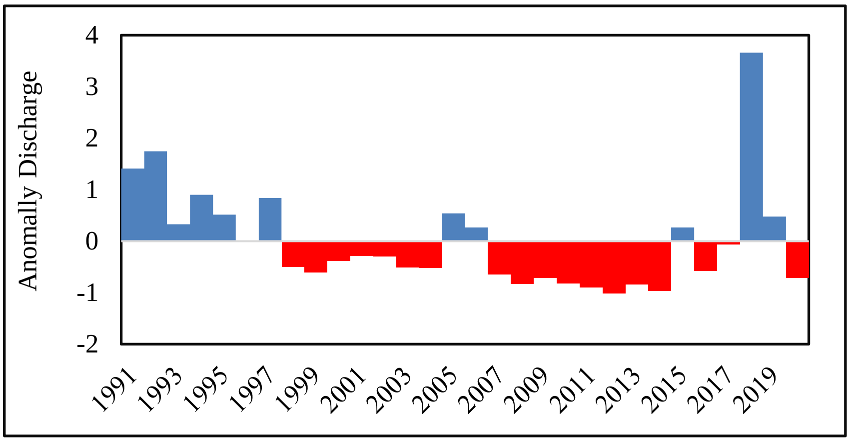


Fig. 4. Anomaly of discharge in the Cham Anjir watershed

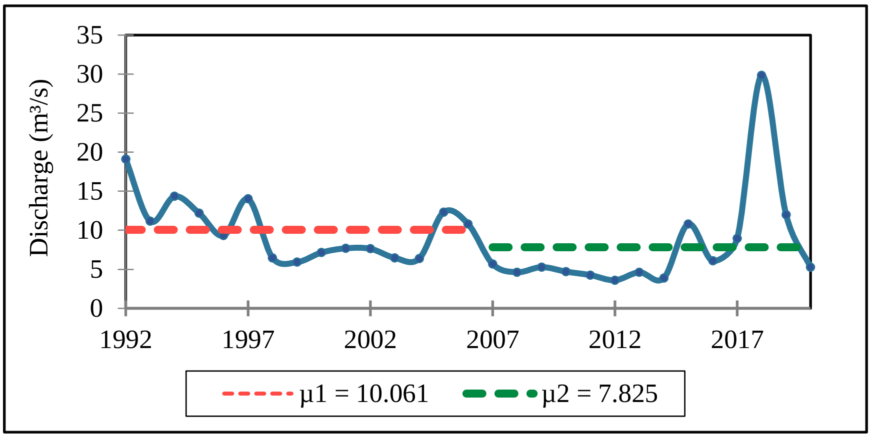


Fig. 5. Pettitt's-Test of Discharge in the Cham Anjir watershed

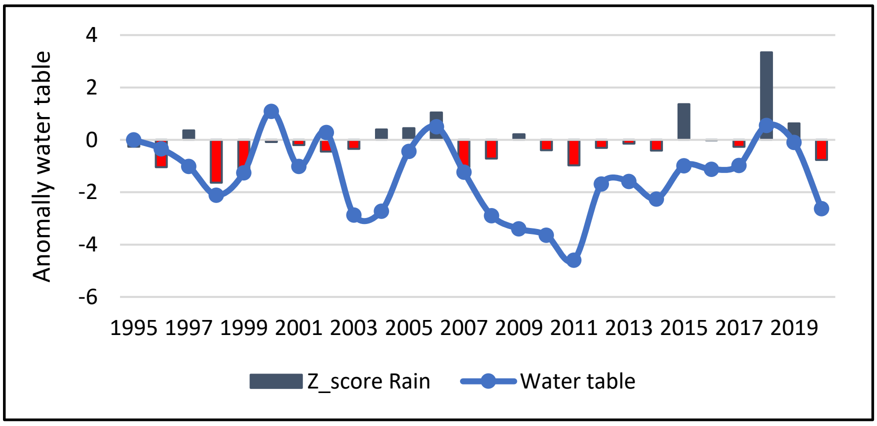


Fig. 6. The Anomally water table and rainfall of the Cham Anjir watershed

3.1.3. Annual Rainfall

The annual rainfall in this watershed is 550 mm, but there is high variability (CV= 33%).The finding on rainfall trend changes at 95% confidence level in turning points (Petit test) indicates that the annual rainfall is trend less (P-value = 0.077).

