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The relationship between water scarcity and farmer migration in Isfahan, Iran

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List of Abbreviations:

SES	Social-ecological systems
IAD	Institutional analysis and development
MENA	Middle East and North Africa
GDP	Gross Domestic Product
SPI	Standard Precipitation Index
SWSI	Surface Water Supply Index
FCM	Fuzzy cognitive map
RU	Resource units
RS	Resource systems
GS	Governance system
U	Users

Abstract

One of the problems that farmers in the Middle East and North Africa region are dealing with is water scarcity. Many farmers decided to migrate because of this problem. In the Isfahan province of Iran, different factors contribute to the water scarcity and farmers' migration decision. The Zayandeh-rud River is the central water basin in this province. Isfahan has been developed at a fast pace regarding industrialization and urbanization. Since the province is located in a semi-arid region, this development has caused problems with water distribution among different sectors. Farmers are migrating from their villages, because of water scarcity and not having enough available water to continue farming. I chose the Kafran village in the east of Isfahan as the case study area, where water scarcity is intense and farmers started to migrate. By applying the SES and IAD frameworks, I first investigate which factors contribute to the water scarcity in Kafran and, next, what elements the water scarcity affects. In the case of Isfahan, the management methods, policies, and climate change effects have led to problems in water distribution and exacerbated water scarcity. The following water scarcity impacts farmers' lives through economic, environmental, health, and social aspects. The main reason for migration is economic and not having enough money to live on for basic needs. The second reason is environmental and health conditions, and the third is social factors.

Acknowledgment

Water has always been a major issue in Iran. And I was always curious about the problems about water. My master's degree in MEEM provided me with the knowledge I needed to comprehend those problems. I am pleased that I am able to apply my knowledge in one region of Iran for my thesis. I am hoping for the freedom and prosperity of my country.

I am grateful to everyone who has helped me. First and foremost, I want to thank Dr. Gül Özerol for her unwavering support and patience. Her feedback assisted me in developing a detailed and specific content. Whenever I had a problem, she made me feel welcome and quickly scheduled meetings. Dr. Athanasios Votsis' feedback was extremely helpful in developing the technical aspects of the research. I want to thank him for his time and assistance. This research would not have been possible without Dr. Dariush Rahimi, who assisted me in locating farmers in the region and scheduling expert interviews. I would also like to thank my family and boyfriend for their support.

1. Introduction

1.1. Background

Climate change is increasing the frequency and intensity of extreme weather events, such as droughts, floods and heatwaves, in various regions, especially in the Middle East and North Africa (MENA). Moreover, the geographical distribution of climate change and its impacts is uneven, often with sharp differences from one region to another (Masson-Delmotte, 2021). Because agriculture is a sector with a high demand for water, climate change poses challenges to this sector (Waha et al., 2017). Climate change in the MENA region, along with other factors such as increasing agricultural production and exports and population growth, has led to serious drought risk. (Kamal et al., 2021; Madani & Mariño, 2009). To reduce the damage caused by droughts and water scarcity, several MENA countries have experimented with methods and strategies that increase water supply, such as building new dams, improving water collection and distribution systems (Waha et al., 2017).

Farmers are harmed as a result of the endangerment of agriculture due to a lack of available water and proper working conditions (Falco et al., 2018, 2019). This harm can be so severe that farmers are forced to change their occupations or, in some cases, migrate to other rural or urban areas (Cottier & Salehyan, 2021; Falco et al., 2018). To increase farmers climate resilience, it is critical to identify the factors that can exacerbate water scarcity, such as policies, climate change, and availability of resources (Kosoe & Ahmed, 2022).

In Iran, farmers migrate primarily due to a lack of proper income or cultural issues, as well as environmental and political issues (Jamshidi et al., 2019). They migrate to places where they can either continue farming or find a service job. Some of them migrate to outer suburbs and live in poor conditions (Ahmed et al., 2009; Cottier & Salehyan, 2021).

This research will investigate the role of water scarcity and its relationship with the other factors that force farmers to migrate. For this purpose, the drivers that cause migration and factors that can aggravate water scarcity in the agricultural sector will be identified. As introduced in chapter 2, the social-ecological systems (SES) framework (Ostrom, 2009) is applied to analyze this problem, which is operationalized through the technique of fuzzy cognitive maps (Kosko, 1986).

1.2. Problem statement

Iran is located in an arid and semi-arid region and often suffers from drought. According to Daneshvar et al. (2019), the temperature in the Middle East will rise by 2°C over the next one to two decades, and precipitation will fall by 20%, but statistics show that Iran will face a 2.6°C higher temperature with a 35% decrease in precipitation and heat waves will also increase by 30%. Due to climate change, Iran's hot days and nights are increasing by 66%, while cold days are decreasing by 40.9% and cold nights are decreasing by 68.5%. The most precipitation falls in the central region of Iran during the winter, while the most precipitation falls in the northwestern region of Iran, near the Caspian Sea, during the autumn. Thus, climate change in Iran causes warmer days and nights, and precipitation in specific areas occurs only during specific months (Mansouri Daneshvar et al., 2019). In terms of the minimum temperature in winter and maximum temperature in summer, the mean of surface temperature has a huge raise, which explains why precipitation is decreasing, particularly during the winter (Mansouri Daneshvar et al., 2019; Waha et al., 2017). Therefore, agriculture, as a sector with a high water demand (approximately 70% of total surface and underground water resources), is one of the first concerns for people living in Iran's central region (Mohsenzadeh , 2021).

Isfahan is a province in Iran's central region with three distinct areas: mountains, plains, and deserts. Various agricultural and horticultural products can be grown in Isfahan due to its diverse climate in these areas. Isfahan has 3% of the country's agricultural lands and produces 6% of agricultural products, which indicates a greater utilization of available resources' (Alizadeh, 2021). Agricultural activities in the desert face numerous challenges due to soil salinity and water scarcity (Alizadeh, 2021). Climate change and a lack of proper management exacerbate these issues, as do existing industries with a high demand for water, causing people dependent on agriculture to migrate (Alizadeh, 2021). Agricultural production becomes more challenging due to several issues such as dam development, insufficient water resources, a lack of proper legislation, lower rainfall, and heatwaves. Many people in rural areas of Isfahan are forced to leave their homes after the Zayandeh-rud River, the province's largest and most important river, dried up, or to change occupations and work as a taxi driver, or do service work, or are forced to work as a laborer in nearby factories (anonymous, 2014).

The permanent migration of Isfahan's rural population is primarily to the city of Isfahan and neighboring cities (anonymous, 2021). They mainly move in search of better living conditions and a steady income, and the majority of them settle in urban slums with poor living conditions (anonymous, 2014). Seasonal migration occurs mainly in the winter and when farming conditions are unfavorable, and this migration is primarily to cities with labor opportunities at a median wage (Demont, n.d.).

As a group that is vulnerable to climate change and rely heavily on water, farmers have not received adequate consideration. However, there are no earlier studies that define the specific conditions for the farmers to help them maintain their resilience to changing climate conditions, which constitutes a scientific gap. This research will investigate the factors that can worsen the situation for agriculture and identify the conditions that cause people to migrate, particularly farmers.

1.3. Case study

Kafran is the center of the Rudasht district and one of Varzaneh's villages. Varzaneh is a city located in the province of Isfahan, 105 kilometers from Isfahan and 30 kilometers from the Gavkhoni marsh. The Zayandeh-rud river flows through Varzaneh, benefiting the city and its surrounding villages, including Kafran. According to the 2016 census, the Kafran's population was 3,679, with a total of 887 households. (National Statistics Portal, 2016).

Varzaneh villages are experiencing water scarcity, and villagers are migrating in large numbers. Both permanent and temporary migration from Varzaneh city and its villages are possible. Residents of this city, particularly Kaftan village, have both permanently and temporarily relocated. According to interviews with villagers and farmers, those who purchased tractors are working on other farmers' land in various villages, and some of the people are working for industries in their nearest industrial park, others in Isfahan city, and a few have moved to Yazd city.

People with tractors partially relocate to other villages during agricultural seasons, while those who work in industries live in a house near the industrial park and return to their village on holidays. Those who moved to Yazd or other cities, moved permanently but in years when there is enough available water, they will return to the village to farm.

Varzaneh city and its villages are heavily reliant on the Zayandeh-rud river, as are all agricultural cultivation, cattle, and other businesses in the villages. Drinking water was previously obtained from the Zayandeh-rud River or qanats in villages fed by the Zayandeh-rud River.

The district in which Kafran located is depicted in Figure 1. The Kafran shown by a black circle, and the Zayandeh-rud River can be seen in this district. Varzaneh city is shown in Figure 2.

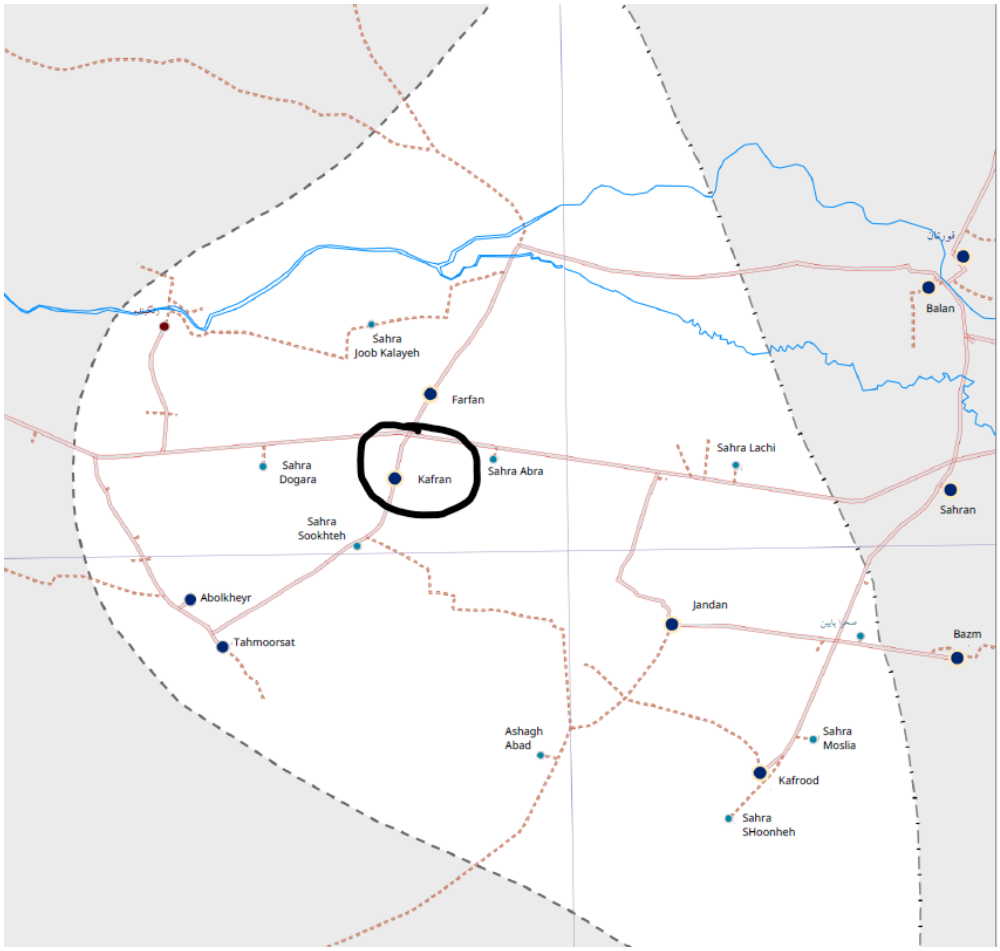


Figure 1. The location of Kafran village in west side of Varzaneh city

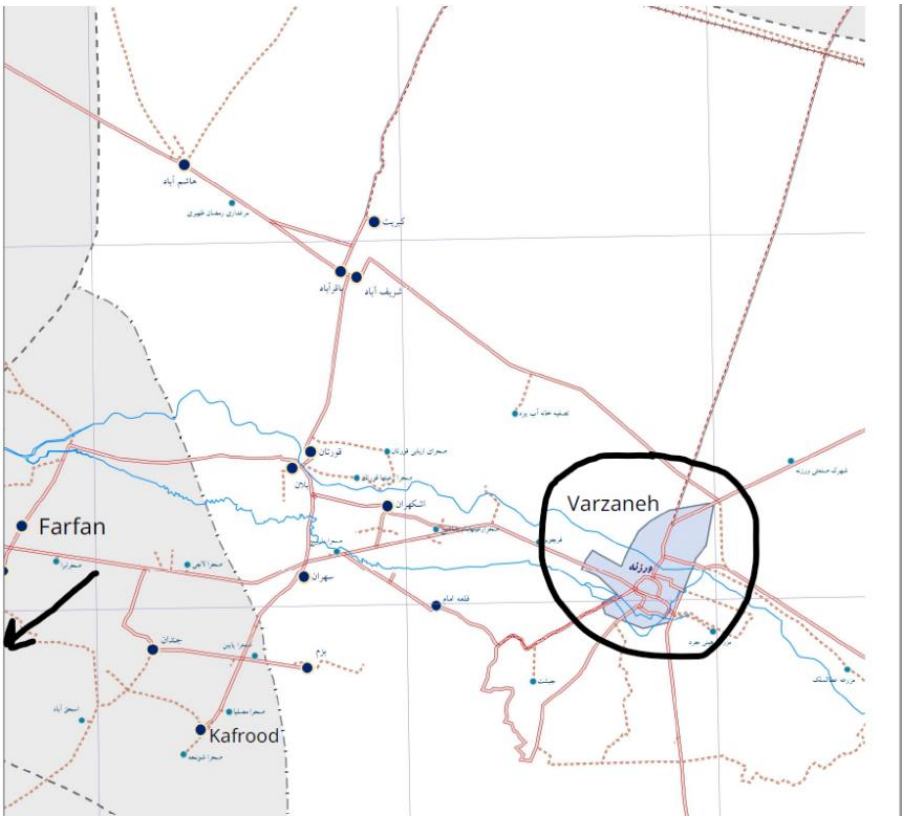


Figure 2. The location of the Varzaneh city

Zayandeh-rud River is the largest river in Iran's Central Plateau, starting in the mountains of the Central Zagros and flowing east for about 400 kilometers, ending at Gavkhooni lagoon, with a basin area of 41,524 km2. This river is now fed by several springs in the Zagros Mountains, but the first spring that water to this river was Chadegan and later the Zayandeh-rud Dam was constructed near this spring. Water from other springs in the same mountain chain was added later by constructing tunnels (Rahimi & Mohamadi, 2010). The location of the Zayandeh-rud River and its springs are shown in Figures 3 and 4, respectively.

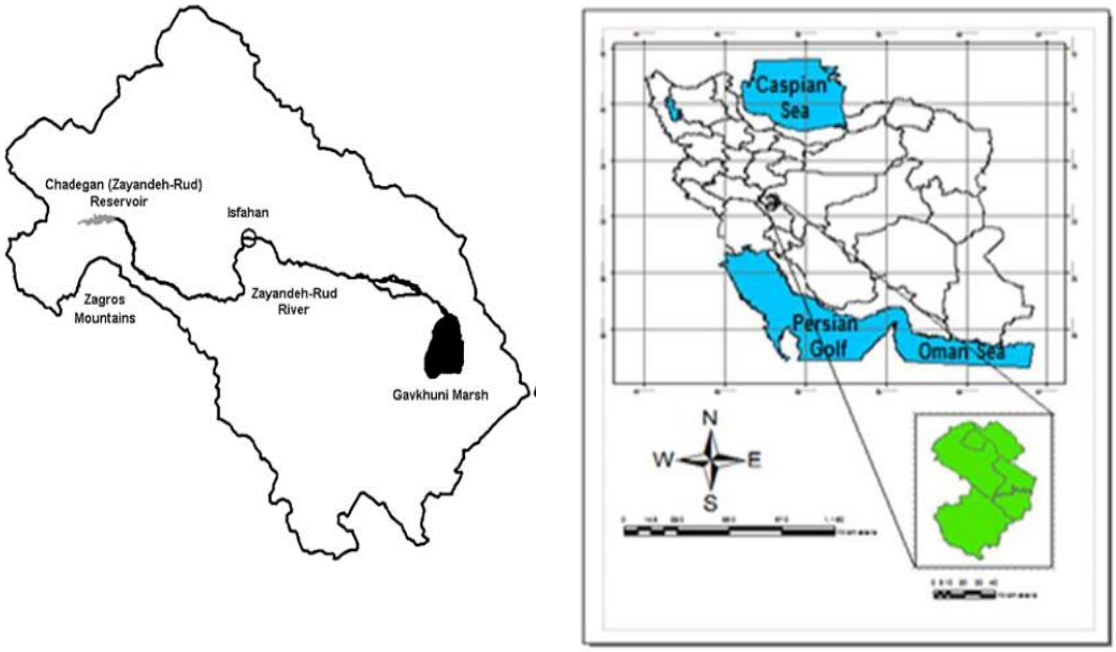


Figure 3. Zayandeh-rud River from its springs to the Gavkhooni Lagoon
Source: (Rahimi & Mohamadi, 2010)

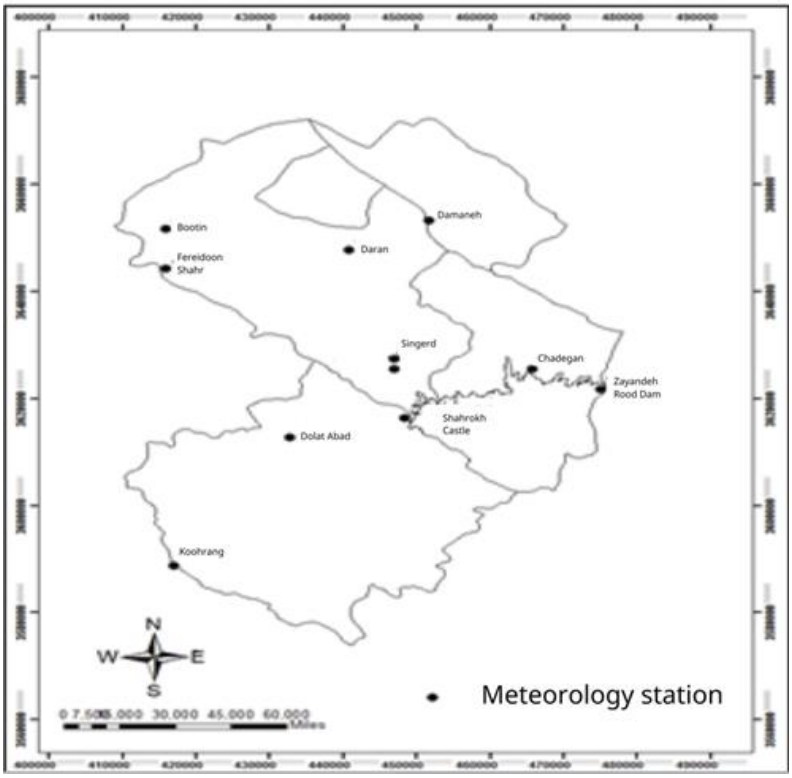


Figure 4. The location of the springs of the Zayandeh-rud River in the Zagros mountains

1.4. Research objective

The objective of this research is to identify the relationship between farmers' migration and water scarcity. To achieve this objective, the factors that can exacerbate or cause water scarcity and have a direct or indirect impact on migration flows are investigated. This relationship is conceptualized by applying relevant elements of the socio-ecological systems (SES) and institutional analysis and development (IAD) frameworks, and further operationalized by developing a model of the case study's SES through fuzzy cognitive mapping (FCM).

1.5. Research questions

The main research question is based on the geographical conditions in Iran. Climate change and other issues, such as dam construction, have an impact on this country's water resources. Finally, it causes issues for the agriculture industry and farmers' living conditions. Thus, the main research question is stated as follows:

> ***What are the effects of worsening water scarcity on the temporary or permanent migration movements of farmers in Isfahan, Iran?***

To answer the main research question, the following three sub-questions are formulated:

1. What factors worsen water scarcity in Isfahan?
2. What drives farmers in Isfahan to migrate, either temporarily or permanently?
3. How do changes in the water scarcity factors in Isfahan affect farmers' migration?

1.6. Thesis outline

The frameworks used for this research are introduced in Chapter 2, as well as the definition of complex adaptive systems and an overview of the effects of climate change on migration. The research design is covered in Chapter 3, which includes the research strategy, data source, data validation, and ethical considerations. The answers to sub-questions 1, 2, and 3 are explained in Chapter 4. The answer to sub-question 1 is in section 4.1, the answer to sub-question 2 is in section 4.2, and the fuzzy cognitive map is in section 4.3. Chapter 5 is the discussion section, in which the results are elaborated using the SES and IAD frameworks. The thesis is concluded in Chapter 6.

2. Theoretical Framework

This thesis investigates the factors that can exacerbate water scarcity and its effects on agriculture, as well as the factors that affect rural farmers' migration. The causal relationship between water scarcity and farmers' migration were identified and analyzed by applying the relevant elements of the SES framework and a model was developed using the FCM approach.

2.1. Climate change and migration

Climate change has various effects in different countries, with social, economic, and environmental consequences (Khanian et al., 2018; Waha et al., 2017). Some countries may become even drier and experience droughts and heatwaves, while others may experience severe and frequent floods, as well as long and extremely cold winters (Waha et al., 2017). As a result, given the current situation and the effects of climate change on humans and livelihoods, new policies and management systems should be considered. Otherwise, the consequences could be irreparable.

In the MENA region, temperatures increased at a rate of 0.2°C per decade between 1961 and 1990, and the summer temperature has risen above the global mean temperature (Mansouri Daneshvar et al., 2019; Waha et al., 2017). The temperatures are expected to rise further, reaching more than 8°C above the average summer temperature, and there are heatwaves in the summer months. Precipitation is expected to decrease in western Asia and northern Africa. Although an increase in precipitation is predicted for the southern part of the MENA region, this increase will be negligible due to the predicted increase in drought conditions and dry pattern of weather (Denton et al., 2015).

Agriculture and especially rainfed agriculture crops are extremely vulnerable to new climate conditions. Because of the decrease in precipitation and increase in temperature, farmers will face agricultural challenges. As water will be insufficient to meet agricultural needs, providing food will become a challenge, and the most vulnerable groups will be forced to migrate (Falco et al., 2018, 2019). Forced migration is one of the decisions that individuals can take in response to climate change (Cottier & Salehyan, 2021). There are also estimates that by the 2050s, many people migrate temporary or permanent because of environmental issues, which is a type of forced migration. (Falco et al., 2019).

According to Waha et al. (2017), people migrate when they lose their social, economic, physical, and political security. In developing countries, the impact of climate change on agriculture plays a significant role in rural migration (Rezaei et al., 2017). As previously mentioned, agriculture is a sector that is vulnerable to the effects of climate change, which can have both long and short-term consequences. Food insecurity, i.e., the availability of food as well as access to safe and healthy food (Falco et al., 2019) and economic insecurity, which can cause farmers problems, are among the main factors that contribute to farmers' migration (Falco et al., 2019; Rezaei et al., 2017).

Depending on the impact, migration from the rural areas may be temporary (seasonal) or permanent, and it may result in intercity and rural migration, as well as migration from one country to another. Persons who migrate due to environmental concerns are those who have had long-term difficulties (Cottier & Salehyan, 2021).

2.2. Socio-ecological systems framework

When there is a system comprised of variables that interact with each other, a small effect in one variable can cause changes in the entire system due to the causal relationship between the variables (Cox, 2011). Some variables, depending on their intensity and time frame, can have a direct or indirect effect. The relationship between agriculture, water scarcity, and farmers' migration can be conceptualized as such a system.