The analysis of the frequency of droughts in Cham Anjir reveals that the probability of drought (60%) in this watershed is higher than (40%) normal and wet conditions. What increases the impact of droughts exponentially is their duration (Fig. 7). This descending trend directly influences the river flow at the rainfall-discharge correlation in Cham Anjir ($R^2 = 0.65$) (Fig. 8 and Table 2). Therefore, any change in the volume has a direct effect on the basin discharge volume. In long-term droughts, the flow rate decreases, leading to an increase in the vulnerability of the surface water resources.

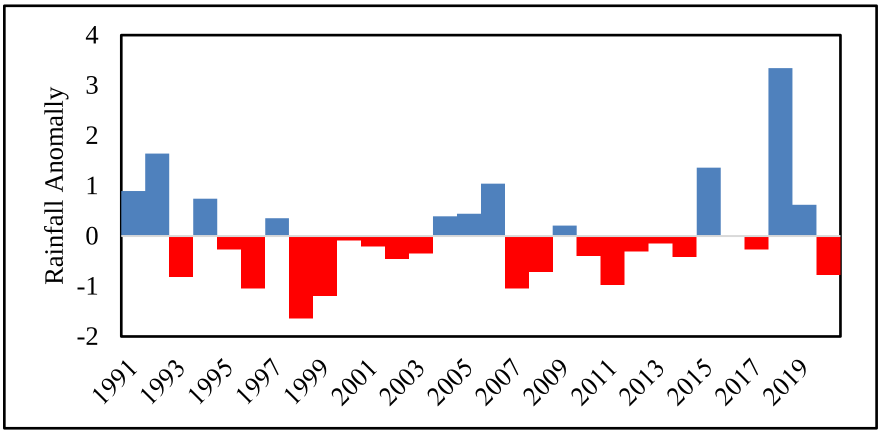


Fig. 7. Annual rainfall anomaly of the Cham Anjir watershed

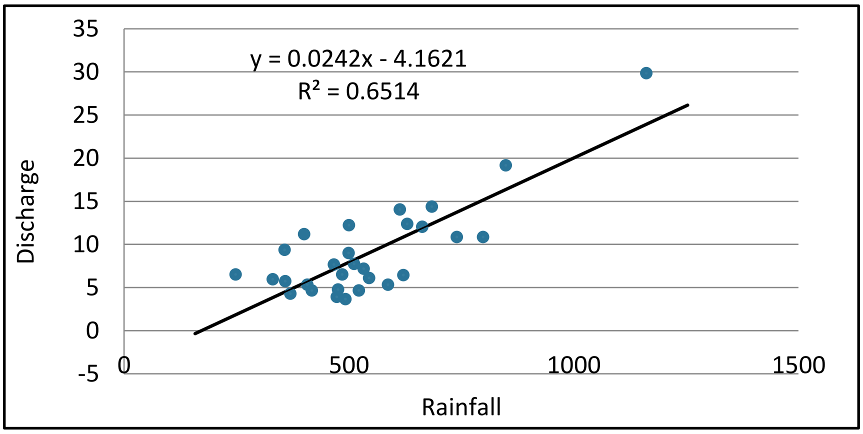


Fig. 8. Rainfall-Discharge regression model of the Cham Anjir watershed

Table 2. Regression matrix of rainfall-discharge of the Cham Anjir watershed

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	-4.162	1.950	-2.134	0.042	-8.163	-0.161

713.3	0.024	0.003	7.103	<0.001	0.017	0.031

3.1.4. Minimum and Maximum Temperatures

Annual minimum and maximum air temperature temporal changes Temperature changes in the time series are obtained by running the Pettitt Test, where the results indicate the minimum temperature has increased by 1.4 °C (p-value = 0.026, turning point in 1996).and the maximum temperature by 1.6 °C (p-value = 0.02, turning point in 1997).