I employ the SES framework to analyze agriculture- and climate-induced migration. The SES is a general framework with specific sub-systems. The elements of this framework and their interaction with each other indicates the requirements of a system to be sustainable. These sub-systems fall into four categories: resource units (RU), resource systems (RS), governance system (GS), and users (U), each with their own components. Each of these subsystems interact with one another to produce a result at the system level. The relationship between the sub-systems and their components over time and space determines whether or not the overall system is sustainable (Ostrom, 2009).

The SES framework has several levels, the first of which, as previously stated, are the sub-systems of RU, RS, GS, and U. The components of each subsystem are demonstrated in Figure 5. This study is classified as a diagnostic study, implying that by analyzing the SES framework, the most important variables which have an impact on the problem can be identified (Cox, 2011).

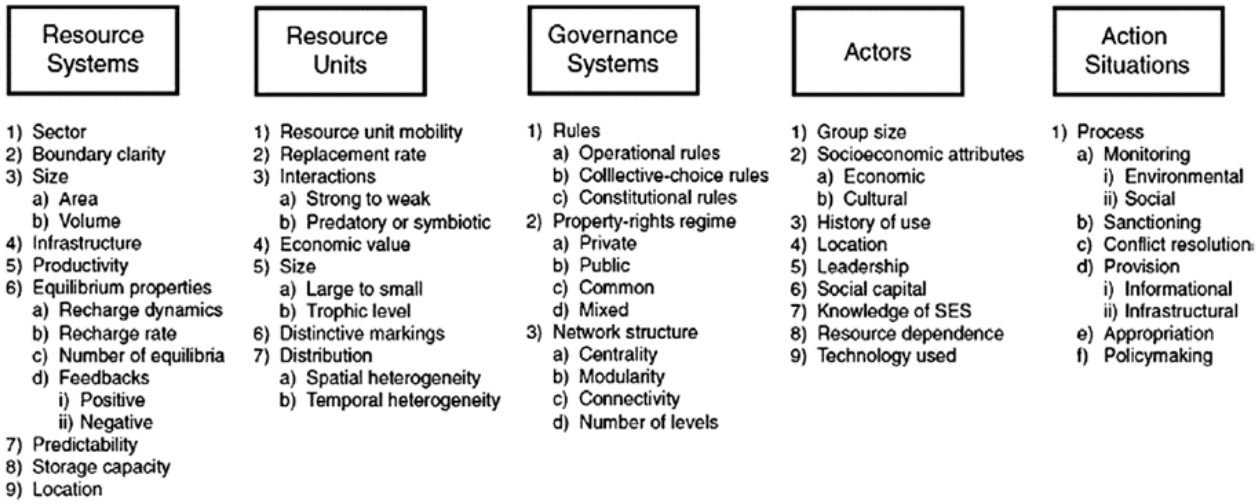


Figure 5. Social-ecological systems framework
Source: (Ostrom, 2009)

In order to analyze the variables that affect migration, I used the IAD framework. The IAD framework offers a systematic approach to analyzing a large volume of variables affecting the system (Oñate-Valdivieso et al., 2021). The IAD framework has three main elements: 1) existing institutions (rules and regulations), 2) the community, and 3) features of the environment in which the community exists (Oñate-Valdivieso et al., 2021). These variables are classified into three arenas: exogenous variables, action arenas, and external operational status, which form the foundation of the IAD framework (Ma et al., 2019).

Figure 6 shows the IAD framework adapted to analyze farmers' willingness to migrate from rural areas to urban areas in China. According to this adapted framework, farmers' willingness to migrate is influenced by a variety of factors such as family, living conditions in urban areas, physical condition of the environment, rules, land policy, income, and social security. This model divides the action arena

for farmer migration to urban areas into "situational awareness" and "intellectual decision model." Changes in exogenous variables can cause changes in external operational status and the action arena (Ma et al., 2019).

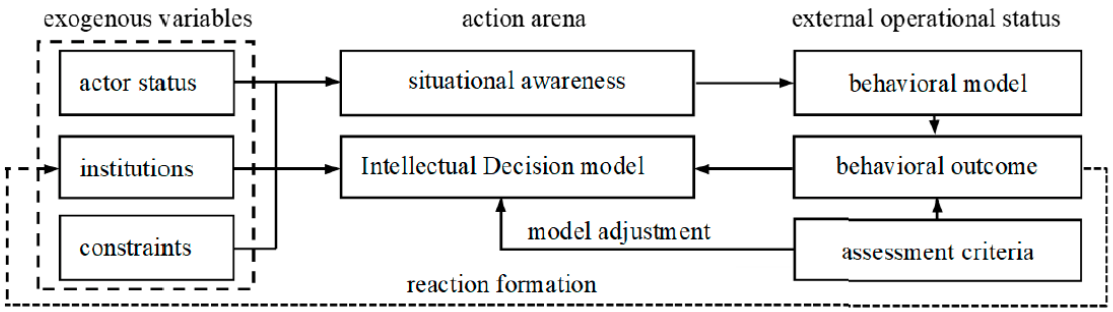


Figure 6. Adapted IAD framework of farmer's migration to urban areas
Source: (Ma et al., 2019)

2.3. Complex adaptive systems

Complex adaptive systems are open systems with agents that interact with one another and are difficult to separate, as well as the ability to adapt to new situations, as open systems freely exchange information and energy inside of their environment and agents. This feature can give rise to a new term, "emergence," which refers to the emergence of a new condition in a system. But since interactions occur locally in the system, the emergence of a new situation occurs first at the micro and local levels, and then at the macro level (Turner & Baker, 2019, 2020).

In addition to self-organization, emergence, and adaptation, complex adaptive systems have other features including, path dependency, irreducibility, and nonlinearity. Path-dependent systems are dependent on their initial state, to the point where the same change in systems with different initial conditions but the same current condition can act differently, as a small change in one system can have a huge impact while the same change in another system can have a small impact (Turner & Baker, 2019). Furthermore, the nonlinearity of these systems makes them difficult to predict because they respond differently to perturbation than simple systems (Turner & Baker, 2020). SES and IAD are both frameworks used in the case of complex adaptive systems.

This thesis is using Fuzzy Cognitive Maps (FCM) to operationalize the two aforementioned frameworks, and as a means for the complexity of the studied SES to be easily understood. Section 3.4.2 introduces further FCM as an experimental tool and its application to the present study.

3. Research Design

In this chapter, I describe the steps that must be taken to answer each of the sub-questions in order to come at the answer to the main research question.

3.1. Research framework

A research framework, according to (Verschuren & Doorewaard, 2010), is a schematic illustration of the research objective. It is made up of step-by-step instructions for addressing the research objective. The research framework is divided into seven steps (Verschuren & Doorewaard, 2010).

3.1.1. Research object

The first step is to identify the factors that contribute to water scarcity and impede water availability through interviews with experts and farmers. Review of water policies for households, agriculture, and industries in the Isfahan province. Conducting a review of the literature on the effects of climate change in the resource area. The second step is to look into the factors that influence migration. Finally, to comprehend how exogenous factors causing water scarcity can influence farmer migration.

3.1.2. Research perspective

In this study, I use the SES and IAD as the basis of my theoretical framework, which includes subsystems and different groups of components and helps to demonstrate their interaction. I investigate the contributing factors in criteria that worsen water scarcity based on these subsystems (as defined in the literature review) and selected components. After that, I apply the data collected to the FCM, which is a collection of policies, concepts, climatic situations, water-consuming industries, and factors that contribute to migration, such as income, health, and ecological situation.

3.1.3. Sources of the research perspective

In this study, I reviewed the scientific and grey literature to define the main concepts and empirical topics, and to discover the relationships between the outcomes. The concepts and topics that are discussed in this study are as follows: impacts of climate change on agriculture, drivers of migration, drivers of water scarcity, Isfahan's water problem, agriculture in Isfahan, permanent and seasonal migration. I used Scopus, Web of Science, and Google Scholar to search for and access to the scientific literature. For accessing grey literature, I mainly used Google Scholar and the websites of governmental organizations, and trusted websites which describe the current situation and institutional policies, statistical data, and the social structure in Iran.

3.1.4. Schematic presentation of the research framework

Following the determination of research objectives, it is critical to develop a strategy for achieving those objectives. As a result, the steps are designated as A, B, C, and D in the schematic representation of the research framework for Kafran Village in the Isfahan province (Figure 7).

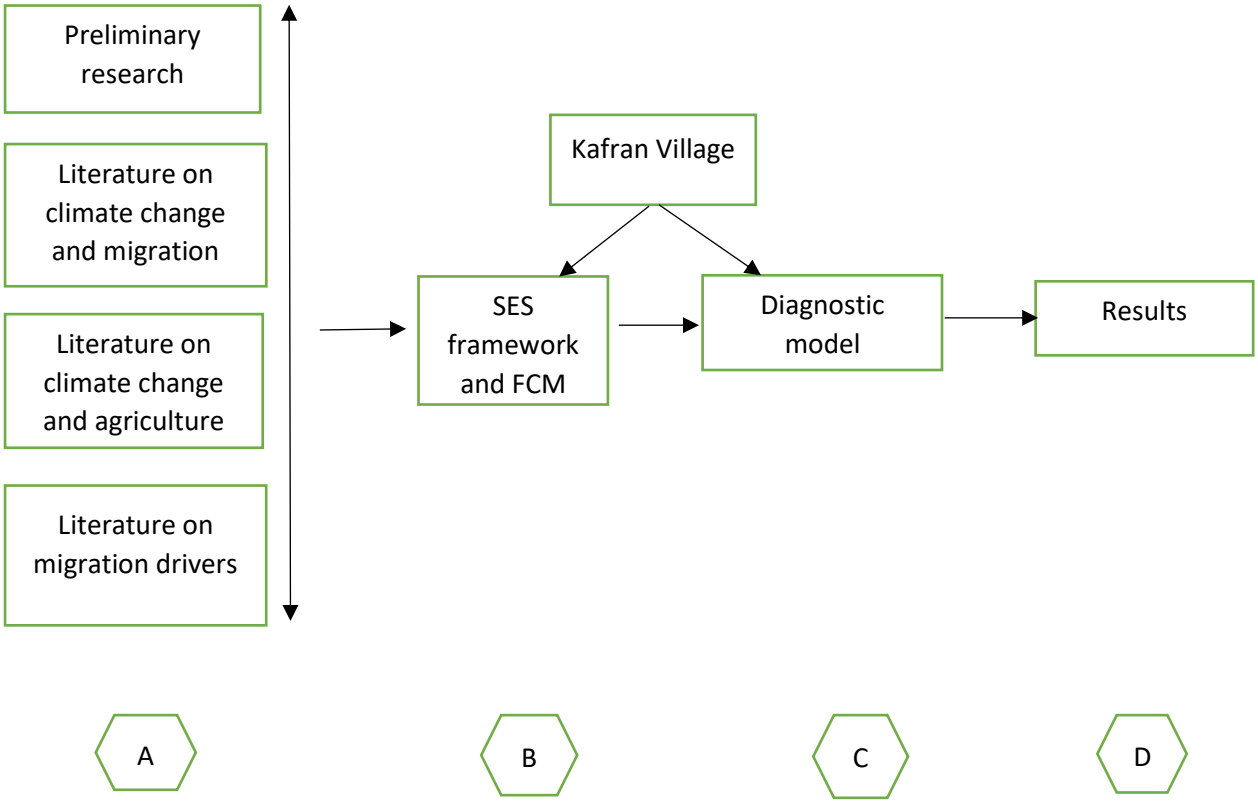


Figure 7. Schematic representation of the research framework

A: Conducting the preliminary research and going through literature review for relevant topics as mentioned in the scheme above, using gray literature and interviews to make it specific for Isfahan city and migration of farmers.

B: using the IAD and SES frameworks to categorize the system components, and to describe the system with specific elements, which will lead to the development of a theoretical framework.

C: using the data collected from desk research and interviews to apply the theoretical framework and then the FCM.

D: analyzing the data and their causal relations to reach the result in terms of the effects of water scarcity on farmers' migration decision.

Using the FCM, I will investigate the effect of each component, primarily on migration, ranging from climate change to the situation of environmental change. After that, I will create two scenarios and change the strength of the interactions between the drought and the other variables to see how they affect the migration pattern. The scenarios are described in Table 1.

Table 1. Applied scenarios

Scenario	***Description***	***Changes in causal relationships simulated from scenarios A, B, and C***	***What the scenario aims to say.***
A	Reduction in industry and, as a result, less water dedicated to this sector	Asymmetry in power, urbanization, water transferred from other resources, change in basin management and increase in number of stakeholders	Examining how industry reductions can reduce drought and, ultimately, migration rates
B	Assuming there has been no change in water management boundaries, which have remained as basin boundaries and are not changing at the provincial level.	Change of Basin Management (CBM) to industries, CBM to mismanagement, CBM to numbers of stakeholders, CBM to water transferred to other cities.	Examining how changing the water management boundaries can affect the drought and then migration
C	Reduction in the climate change effect on migration	Climate change to mismanagement, climate change to drought	Examining how migration would change if the impact of climate change was reduced.

3.2. Research strategy

This research involves a systematic investigation in Kafran village, which is located in Isfahan city in Iran.

Following the news about Isfahan, I learned that the province is dealing with water scarcity, particularly in the east of the province. With the help of friends and colleagues in Isfahan who are active in the tourism industry and have a good knowledge of the villages, I discovered that Varzaneh city and its villages have the most problems. Following that, an interview with a university professor assisted me in selecting the Kafran village because the scope was smaller and it was easier to find farmers than the Varzaneh city. In the first step of this study, I identify the factors that affect water scarcity in Isfahan, such as urbanization, industrialization, top-down management approach, etc.). In the second step, I identify the factors that can force affect farmers' decision to migrate with regards to environmental, health, economic, and societal dimensions. In both steps I apply the SES and IAD framework. Then, I use FCM to examine the effect of the components of the resulting system on each other.

To conduct a feasible research within the specific timeframe of the MEEM programme, I have narrowed my topic to rural areas in Isfahan province. By using the SES and IAD framework with definite components I developed my research based on these components.

3.3. Data sources and collection methods

Table 2 provides an overview of the data sources and collections methods that were used to answers the three sub-questions.

Table 2. Data sources and collection methods

Research Question	Data/Information Required to Answer the Question	Sources of Data	Accessing Data
What factors worsen water scarcity in Isfahan?	- Implemented Policies - Resources available - Actors - Climate change effects - Industries effects - Management methods	- Scientific and gray literature - Experts - Media - Governmental organizations	- Desk research for the definition of water scarcity, thresholds, and water availability, implemented policies and local customs in Isfahan - Interviews with experts on the available resources and the effects of share of industrial, agriculture and drinking water
What drives farmers to migrate, either temporarily or permanently?	- Predictability and situational awareness - Actions taken by authorities and farmers - Economic effects - Environmental conditions - Social effects - Ecological services effects	- Farmers - Scientific and gray literature - Media	- Interviews with farmers to understand their living conditions - Desk research to find scientific and grey literature on factors and their definitions
How do changes in the water scarcity factors in Isfahan affect farmers' migration?	- FCM study - Diagnosis steps - Information and data gathered from previous questions	- Farmers - Scientific and gray literature	- Interviews with farmers to see what variables have the most impact on their livelihood - Desk research to identify the steps for making a FCM

3.3.1. Desk research through document reviews

For this study, I primarily use peer-reviewed literature from Scopus and Web of Science, and Google Scholar for grey literature. Literature sources were used to identify the main water scarcity problems in Isfahan and the factors that may contribute to farmer migration. The keywords for the literature search are "water scarcity", "MENA", "Middle East", "agriculture," "farmer migration," "Iran" and "Isfahan". I also looked to the references used in the articles for additional data before using more specific keywords. I also reviewed grey literature and websites to find statistics and current news, which helped me understand what factors affect water scarcity in the province of Isfahan.

3.3.2. Interviews with experts and farmers

I prepared a guide for the interviews with experts and farmers, which assisted me in connecting the concepts discovered in the literature review. Both types of interviews are based on the SES and IAD frameworks and include multiple sections.

I interviewed seven farmers in Kafran village near Isfahan, which is affected by water scarcity and migration. Since some farmers may have difficulty writing their thoughts down, I requested a one-hour oral interview to focus on the factors that may encourage farmers to migrate. The guide for the farmer interviews included five sections: 1) farmers' awareness to investigate their preparedness for water scarcity and know possible solutions, as well as whether or not they would have chosen migration if they were aware of this problem; 2) the regime of users from a specific water resource to investigate how these users can affect water availability and cause migration; 3) the impact of institutions and their legislation on farmers; 4) the scope and consequences of Actions taken by authorities and farmers to provide solutions and, ultimately, limit migration; 5) reasons may encourage farmers to migrate as an intellectual decision model and actor status. To investigate which factors, including environmental, economic, political, social, and ecological, have the greatest impact on migration (The interview guide for Farmers is available in Appendix 1).

Overview of interviews with farmers and is presented in Table 3. I added the farmers' current occupations to the table, though all of them used to be farmers. I attempted to speak with farmers of various ages to see how people of different generations and different physical abilities react to water scarcity in their communities. The youngest is 28 years old, and the oldest is 76 years old.

Table 3. Overview of interviews with farmers

Code	**Age**	**Current occupation**	**Living area**	**Interview date**	**Interview duration**
Farmer interview 1	76	Unemployed	Kafran	15/06/2022	60 minutes
Farmer interview 2	63	Unemployed	Kafran	15/06/2022	48 minutes
Farmer interview 3	60	Unemployed	Kafran	15/06/2022	55 minutes
Farmer interview 4	50	Plumber	Isfahan	16/06/2022	45 minutes
Farmer interview 5	38	Working in industry	Yazd	24/06/22	66 minutes
Farmer interview 6	32	Working In industry	Isfahan	17/06/2022	39 minutes
Farmer interview 7	28	Carpenter	Isfahan	16/06/2022	65 minutes

For the interviews with experts, I involved academics and practitioners. I send invitation emails to academics at universities in Iran, who have published on farmer migration and water scarcity in Iran, as well as the practitioners who work at the Water and Sewerage Company in Isfahan, to obtain data (including statistics and records) from them and to inquire about the main problems they are facing due to water scarcity. As shown in Table 4, I interviewed one academic and two practitioners. (The interview guide for experts is available in Appendix 2).

Table 4. Overview of interviews with experts

Code	**Position and organization**	**Interview date**	**Interview duration**
Expert interview 1	Professor at Isfahan University	17/06/2022	68 minutes
Expert interview 2	Employee at Ministry of Agriculture	20/06/2022	51 minutes
Expert interview 3	Employee at Water and Sewerage Company	13/07/2022	55 minutes

3.4. Data analysis

To analyze the collected data, I first created codes based on the most important elements and variables affecting migration by reviewing the scientific and grey literature. These codes include policy, the effects of climate change, and other variables. Parallel to this step by identifying the codes, I transcribed the interviews by hand and analyze them on paper making charts. Then, I categorized the information based on the codes defined in the literature review and data given by the experts, practitioners, and farmers.

3.4.1. Analysis of data from document reviews and interviews

It is important to follow a plan in order to conduct orderly research and produce clear output. Regarding this, I used the SES and IAD frameworks for each step of the reviews and analysis. I used the SES subsystems of resource systems, resource units, and governance systems for the first step. Actor status, institutions, and constraints from the IAD framework are used for this step. According to these frameworks, I went over the document reviews and discussed the issues that this village is facing. The first document dealt with the region's water resources, while the second dealt with management methods and policies. After that, I went over the factors that can cause issues when allocating water to agriculture, which was industry and urbanization. After reviewing these documents and coding the expert interviews, the answer to sub-question one was discovered.

Then, for the factors influencing migration from rural to urban areas, I used the actors and action situation subsystems from SES and intellectual decision model, situational awareness and assessment criteria from IAD framework. I looked for articles that discuss reasons for migration, such as the environment, the economy, and health. The answer to sub-question two is found by coding the interviews and reviewed articles.

3.4.2. FCM construction

Sub-question 3 is answered with the causality map of FCM. This FCM is based on the effects of sub-question one and sub-question two on one another.

The main concepts and elements should be clear before creating the FCM based on the interviews and literature review. Because the FCM is built on the answers to sub-questions 1 and 2, the questionnaires from the interviewees, both farmers and experts, were included with the data required to understand the problems in different sections. These questions are from the SES and IAD frameworks. The IAD framework specifies how various factors are related to one another. Along with the interviews, I conducted a literature review on why farmers migrate, how different laws and policies affect water scarcity, what role climate change plays in water scarcity, and so on. I came up with links between the concepts using the literature review and the IAD framework introduced in Figure 6. The strength of each interaction is determined first by the interviews and then by the support provided by the literature reviews for the specific links and concepts.

FCM aids in the understanding of a system by identifying key concerns and displaying the relationships between its components (Nápoles, 2020). In this thesis, causality is defined as the fact that A can cause changes in B, whether positive or negative. Directional arrows with positive or negative weights and nodes indicate the components used to draw the FCM (Nápoles, 2020). The inhibitor relation is indicated by the negative arrow, whereas the stimulus relation is indicated by the positive arrow. Furthermore, the intensity of the arrows that connect the nodes can be specified. The numbers range from -1 to +1, with +1 indicating the strongest positive relationship between two components and -1 indicating the strongest inhibitory effects between two components. This aids comprehension of the system and how active the variables are in each causal relationship (Kosko, 1986; Nápoles, 2020). The action of assigning weights to qualitative relationships allows for the exploration of more diverse

scenarios and the examination of various situations (Özesmi & Özesmi, 2004). To avoid alternating and non-finite functions, FCM employs four convergent transfer functions. These transfer functions are responsible for keeping the values in the (0, 1) or (-1, +1) intervals. The four transfer functions are bivalent, trivalent, sigmoid, and hyperbolic. I used the hyperbolic function in this study first, because it is in the (-1,+1) intervals and includes all the integers in this interval. The factors contributing to my research have different intensities of impact on each other, and the variables consist of both positive and negative values, thus the interval of (-1,+1) is necessary. The second feature is its linear behavior around y=0. The formula is as follows (Koutsellis et al., 2022; Papageorgiou et al., 2020):

Hyperbolic tangent function: $f(x) = \tanh(\lambda x)$, where x is the outcoming value from a concept, tanh denotes the hyperbolic tangent, and λ is a user-defined parameter that controls the slope of the curve as shown in Figure 8. The purpose of this transformation is to convert the sum of changes in the concept, caused by all the incoming values from all around the FCM, back to the [-1,+1] interval.