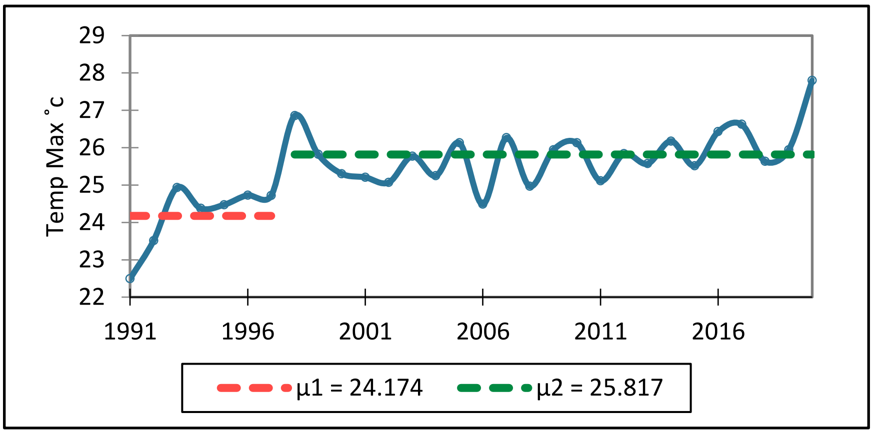


Fig. 9. Turning Point(Pettitt's-Test) of average maximum temperature of the Cham Anjir watershed

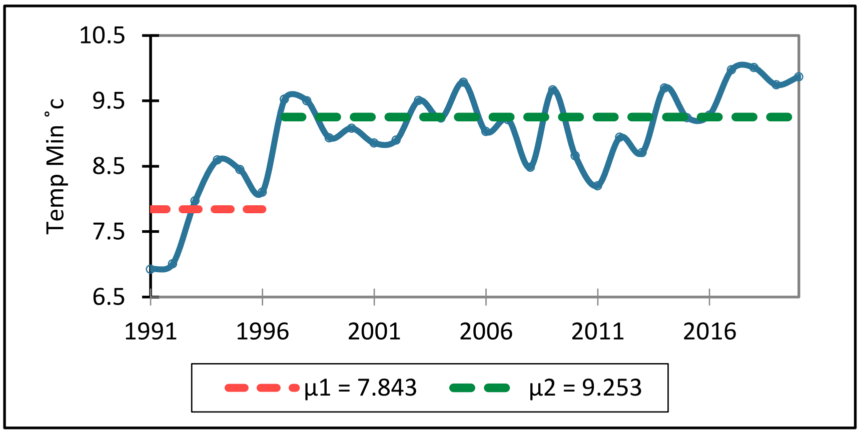


Fig. 10. Turning Point(Pettitt's-Test) average minimum temperature of the Cham Anjir watershed

3.2. Problem Cognition Index , and Adaptation Strategies Index

Local communities, especially in rural and agricultural areas, are the most vulnerable to climate change because of their high dependency on natural resources and weather conditions regarding livelihood and economy. The population of this region lacks financial support like regular income, savings, and insurance coverage. In countries with arid and semi-arid climates and subject to special economic conditions, like Iran, these issues are more evident. The great vulnerability of these communities has become the focus of governments, NGOs, and international organizations regarding resilience and providing solutions like achieving sustainable development. Realization of climate change by the beneficiaries, resorting to the Problem Cognition Index (PCI), and the Adaptation Strategies Index (ASI) are considered vital elements in this context. These three component are assessed through field observations and studies through questionnaires filled by farmers, local government experts, and farm management experts (Organization of Agricultural Engineering and Natural Resources).