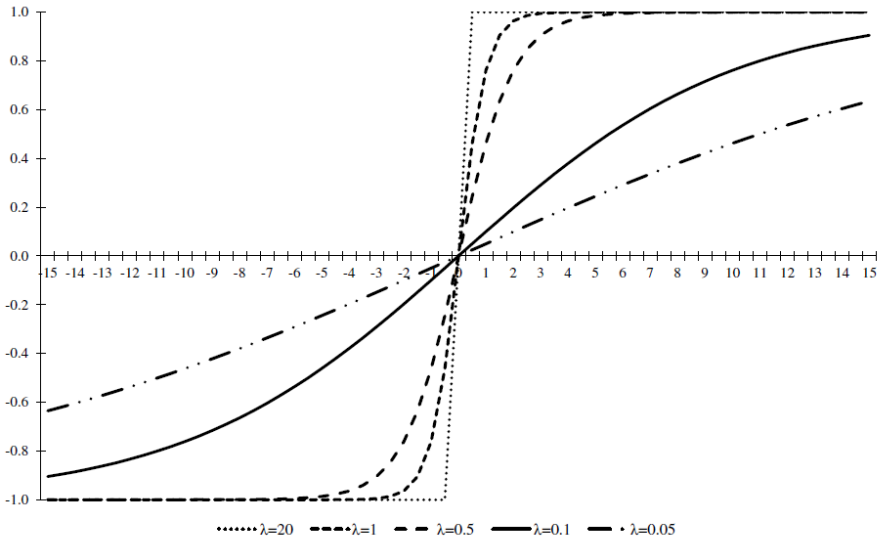
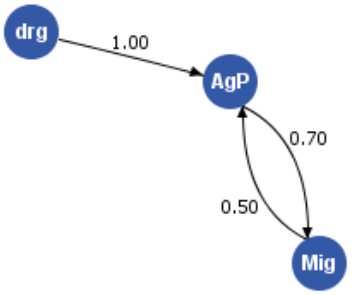


Figure 8. Hyperbolic function diagram

Let's assume that drought has affected agriculture in a region of Isfahan, making it difficult to do farming and maintain the agriculture and resulting in the migration of farmers. This will serve as an example of the FCM and causality matrix. Here, we can assert that the agricultural problem is positively impacted by drought. Drought has a high influence on agricultural problems, which I rate as a 1.00 with a positive sign. Assuming that more agricultural problems, i.e., lack of proper farming conditions, can cause farmers to migrate from that specific area in Isfahan, I conclude that agricultural problems have a positive and high impact on migration. I also assume that this influence is greater than medium but less than full, so I assigned a positive sign to the number 0.70. As a result, increased migration of farmers from that region may exacerbate agricultural problems, meaning that there are fewer farmers to work in agriculture. Then migration has a positive impact on agriculture as well, but I gave it a medium rating of 0.50.



Caption: Causality matrix of drought impact, agricultural problems and the migration of farmers

drg: drought , AgP: agricultural problems , Mig: migration

3.5. Data validation

For the data validation, I used data triangulation. Triangulation is a method of validating data by combining multiple data sources to produce a valid result. There are various types of triangulation, but the one I intend to use is *method triangulation*, which is used for qualitative studies and consists of observations and interviews, which will be applied in the FCM. In my case, both interviews and the literature review align. The literature review completes the data I obtained from the interviews.

3.6. Ethical considerations

I followed the ethical assessment procedure as required by the University of Twente to ensure that interviewees are informed about the scope and objectives of the research, and they are not put in a dangerous or uncomfortable situation. Because of political issues that the government may cause for farmers in Iran, I asked them in advance if they are willing to participate in my research or not. I assured them that this is an academic research and no political issues that may put them in dangerous situation is involved. I explained my thesis topic and how long the interview may take. I also explained the data I need to gain from the interviews (Please see Appendix 3 for the informed consent form).

4. Results

Based on the data sources and collection methods outlined in section 3.3, I present the findings in relation to sub-research questions 1, 2 and 3. Sections 4.1 contains findings to sub-question 1, and sections 4.2 contains the findings for sub-question 2 and section 4.3 contains the findings of sub-question 3 and the scenarios.

4.1. Factors that cause or exacerbate water scarcity in Isfahan

As previously stated, several factors contribute to water scarcity in Kafran village. The following sections examine the effects of climate change and the factors that contribute to mismanagement of water allocation and harvesting.

4.1.1. Governance, implemented policies and management problems

In this section, I will discuss how water resources are among the government's assets, the applicable laws and rules on water distribution and rights, management approaches, the raised problems, and then the solutions proposed by the government, followed by the effects of the solutions implemented in the province.

Because Iran has limited water resources and is a large country, the government has proposed various management methods. These management methods have been proposed without regard for the local community and only with the intervention of the government (Kamal et al., 2021). As it is mentioned by Nabavi (2017), usually Surface water resources can cause asymmetry in power for water exploitation, causing upstream users to make problems for downstream users. Water distribution can fail in a system with a single organization with total power. Following the establishment of the Islamic Republic of Iran, the new government passed the Law on Equitable Distribution of Water in year 1983 based on the idea that water is not distributed fairly among people. Which states that water resources are the government's assets (Nabavi, 2017). Any exploitation of these water resources requires the government to issue a permit in the presence of an expert approved by the government. These experts are responsible for determining the amount of required water and the capacity of the resource (Kamal et al., 2021; Nabavi, 2017). The governmental authority that has control over and responsibility for managing the water resources is the Ministry of Energy.(Kamal et al., 2021; Nabavi, 2017)

The Law on Equitable Distribution of Water outlines the duties of the ministries of energy and agriculture: the allocation and permission to exploit public water resources for drinking, agriculture, industry, and other purposes is solely with the Ministry of Energy. However, the distribution of agricultural water, billing for water, and supervision are the responsibility of the Ministry of Agriculture (Law on equitable distribution of water, 1997). According to Expert interview 3 "having only one or two ministries in charge of water management is a suitable method due to the limited water resources that one ministry is in charge of, but they should also have an integrated program in order to overcome the problem, rather than just solving the current ones. This mismanagement is causing drought in some parts of the country. Not having an integrated program to solve the root of the problems is one of the reasons exacerbating the drought, which is considered mismanagement of the involved organization.

On one hand, different management problems, such as conflicts between two different users (the industries and agriculture sector) caused by governmental organizations, exist in various parts of Iran. Only the government can solve these problems, since it is legally held responsible to solve the problems. On the other hand, difficulties in water management in Iran, a vast country with limited water resources, has been exacerbated by climate change, urbanization, industrialization, and years

of drought, which results in more conflicts and victims with limited water rights.(Kamal et al., 2021; Nabavi, 2017).

In recent decades, two major approaches to water resource management in the country have been proposed: the top-down approach and the bottom-up approach. Top-down approach, also known as centralized management, is a management style that emphasizes the organization's ability to carry out tasks. This management method is known as an effective way to achieve complex system balance and efficiency in case of common resources (Weimer & Vining , 2017). For many years and still today, the country's water management has relied on a top-down management, which has encountered new constraints as a result of the conflicts in different sectors and asymmetry in power mentioned in the preceding paragraph.

Iran's water crisis is seen as a result of trying to fix the symptoms rather than identifying the causes (Madani, 2014; Expert interviews 2 and 3). The three main causes of the water crisis are identified as follows: 1. a growing population and an uneven distribution of people in cities. 2. Not efficient agriculture regarding to water capacity 3. poor management and a desire for growth, which are explained in the following paragraphs.

According to statistics, the population of Iran as well as Isfahan has increased dramatically since the establishment of the Islamic Republic of Iran, resulting in a reduction in the available amount of renewable water resource per capita. additionally, the overexploitation of fossil waters has occurred. And now, with frequent years of drought causing water scarcity, people are forced to migrate to cities, which can provide better living conditions (Madani, 2014).

This migration and excessive population growth to cities occurred without proper distribution. In Isfahan, in order to supply water from the spring in the Koohrang mountains to the Zayandeh-rud River, two large tunnels named the Koohrang tunnels were built in Isfahan to meet the needs of such a large province's drinking water demand, agricultural water demand, and industrial water demand. Although this solution was a response to water scarcity, the assumption of sufficient water availability led to more migration and the emergence of large industries in the region, which in turn worsen the situation and led to severe water scarcity (Madani, 2014; Madani & Mariño, 2009).

Despite the fact that the Islamic government has attempted to provide a suitable condition for agriculture in order to improve food security, this sector has not been as effective in GDP as the government had hoped for. The rural community and farmers are then not taken into account in order to properly educate and empower them (Madani, 2014). During the years of war between Iran and Iraq, the majority of water resources, particularly groundwater resources, were dedicated to the agricultural sector. However, the economic efficiency of this sector has declined over time. Its contribution to GDP fell from 33 percent to 13 percent between years 1980 and 1988 (Madani, 2014). These were primarily caused by a lack of a proper crop cultivation program based on the appropriate regional planning and available water resources. Because of climate change and changing rainfall patterns, rainfed agriculture has become unproductive in some areas. Farmers were considering changing their occupation due to low income and low product prices.(Madani, 2014)

Iran is investing more and more in industrial development alongside agricultural development. One of the victims of this development is the Zayandeh-rud River. In 2005, the president of the time proposed a new management program to shift water management boundaries from watershed (basin) boundaries to provincial boundaries in order to provide water for different regions of a province to establish industry and help the economy of provinces. This shift increased the number of stakeholders exploiting water from the basins and caused conflicts among the stakeholders and different sectors,

such as industry and agriculture. (Kamal et al., 2021; Madani, 2014). This focus on industry and industrial growth, combined with the ministry of energy's monopoly on water allocation and exploitation rights, makes the agricultural sector vulnerable to mismanagement and drought periods. to the point where investment and a desire for growth in one sector (industry, economy) can cause problems in another (ecosystem and agriculture) (Madani, 2014).

According to article 7 of the equitable water distribution law's water right section*, the priority for consumption is for drinking water, horticultural water, agricultural and animal husbandry water, and industrial water, respectively*. (Law on equitable distribution of water, 1997). This article indicates that agricultural water rights take precedence over industrial water consumption. Later in this article, it is stated that *"if the implementation of development programs and economic plans requires, the ministry of energy must take the necessary decision due to changing the priority of agricultural, industrial, and mineral consumption by consulting the ministry of agriculture."* Which indicates why the industry have water rights while the agriculture doesn't.

Regarding water allocation the first priority in the province of Isfahan is drinking water and power generation, and the second is industry, the agriculture depending on the value it brings receive different importance (Farmer interviews 4, 6 ,7 and Expert interviews 2, 3). This situation indicates an asymmetry in power for different sectors. According to all of the farmers interviewed, Farmers from Varzaneh's various villages protested, requesting their water rights for agriculture behind the doors of the industries. As one farmer : *"Those who have tractor alongside the other farmers, we went to the Mobarakeh steel industry for several days in a row to ask for water, but no one responded to us."* (Farmer interview 7).

4.1.2. Interbasin water transfer to Zayandeh-rud River

The Zayandeh-Rud Basin is an example of a watershed with multiple stakeholders, including domestic water users, industrial users, and a large agricultural industry that is experiencing water scarcity due to a lack of experts and knowledge about the interaction of these subsystems (Madani & Mariño, 2009).

An order was issued in 1922 to connect the water of Koohrang spring (another spring in the Zagros mountains), to the Zayandeh-rud River, which resulted in the construction of the Koohrang tunnel 1. However, construction of this tunnel began many years later, and the water transfer occurred in 1952. Koohrang spring is one of the main resources that fed another river named Karoon in the southwest of the country, which is now very crucial and important for the Zayandeh-rud River water supply. Table 5 shows the steps of the water exploitation program and supplying the Zayandeh-rud River.

Table 5. The Zayandeh-rud River basin from a system dynamics analysis perspective

Year	Description	Annual capacity (MCM)
before 1952	Zayandeh-rud River Exploitation	NA
1952	The first Kuhrang transbain diversion tunnel is built.	337
1972	Chadegan (Zayandeh-Rud) Dam Construction	1,500
1985	The second Kuhrang transbain diversion tunnel is built.	250
2004	The Cheshmeh-Langan transbasin diversion tunnel is built.	150
2007	The third Kuhrang transbain diversion tunnel is built.	280

Source: (Madani & Mariño, 2009)

Prior to 1952, the main source of water was a diversion of the Zayandeh-rud River from Chadegan reservoirs for agricultural users and feeding the qanats and wells. Because this river basin was one of the rich-water basins, agriculture and industry began to form nearby. and the human migration began. As a result, the water demand increased. To meet this demand, the Koohrang tunnel 1 was built to supply more water to the river. As the river became more water-rich, water-distribution projects among other cities, including Yazd and Meibod, which are not included in this water basin, began. Because these cities are located in arid regions, this water transfer has become very important, and the government cannot stop the water flows to these cities. As a result, the condition and quantity of water in the Zayandeh-rud River are becoming increasingly important not only for the province of Isfahan, but also for other cities in the province's surrounding neighboring area. As previously stated, these diversions and tunnel construction shaped a belief that there is enough water available to start different industries, transfer water to other cities, and even boost ineffective agriculture (unsuitable due to water capacity, location, and climate condition) in the area.

During Rafsanjani's presidency in the 1989 till 1997, there were years when too many dams were built with the goal of development and becoming more industrialized. Zayandeh-rud (Chadegan) Dam is one of them. The dam was built to generate electricity and provide water to cities and industries, including the Mobarakeh steel industry, which has a high water demand. Water demand increased due to the emergence of industries, increased urbanization, and increased agriculture industry. To answer this demand, two other tunnels were built to supply water to the Zayandeh-rud River in 1985 and 2005, respectively. Later in 2007, the construction of another tunnel began, but is still not usable. Nonetheless, Koohrang is a vital source of water for the Zayandeh-rud River, which is located in the same basin as Chadegan.

Tunnel construction and the use of other water resources can indeed enrich the Zayandeh-rud River and increase its capacity. However, having enough available water resulted in the establishment of more industries, urbanization, the expansion of the river basin boundaries, and, as previously stated, inefficient agriculture. All of the water transferred to the Zayandeh-rud Basin is used for the purposes stated above. Despite the fact that the capacity of the Zayandeh-rud River has increased, the basin faces numerous problems during the drought years. According to scholars such as Madani and Mariano (2008), this water transfer from different resources to this basin has caused drought in other basins, which is beyond the scope of this study.

4.1.3. Effects of climate change on the Zayandeh-rud Basin

Climate change and its consequences have resulted in the reduction of water volume in the Zayandeh-rud Dam, flow volume, and a significant drop in static level (Rahimi & Mohamadi, 2010). Rahimi and Mohamadi (2010) investigated the hydrological drought in the resource basins in the Zagros mountains (where the Zayandeh-rud resources are located) as depicted in Figure 4. Hydrological drought monitoring is carried out using data from hydrometric stations (river flow information), lake and reservoir water levels, and underground water levels. The upstream conditions and changes in the watershed in that location influence the flow information and water level of the reservoirs, and the underground water is also influenced by the parameter of feeding on surface water and incoming flows (Rahimi & Mohamadi, 2010).

According to expert interviews 1 and 2, the Zayandeh-rud River's resources are located in a mountainous region, and the most common form of precipitation in this region is snow. Because of climate change, precipitation has shifted from snow to rain, exacerbating water scarcity. Precipitation in form of rain easily causes flash floods, and it is difficult to store the water and use it throughout the year. While precipitation in the form of snow has a longer durability and usually begins melting in the

late spring or early summer and then flows in the river, there is water available during the hot months of the year.

To analyze the effects of climatic and hydrological drought, Standard Precipitation Index (SPI) and Surface Water Supply Index (SWSI) were compared by Rahimi and Mohammadi (2010) in the resource basin of Zayandeh-rud. SPI is a climatic drought indicator in this study, while SWSI is a hydrological drought indicator. As shown in Figure 9, the columns showed as SPI and SWSI are compared to one another. Changing the SPI causes changes in the SWSI. SPI changes range from +2 to -2, while SWSI changes range from +3 to -3. Rahimi and Mohammadi (2010) found out a positive relationship between SPI and SWSI. With the increase of the climatic drought, the hydrological drought also increases. These conditions demonstrate that the basin's hydrological regime is highly sensitive to climatic droughts. Furthermore, the time lag between climatic and hydrological drought is approximately 1-2 years (Rahimi & Mohamadi, 2010). In the next paragraph, I explain the climatic and hydrological drought frequency in the resources of the Zayandeh-rud Basin.

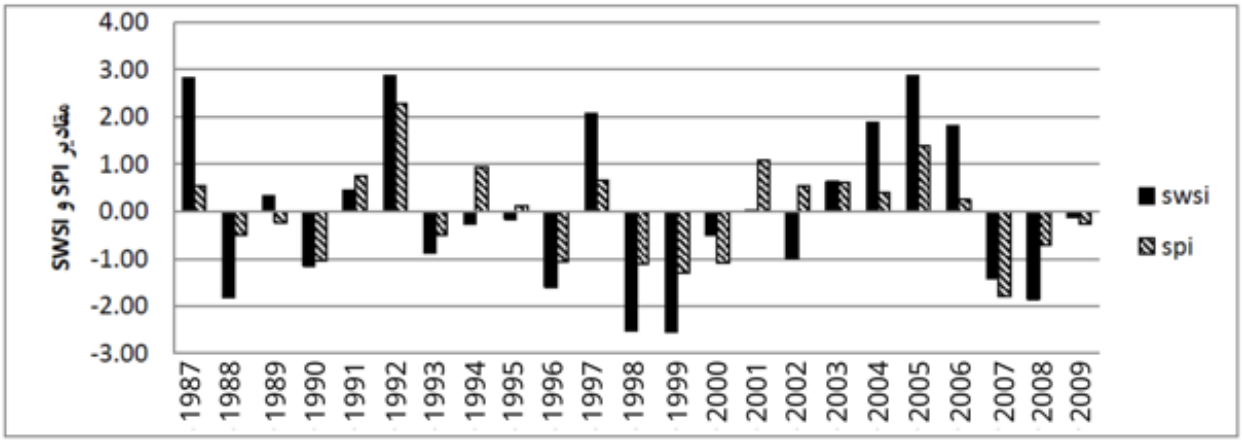


Figure 9. SPI and SWSI from 1987 until 2009
Source: Rahimi and Mohammadi (2010)

According to (Rahimi & Mohamadi, 2010), from 1987 until 2009, climatic and hydrological droughts played an important role in lowering the basin's flow coefficient and base discharge value. The impact of these droughts has resulted in a 50% decrease in precipitation at the Koohrang station in 2008, which was the milestone of drought in the studied years. In the drought years, the flow pressure has decreased by 33% of the base discharge. Drought frequency has increased in recent decades, occurring more frequently and with greater intensity. This basin's hydrological drought occurs almost every three years (Rahimi & Mohamadi, 2010). The same drought sequence in the following years is happening, with minor variations in the numbers, but the conclusion remains the same. Some years have very severe droughts, and some years have better precipitation. (Expert Interview 3).

4.1.4. Isfahan as an industrial hub in Iran

Isfahan is known as one of the industrial hubs in Iran, and industrial parks are a collection of industrial units, workshops, and production and service factories that have been established and launched in the suburbs of Isfahan's surrounding cities in industrial areas. The goal of clustering industrial units next to each other in the form of industrial towns is to increase output and create opportunities for export and investment. (economic news , 2022).

There are 72 industrial parks in the province of Isfahan, each with a specific purpose, such as textile, refractory bricks, greenhouse products, home appliances, steel, paint, active pharmaceutical ingredients, and many other factories. (virgool, 2018) According to experts, "*Being an industrial hub*

in Iran has provided job opportunities for many people, and as a result, many people have migrated to Isfahan city, and urbanization has increased. 60% of the people who live in Isfahan were born in Isfahan, with the remainder coming from other cities from different provinces. This number drops to 20% in the other cities in Isfahan province due to their importance and proximity to industrial towns." (Expert interview 3).

Steel plants are among the most water-intensive industries. One of these plants that has had an impact on the Kafran village is the Mobarakeh Steel Company, which is located upstream of the river basin and, according to all farmers and experts, is one of the reasons that the water farmers from Kafran village and other villages near Varzaneh City need for agriculture is being used for this steel plant. Even though it is claimed that only a small portion of the Zayandeh-rud River is used for industry, the water demand by a large number of industrial parks and active plants cannot be overlooked (Expert interview 2). This factory's products supply more than half of the country's steel consumption and are used in the automobile, light and heavy metal industries, fluid transmission pipes, household appliances, and profile pipe industries. Mobarakeh Steel Company has seven factories located throughout the country, and over 20,000 people work in these factories. (economic news , 2022). According to the public relations manager of Mobarakeh Steel, the company owns 1.5 percent of the water in the Zayandeh-rud River. This company's water consumption has decreased from 40 million cubic meters to 23 million cubic meters per year (Mobarakeh, 2022). According to experts, this number may not be high for one factory's consumption, but keep in mind that Isfahan also has other steel and manufacturing industries with water demands (Expert interview 1). The villages of Varzaneh City used to consume 90 million cubic meters of water per year; however, this amount is no longer available and is primarily distributed to industries (Expert interview 1). There are 5 industrial parks with different products around Varzaneh and as a result around Kafran village.

4.2. Factors that affect farmers' decision to migrate

According to the findings from the interviews, both temporary and permanent migration from the village has occurred. The majority of the younger generations, primarily men, moved to other cities for work, some permanently and with their families, and others temporarily while their families remained in Kafran. The older ones have remained in the village and are living there with the money provided by the government and their children. In this section, I investigate the factors that influence farmers' decisions to migrate or stay.

4.2.1. Predictability and situational awareness

Because Isfahan is located in a semi-arid region, when farmers were asked how much they predicted this drought and how frequent it was, all of them said they were unable to predict it. There has been an ongoing water shortage since 20 years, with water available for a few days in cultivation seasons and only for a few hours. All of the older farmers claimed that they couldn't predict the drought: *"We didn't predict the drought because there was so much water that it was difficult to control or even consider collecting water, and the wells were always full. We didn't expect the drought to affect the Zayandeh-rud [river] so severely because this region receives little precipitation. We didn't expect lot of precipitation in this region. But there was always enough precipitation in the mountains."* (Farmer interview 2). They were unable to predict the drought, which occurred unexpectedly. They were unable to predict the drought, which occurred unexpectedly. There was not much rain in the village, and they didn't expect precipitation. Still, the mountain area (where the resources of river are located) had enough precipitation to keep the river flowing throughout the village, even during drought.

In the following is what almost all the farmers claimed about the water quota. According to one of them, "*after the dam was built, there was a water quota, but the government would initially open the*

water to flow through the village, but after a while, they didn't open the flow and dedicated days and hours to flow the water for agricultural purposes. Initially, we had enough water for agriculture, and we could have made it ourselves to cultivate different crops with what we used to cultivate. However, the quota was getting smaller and smaller with each passing year. Currently, some years we have water 5-10 days out of the year for agriculture, and other years they pay us money in exchange for the value of water they gave us." (Farmer interview 3). Farmers changed their crops from melons, tomatoes, cotton, alfalfa, and sugar beets to wheat and barley in the early years of water quotas so that they could farm with the available water. They had also defined patterns for cultivation and water use among themselves during those years. However, after total drought, these measures seemed ineffective.

Given the inefficient agriculture in the Isfahan province mentioned in section 4.1.1 farmers were asked if this region has the water capacity to grow water-demanding crops, such as sugarbeet, cotton, and melon. According to several farmers (1, 2, 3 and 4), water was available in this region for harvesting various crops, and the soil is of high quality. One farmers also stated that "*Those times when Zayandeh-rud [river] passed near the village and the river flowed, the water in the wells was always full, every year we could grow different crops, we didn't need to measure the water because it was always enough, sometimes there was so much water that if we didn't harvest the crop on time, it would destroy.*" (Farmer interview 1)

4.2.2. Actions taken by authorities and farmers

As previously stated, the organizations in charge of water regulations and policies, as well as water allocation are the Ministry of Energy and the Ministry of Agriculture. The Ministry of Agriculture is responsible for issuing certificates to farmers indicating that they have water rights, and the Ministry of Energy and its subsidiary company ("water and sewerage company") will then dedicate the water that farmers need. This company is in charge of providing the physical infrastructure for water supply to the lands, as well as distributing water based on the amount of available water and the crop produced by the land, as specified by the ministry of agriculture. The Ministry of Agriculture is also in charge of resolving water disputes in order to provide enough water (ministry of agriculture sita system, 2022) Farmers also complain to parliament candidates and ask them to address their concerns directly in the legislature (Farmer Interviews 1,2, and 4).