3.2.1. Realizing climate change

To assess and realize the statistical community's concept of climate change, based on the scientific and technical knowledge of the respondents regarding climate issues, their perception of temperature increase, decrease, increase in droughts and dust blow, groundwater loss, and decrease in surface waters are measured in the 5 Likert scale (very high, high, medium, low and very low). The 0.98 Cronbach's alpha verifies the realization of climate change occurrence among all involved, where 41% believe that the temperature has increased, 43% believe that the rainfall has decreased, 43% believe in drought effect, and 39% believe that dust has increased. In general, 70% of the beneficiaries declare that the underground water table has decreased too much, and 38% state that surface water has decreased drastically a lot (Table 3). The findings here indicate that there exists a correct understanding of climate change and recognition of the problem in society.

Table 3. Perception of climate change among agricultural industry operators

Perception and observations	Very much	Frequency	Much	Frequency	Moderate	Frequency	little	Frequency	Very little	Frequency
Increased in temperature	69	33	86	41	46	22	7	3	1	0
Decrease in rainfall	89	43	72	35	35	17	9	4	3	1
Increased drought	90	43	76	37	32	15	6	3	4	2
Increase in dust	46	22	82	39	57	27	19	9	4	2
Decreased water table	72	35	72	35	48	23	10	5	4	2
Decrease the volume of surface water	76	36	80	38	38	18	8	4	7	3

3.2.2. Perceived Effects of Climate Change

The consequences of climate change influence economic and social conditions. To measure the perception of those involved in this phenomenon, the concepts of plant diseases, decrease in crop yield, farmland area reduction, decrease in income, and abandoning agricultural occupation are applied in the subject questionnaire. The calculated Cronbach's alpha coefficient is 0.96, indicating the significance of the results. According to the beneficiaries' opinions, the increase in plant diseases is more than 46%. Among the questioned, 38% believe that the cultivated area has decreased to a great extent. The decrease in performance and income among the participants is 42% and 43%, respectively; 55% believe that abending this occupation has an average rating (Table 4). All in all, this means reduced food security, income, and an increase in social tensions over water resources.

3.2.3. Obstacles of adaptation strategies regarding

Obstacles and problems of adaptation strategies to climate change in local communities are among the assessing indices. These obstacles consist of low financial resources for applying new and simple and efficient technologies in the fields of irrigation, consuming drought-resistant species, biological pest control, low training and technical skills in the field of development of local communities, and lack of scientific and financial aid from the government and local organizations (Table 5). The PCI is applied in assessing and analyzing the barriers to climate change adaptation strategies. The value of Cronbach's alpha for the items of obstacles vs. adaptation strategies is 0.978, which confirms the reliability of the results. According to Table 5 and PCI, the lack of financial resources in irrigation renovation, inefficiency in administrative correspondence and banking complexities, non-applying the agricultural meteorological data, lack of familiarity with the effects of climate change, non-familiarity with an appropriate strategy to adapt to climate change are ranked 1 to 5. These problems are effective in adjusting and removing barriers to adaptation to climate change.

Table 4. Realizing the effects of climate change on agriculture in the Study area

Understanding the effects of climate change	Very much	Frequency	Much	Frequency	Moderate	Frequency	little	Frequency	Very little	Frequency
Increase in pests	57	28	94	46	47	23	5	2	3	1
Reduction of cultivated area	28	13	79	38	73	35	26	13	2	1
Decreased performance	45	22	87	42	57	28	15	7	3	1
Decrease in income	46	22	88	43	55	27	16	8	2	1
Abandoning the agricultural job	29	14	55	26	68	33	38	18	18	9

Table 5. The obstacles farmers face in fully adapting to climate changes with the PCI in the Study area