Governmental organizations support farmers different ways. The Ministry of Agriculture lends money to farmers or give them seeds. Farmers primarily use this loan to purchase tractors and work on the lands of other farmers on the other side of the province or in neighboring cities. Others invested money in cultivating new crops but were unable to harvest them due to a lack of available water. Some farmers receive permission to dig a deeper well to have access to saline water and use the loan for well digging and fish farming, so they changed their occupation to fish farming (All Farmers). Others have kept their money in the bank and live off the interest they receive each month (Farmer Interviews 1, 2, 3, 5, and 7). However, farmers face a number of challenges. According to one farmer, "*there are loans provided but not for everyone there are some specific conditions for loans and too many steps.it is easier for those who are literate to apply for the loans."(*Farmer interviews 1). Another farmer claims *"Loans for fish farming are only available to those who have a family member who worked in this industry. As a result, not everyone is eligible to apply for this loan."* (Farmer Interview 4). Applying for a loan requires following a bureaucratic procedure. Farmers who are older face problems in this procedure. They are often not fully educated, and they are unable to follow the administrative work, which is why most people who apply for loans are from younger generations (Farmer interview 1, 2, 3). However, the difficulty in obtaining a loan, as well as having difficult conditions for eligibility of people for loans, were the reasons why older farmers did not seek for loan. Regarding the terms of

returning the loan to the bank, several farmers stated that they would have to pay it back on a monthly basis. (Farmer interview 2, 3, 4, 5) Those who have purchased tractors or have fish farming can provide funds to pay back the loan, but it is difficult for others. In some cases, such as when seeds fail to germinate, the loan will not be returned or payment is in small amount of instalments (Farmer Interview 2,3).

The Ministry of Agriculture also provides farmers with trainings on what to cultivate during drought. However, these trainings were theoretical rather than practical. As a result, they failed to produce new crops (Farmer interviews 1, 3, 4, 5 and Expert Interview 1). The farmers in this area had the knowledge of growing crops that they had learned from their families.(Farmer interviews 1, 3, 5)

The steps taken by the government to support the farmers in this region have been somewhat positive. Those who were able to change their business and earn an income as a result of this have stayed in the village, with only the man of the family (in some families) temporarily migrating to other cities for a few months of the year.

4.2.3. Reasons that may encourage farmers to migrate

This section seeks to assess the prioritization and most effective parameters influencing farmer migration, including economic, environmental, social, and health concerns. The farmers were asked a question about the aforementioned elements and how they might affect their living conditions.

4.2.4. Economic effects and problems

Regarding the economic effects of water scarcity, I asked farmers whether it was more important for them to work in their field of expertise (farming), or just to work and earn money, and why some of them did not migrate, how they earn money, and whether or not it is sufficient for their needs.

Some farmers are living based on the government's monthly subsidy for people with lower-than-average income and the assistance of their children (Farmer interview 1, 2, 3 and 4). Also all farmers claimed that, year after year, the value of their lands declines due to droughts, a lack of job opportunities, and a lack of adequate living conditions. As a result, the older ones hesitate to migrate because they do not have any funds to begin their migration. When the government does not open the gates to allow water to flow through the city, they pay money equal to the value of the water that was opened in a year. Many farmers' first priority is to find a job with a decent salary; agriculture is not a priority right now, but if the water flows through the city again, they will return to their village. The younger generation has migrated, while the older generation is having difficulty finding work. The younger generation has migrated, while the older generation is having difficulty finding work (Farmers interviews 2, 3, 5, 6, and 7). According to the plan approved by parliament, the government is responsible for giving money to the people on a monthly basis, which is 400,000 tomans, or 15 euros per person. (anonymous, subsidy of 2022)

4.2.5. Health and environmental problems

This part starts with effects of water scarcity on the environment their living and its impact on their health situation. Regarding the interviews, the health problems concern both aspects of mental and physical. The environmental issues are mainly about the land, the degradation of the soil, and the consequences.

Table 6. Health and environmental problems

Health and environmental problems	***Farmer interview***
Respiratory diseases caused by dust in the air as a result of the village's lack of flowing water	1, 2, 4
Some buildings have been damaged due to land subsidence.	2, 3
increased heat as a result of the village's lack of flowing water	1, 2, 3, 4
Mental health issues, especially in men, caused by the unemployment and not having enough income	2, 5, 6
Soil degradation as a result of using the saline water extracted from deep wells to keep the agriculture in some lands	6, 7
Farmers do not have enough food for their livestock because water scarcity prevents them from cultivating food for their livestock.	1, 2, 3, 5

4.2.6. Social effects

The final question asked was whether social problems such as disputes over water or different cultures can cause migration or not. All farmers gave similar responses, indicating that there are not many disputes that cause them to want to leave the village (All farmers interviews). They primarily migrated to larger cities with more open-minded people, which provided them with better living conditions (Farmer interviews 4, 5, 6, 7). Additionally, their children have access to better educational systems (Farmer interviews 3, 4, 5).

4.3. Impacts of water scarcity on farmers' migration and corresponding scenarios

In this section, the FCM is constructed and described based on the data collected for sub questions 1 and 2 from interviews and document reviews, which are explained in sections 4.1 and 4.2. The list of abbreviations and full names of the concepts are presented in appendix 4. The weights of the connections are explained in section 3.4.2. The concepts with the highest impacts weigh +1 or -1, and based on the interviews, document reviews, and effects of the most influential concepts on other concepts, the weights are dedicated. Regarding the metrics of the FCM, stakeholders (indicating the increase in stakeholder numbers) have the highest centrality with the 4.6 in-degree value and the 1.95 outdegree value. Several stakeholders have high relatedness to other variables and also other variables' relatedness to the stakeholders. The total number of concepts is 21, with 61 connections. Among these concepts, 15 are ordinary, 3 are receivers, and 3 are drivers. The three receivers are local ignorance problems caused by management methods and migration which are caused by other concepts. The top-down approach, changes in basin boundary management, and climate change, which only affects other variables, are the drivers.

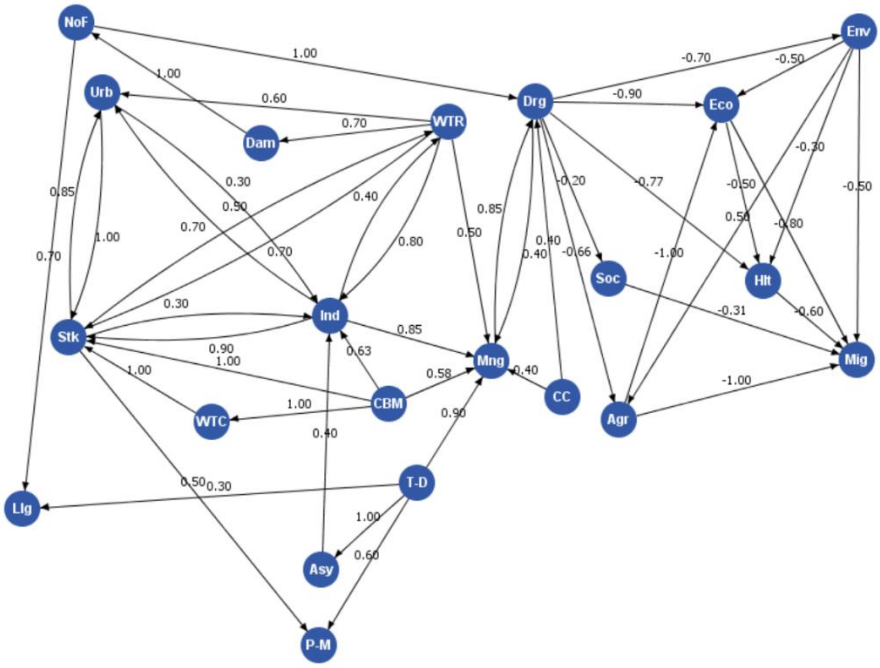


Figure 10. FCM

This FCM is divided into three categories: factors contributing to mismanagement, factors contributing to drought and water scarcity, and factors contributing to farmer emigration. The figure depicts the strength of the relationships. The part with the reasons affecting mismanagement and drought has positive and stimulating relationships. While the effects of drought on the environment, economy, and migration are all negative and inhibiting.

The Zayandeh-rud River is the most important water resource in Kafran. Various factors contributed to water distribution and exploitation, resulting in mismanagement. In the end, the Zayandeh-rud River is unavailable as a source of water from which the local population and ecology could have benefited and it led to drought. In the following, first I will explain the mismanagement and climate change effects on drought and next I will go through how drought effects migration based on the FCM map.

Although the top-down approach (T-D in the FCM) is considered a good management method for limited and common water resources in arid regions, it has exacerbated various factors such as power asymmetries (Asy), lack of education of local community (Lig), and facing problems that can only be solved by the organizations in charge of water management (pmg in FCM). In terms of Isfahan's transformation into an industrial hub (ind in FCM), having the Ministry of Energy in charge of water rights and exploitation permission made the industrial sector more powerful in obtaining water rights. The economic benefits that these industries bring to the country and the ministry of energy, which has the authority to allocate water to different sectors, resulted in the industrial sector gaining access to and benefiting from water resources in some areas (including the east of Isfahan and Kafran) ahead of agriculture and the local community. This is one of the reasons from Isfahan to become an industrial hub.

Water transfer from different resources (WTR in FCM) in the Zagros mountains to the Zayandeh-rud River began due to increased demand for water, which appeared to be the solution to the rising water demands. As mentioned in Chapter 4, it started the belief in having enough and readily available water. This transfer, combined with the priority of becoming more industrialized and the increase in

urbanization, resulted in dam construction (dam in FCM) to answer the needs for urbanization (urb in FCM) and also becoming industrialized (ind in FCM). Along with this construction, people began to migrate to Isfahan, and many industries received permits to begin operations which indicates more stakeholders using the water from the Zayandeh-rud River (stk in FCM). There is also another relationship between migration and industrialization. with more dam construction (dam) and increased water transfer. Because of dam construction, the Zayandeh-rud River does not flow through the province (Nof in FCM map). This causes 3 problems. First, wells have no supply and suffer from drought (Drg in FCM) over time. Second, as mentioned in the previous paragraph, the local community and local businesses, which primarily include agriculture or animal husbandry, are ignorant about the problem (Lig). From the interviews, it is concluded that the main problem and reason for the drought in Kafran are not having the flow of the river through the city (All farmer interviews, Expert interview 1).

Another change was that the management boundaries were changed from water basin boundaries to provincial boundaries (changing the basin management, or CBM, in FCM). This resulted in the transfer of water to other cities (WTC in FCM). Other cities benefited from this watershed, including Kashan, which is located in Isfahan province, but is far from the Zayandeh-rud Basin. This change in the basin management was enacted in order to empower the industry sector, to provide water for various parts of the provinces in order to establish more industries, including agriculture. As a result, there are more stakeholders that use water from river basin (stk). Water transfer to other provinces, including Yazd and Meibod cities in Yazd province that are not part of the Zayandeh-rud Basin, has begun. Furthermore, because these cities are located in an arid region, they have become overly reliant on the Zayandeh-rud Basin. the majority of these water resources are located in this province for industrial purposes.

Every three years, the springs of Zayandeh-rud River in the Zagrous mountains chain experiences a hydrological drought (Rahimi & Mohamadi, 2010). Climate change and the frequency of droughts have reduced the available water. These hydrological droughts occur in the mountains where the springs of the Zayandeh-rud River are located, resulting in insufficient water behind the dams during drought years. Water supply has become more difficult as management boundaries have changed and expanded.