Problems and Limitations to Adapt to climate change	Very much	Much	Moderate	little	Very little	PCI	Rank
Administrative correspondence and obstacles to using banking facilities	66	78	44	18	5	6031	2
Inability to use new technology	54	67	45	35	10	5097	10
Financial limitations and lack of insurance for agricultural products	52	67	54	22	16	5142	8
Weakness of financial resources in the use of resistant species	39	74	56	23	16	5203	7
Lack of access to educational and agricultural extension services	24	54	73	39	19	5121	9
Weak financial resources in irrigation modernization	67	78	41	10	9	6066	1
Failure to use agricultural meteorological data	34	81	61	21	9	5806	3
Lack of familiarity with the effects of climate change	24	71	68	36	2	5742	4
Lack of familiarity with suitable solutions to adapt to climate change	40	72	60	25	11	5351	5
Lack of support from government agencies in the use of resistant species	49	71	52	20	15	5203	7

3.2.4. Adaptation strategies to climate change in water resources

Adapting to climate change can be accomplished by taking short-term measures to improve living conditions and livelihood (cash aid, subsidy, and payment and working capital support); mid-term measures in the optimal management of water resources (correction of water transfer route, irrigation schedule, water purchase and collection from rainfall, ect.); and long-term measures in the field of sustainable development (job activity diversity, cultivation pattern change, cultivation date change, etc.). Consequently, the strategies of adapting water resources consumption vs. climatic change of the basin are assessed within the short-term (one to three years), medium-term (three to five years), and long-term (five to seven years) periodic strategies.

3.2.4.1. Short-term adaptation measures

The measures related to improving the economic status of the beneficiaries are assessed with the ASI (Table 6-A). Studies reveal that poor income and low working capital are the most important challenges for water resource users. This challenge causes the adoption of short-term executive solutions, more pressure on resources, and easy income yield. Based on this index, the index of renting agricultural land to secure a minimum income, ranked first, holds much less importance among the beneficiaries; receiving bank loans to improve their living conditions among the beneficiaries instead of selling some farm equipment is of great importance, thus ranking 2.

Table 6. A. Actions related to users' livelihood to improve life with ASI in the Study area

Livelihood Measures to improve life	Very much	Much	Moderate	Little	Very little	ASI	Rank
Obtaining bank facilities	42	58	43	31	28	4318	2
Establishing microcredit funds to improve the capacity of farmers	38	45	37	25	55	4244	3
Selling some items such as agricultural tools and so on	23	35	46	46	50	4243	4
Renting agricultural land to provide minimum income	23	30	47	43	58	4403	1

3.2.4.2. Mid-term adaptation measures

These measures highly contribute to water supply and increase productivity in their technical context. These measures include water transfer route modification, construction of pools and ponds to collect water, a proper watering schedule (after sundown), reducing the frequency of crop irrigation, and membership in associations of water consumers and water distribution. These measures are ranked 1 to 5, respectively. According to the ASI, the watershed management operations and construction of earth dams for surface water accumulations are assigned the last rank (8^{th} measure), Table (6-B). The Cronbach's alpha coefficient of this section is 0.814.

3.2.4.3. Long-term adaptation measures

Long-term adaptation consists of measures that, if applied, would stop the ascending trend of global temperature (below 2 °C), In this adaptation, reduction in greenhouse gas production, improvement of water consumption management, and sustainable development are considered (UNCCS, 2019).

Considering that more than 90% of water in the subject watershed is consumed by the agricultural industry. The focus here is on optimal management, increasing the productivity of water resources, and directing water consumers to substitute and diversify activities with less water consumption. In this framework, all long-term measures are of concern to adapt climate change technology and increase resilience.

Table 6. B. Actions related to water resources with ASI in the Study area

Actions related to water resources	Very much	Much	Moderate	Little	Very little	ASI	Rank
Modifying the path of directing and transferring water	20	33	46	28	79	5160	1
Construction of pools and ponds to collect water	16	35	55	30	65	4792	2
The best time for watering is during the cool hours of the day	63	51	32	28	30	4548	3
Reducing the number of times the crop is irrigated	63	50	31	24	34	4536	4
Membership in associations of water consumers and water distribution	40	52	58	33	17	4523	5
Buying water from nearby wells	45	38	38	23	61	4470	6
Breaking the bottom and increasing the depth of the well	53	51	30	24	43	4346	7
The exploitation of watershed s and the creation of earth dams to collect surface water	26	41	49	35	51	4250	8

The results of the ASI ranking indicate that out of 11 effective actions for the adaptation strategy, based on the ranking, resorting to drip and rain irrigation (modern irrigation), selecting plant varieties resistant to heat and drought, developing horticulture (land use change) and changing cultivation patterns, are the most important steps to accomplish climate change adaptation strategies, Table (6-C). The value of alpha increased to 0.77 and the results of important criteria were confirmed based on the opinions of users and the reliability of the questionnaire.

Table 6. C. Measures to achieve climate change adaptation strategies with the ASI

Strategy	Very much	Much	Moderate	Little	Very little	ASI	Rank
Modernization of irrigation	87	44	30	19	27	5379	1
Use of drought-resistant cultivars	73	50	45	22	23	4875	2
Move the planting date	41	57	47	40	25	3697	9
Changing the planting pattern	50	66	44	29	24	4398	4
Development of horticulture/change of land use	29	41	78	33	27	4488	3
Development of greenhouse cultivation	49	44	32	23	57	4200	6
Development of animal husbandry and beekeeping	29	45	67	26	42	4363	5
Mixed cropping	34	47	66	41	22	3907	8
Changing jobs from agriculture to services and industry	20	31	61	49	49	3563	11

Cultivation of medicinal plants	35	43	53	29	50	3992	7
Migration	19	27	39	54	71	3644	10

3.3. Assessing farmers’, farm technicians, and local government authorities’ viewpoints

It is obvious that the success of any development program and technical measures in project implementation greatly depends on the coordination among the program developers, executors, and beneficiaries components. The ANOVA at the 95% confidence level is applied to compare the assessments run on the successes made and determine the convergence of water resource adaptation programs with climate change concerning the realizing climate change, perceived effects of climate change, and obstacles of adaptation and adaptation strategies between two groups (farmers and local government experts) (Table 7). There exists a significant difference in this concept among the above-mentioned three components that face the success of these programs with big challenges. This difference is due to the lack of training of farmers and technical technicians, lack of transparency of programs, failure to provide credits on time for the executions of the projects by the local government, and the strong fluctuation in economic variables in the local community.

Table 7. ANOVA analysis of opinions of questionnaire items between farmers and experts

Questionnaire items	F	P-value
Perceptions of climate change among activists	0.00237	0.999999
Understanding the effects of climate change on agriculture	0.000801	0.999999
Actions to achieve adaptation strategies	0.00359	1
Problems and Limitations of Adapting to climate change	0.015582	1
Actions related to water resources with ASI index	0.003753	1
Beneficiaries' Livelihood Actions to Improve Livelihoods with ASI Index	0.001323	0.99993

4. Discussion

The findings indicate that the increase in temperature, decrease in precipitation, long-term droughts, and human activities end in an increase in climate vulnerability in the basin’s water resources due to a 1.6°C increase in maximum temperature and a 1.4°C increase in minimum temperature during 1991–2021. Temperature increase initiates evaporation, transpiration, and high water demand, which constitute climatic high-risk occurrences. Precipitation anomalies indicate the possibility of drought (69%) and normal and wet conditions (31%). Due to the increase in temperature, decrease in rainfall, the occurrence of consecutive droughts, and decrease in river discharge in the studied basin, climate changes and global warming have occurred.

The increase in temperature, decreased precipitation, and long-term droughts led to a 23% decrease in surface water and lowered underground water tables by 17 meters in the region. Hydrological and agricultural droughts due to climate change have increased the vulnerability of water resources in the basin.

This phenomenon has reduced the motivation in cultivation and promotes the and causes migration of rural farmers, who become unskilled laborers on daily wage, thus the negative effect on expenses required by a household. Weakness in financial resources, lack of agricultural insurance, lack of training, inefficient technical consulting, lack of access to new technologies, and administrative bureaucracy are the most important obstacles to adapting to the climate change concept. Executive priorities for water resource adaptation to climate change and water resource management are approved in short-term, medium-term, and long-term plans.

The current findings in the section on the occurrence and effects of climate change are consistent with findings of Koutroulise *et al*., 2019; Bijl *et al*., 2018; Hanasaki *et al*., 2018; Burk *et al*., 2020; Muller Schmed *et al*., 2021; Schelling *et al*., 2020. The findings here in the climate change adaptation strategies section correspond with those of Madelin *et al*., 2009; Wilby and Dessai, 2010; Drogers and Aerts, 2005; Abbaspour *et al*., 2009; Kyani GhaleSard *et al*., 2019; Stringer *et al*., 2021; Legesse *et al*., 2013; Somboonsuke *et al*., 2018; Dhaka *et al*., 2010; Akinnagbe and Iruhib, 2014; Abid *et al*., 2015; Tope, 2022; Ansari *et al*., 2022.

Providing proper model provisions to improve trust between the local community and the local government and monitoring water resources are studies, and suggesting implementation strategies must be of high concern in the future.

5. Conclusion

Water scarcity and tension are the most tangible phenomena in realizing the effects of climate change. The decrease in river discharge, drop in water table, and floodings are among the appropriate and fixed indicators applied in assessing the climate change concept regarding water resources. Long-term droughts, human activities, and global warming are the inevitable and influential factors in determining water resources’ conditions.

The discharge of rivers and water table in the subject watershed is decreasing. The volume of available water has dropped from 316 to 220 MCM, and the aqufier water table has dropped by about 5 meters. As to the turning points test, the year 2007 is the beginning of the descending trend that would continue for 10 years.

Climatic droughts and pressure on underground water resources by digging more wells have faced water management with major challenges. Annual rainfall anomalies indicate the occurrence of a long-term drought 2007-2017. Based on the surface water and correlation, the change in volume leads to a high reaction of water resources. Analysis of the temperature trends in the region confirms the existence of an increasing temperature trend.

The occupied agricultural industry has a direct realization of the effects of climate change on water resources. The results of field surveys and local studies indicate that farmers have a correct perception of climate change and its consequences. They agree with the adaptation strategy as an appropriate solution. Weak financial resources, lack of adequate support and insurance, lack of training and technical consulting, lack of access to new technologies, and administrative bureaucracy contribute to the most important obstacles in adopting this strategy. Executive priorities for the adaptation of resources to climate change and water resources management are approved and planned in short-term, medium-term, and long-term intervals.

In the short-term plans, essential needs are provided next to circulating financial resources; in the medium-term, measures are adopted to improve irrigation and increase available water volumes, improve irrigation, and increase productivity; in the long-term, fundamental measures are adopted to diversify the economic activities, modify the cultivation patterns, increase productivity, and develop technologies in this realm to enrich water resources. The difference between the attitude of the local community and farm technical experts with local government experts is the most important challenge in the implementation of climate change adaptation projects. This concept necessitates: 1) overcoming the conflicts and misunderstandings among the local community and local government officials; and 2) establishing institutional development systems of irrigation that are accepted by water resource users for better and improved water consumption to reduce the effects of climate change and accomplish a sustainable development strategy in the region.

Author contributions

Dariush Rahimi contributed to the study’s conception and design. Maryam Arysadr performed material preparation, data collection, and analysis. Maryam Aryasadr and Dariush Rahimi wrote the frst draft of the manuscript, and Hadi Amiri and Mehran Zand commented on the previous versions of the manuscript. All authors read and approved the fnal manuscript.

Data Availability Statement

The authors declare that data supporting the findings of this study are available and were cited within the article. Data is available and provided to the journal whenever needed.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declarations

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