Different problems have arisen over time. an increase in the number of stakeholders (stk), the effects of climate change, which has resulted in drought in the Zayandeh-rud springs and then less available water is one of the problems. This lower quantity of available water led to problems in allocating water for different sectors. Having only the Ministry of Energy in charge of water management, caused problem in management situation (pmg). It can be stated that these ministries and their affiliated companies are now having difficulty with distributing water in various sectors such as industries, drinking water, and agriculture.

Based on the interviews with farmers, as presented in the sections 4.2.4, 4.2.5, and 4.2.6, the drought has a negative impact on the environment (env), society (soc), agriculture (agr), health (Hlt), and economy (Eco) in this village, leading to migration.

Because no water flows through the city, the land is dry, and land subsidence has occurred, causing damage to some of the buildings (Farmer interview 2 and 3). Because the wells have dried up, people must extract saline water from deeper levels, which harms the soil. All of this has lowered the value of lands and homes and made farming more difficult (causal relationship between environment and economy and agriculture). During the summer, the heat feels more intense than in the past, and there is more dust in the air than before, causing respiratory diseases (impact of environment on health).

People, particularly younger generations, are becoming frustrated as a result of low income and a lack of suitable employment opportunities (impact of economy on health). Because of agricultural problems, livestock do not have enough food, farmers have no product to sell and thus no source of income (impact of agriculture on the economy). These factors have all resulted in migration.

Scenario 1:

For the first scenario, I assumed that Isfahan province is not an industrial hub and made changes in industrialization and elements affected by industrialization, such as asymmetry in power, urbanization, water transferred from different resources, change in basin management, and an increase in the number of stakeholders. All the factors' weights changed to less than 0.1. In this case, the migration rate increased to -0.48.

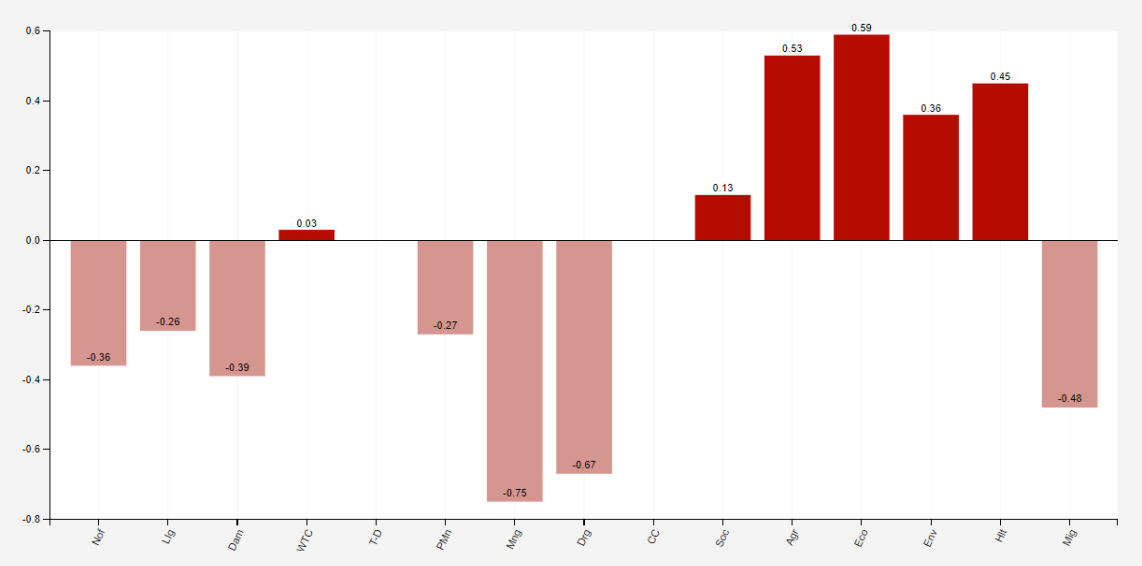


Figure 11. Scenario 1

Table 7 provides a summary of Scenario 1 parameters and resulting changes in the rest of the system. More specifically, following the simulated conditions assumed in this scenario (first column of Table 7), power asymmetry has decreased to 5%, and urbanization has decreased to 1%. I assumed that water transferred from other resources decrease to 7% and basin management would change to 10%. Finally, changes in number of stakeholders fell by 5%. The simulated outcomes (left column of table 7) indicates that local ignorance has decreased by 28%, while drought and mismanagement have decreased by 67% and 75%, respectively. These changes resulted in a 53% improvement in agricultural conditions, a 59% improvement in economic conditions, and a 48% decrease in migration.

Table 7. Summary of scenario 1 input and output parameters.

Scenario 1: A hypothesised scenario where Isfahan is not an industrial hub	
Input conditions	**Simulated outcomes**
Asymmetry in power: decrease to 5%	Migration: decrease by 48%
Urbanisation: decrease to 1%	Economic condition of farmers: increase by 59%
Water transferred from other resources: decrease to 7%	Agricultural condition: increase by 53%
Change in basin management: decrease to 10%	Drought: decrease by 67%
Number of stakeholders: decrease by 5%	Local ignorance: decrease by 28%
	Mismanagement: decrease by 75%

Scenario 2:

For the second scenario, I assumed that the management boundaries remained at the water basin level and did not change to the provincial level. I assigned weights less than 0.1 to the CBM, mismanagement, water transferred to other cities, and the number of stakeholders for this purpose. In this case, the migration rate increased to -0.11.

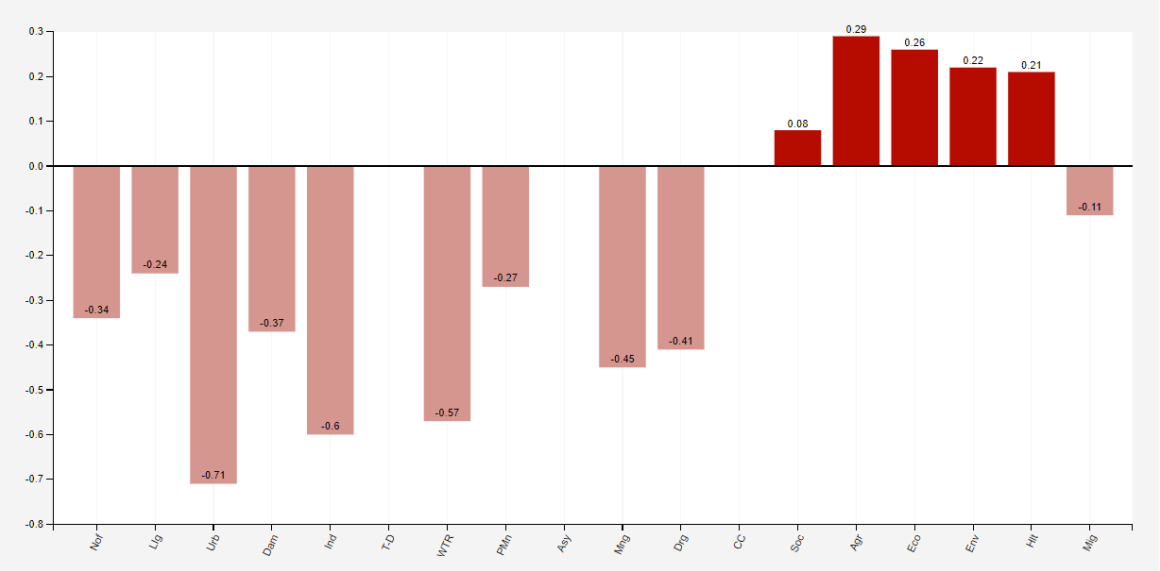


Figure 12. Scenario 2

Table 8 provides a detailed summary of Scenario 2. Following the simulated conditions assumed in this scenario , I assumed that the effect of changing the basin boundaries (changing to the provincial level) would be reduced to 1%. By making this assumption, I thought the management boundaries remained within the basin boundaries. Following this change, I reduced the amount of water transferred from the Zayandeh-rud River to other cities by 2%, and the number of stakeholders by 5%. Because shifting management boundaries resulted in water distribution mismanagement, I made 7% changes to this concept. Local ignorance decreased by 29% in this scenario. Drought fell by 41%, while urbanization and industrialization fell by 71% and 60%, respectively. The agricultural condition improved by 29%, and the farmers' economic condition improved by 26% as a result. Finally, the migration rate fell by 11%.

Table 8. Summary of scenario 2 input and output parameters

***Scenario 2**: A hypothesised scenario where management boundaries remained at the water basin level and did not change to the provincial level*	
Input conditions	**Simulated outcomes**
Change in basin management: decrease to 1%	Migration: decrease by 11%
Mismanagement: decrease by 7%	Economic condition of farmers: increase by 26%
Water transferred to other cities: decrease to 2%	Agricultural condition: increase by 29%
Number of stakeholders: decrease to 5%	Drought: decrease by 41%
	Local ignorance: decrease by 24%
	Industrialization: decrease by 60%
	Urbanization: decrease by 71%

Scenario 3:

In this scenario, I assumed that climate change has less severity than reality. I changed the climate change effect on drought since climate change directly impacted these two elements. In this scenario, the weight changes were proportional to the impact of climate change on mismanagement and drought. These weights were changed to 0.2. in this scenario, the difference in drought is -0.39, while the changes in migration are -0.09.

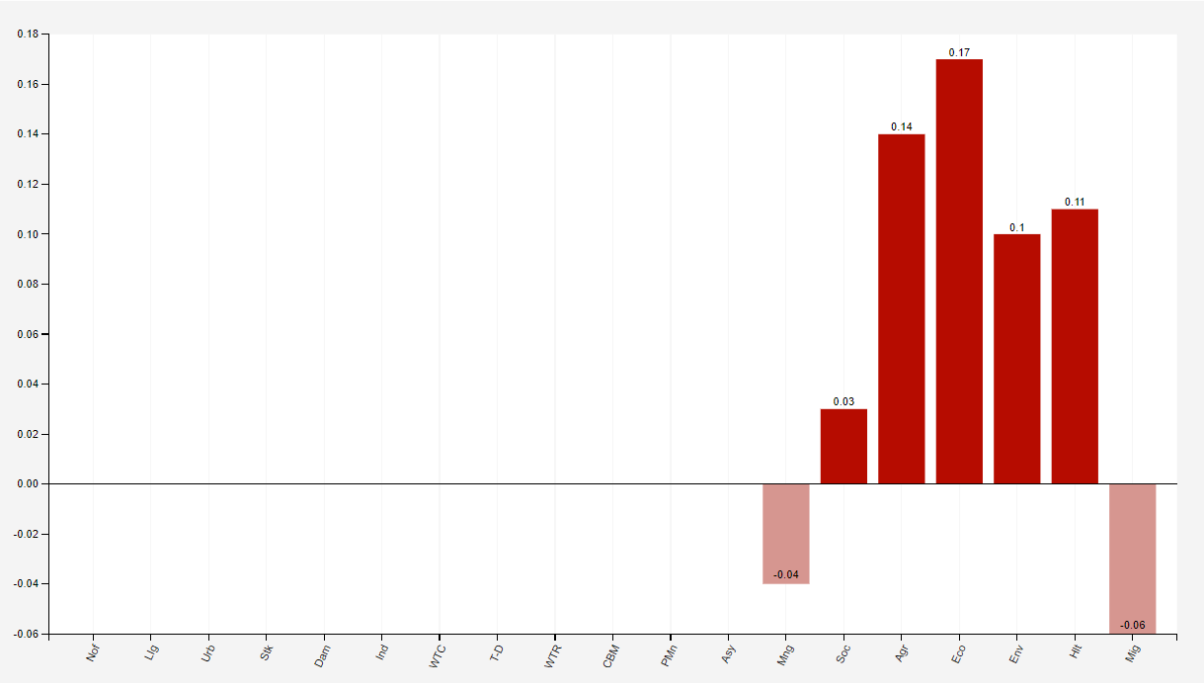


Figure 13. Scenario 3

Table 9 shows the concept changes for the third scenario. In this scenario, the impact of climate change is reduced to 2%, and the drought caused by climate change is reduced to 2% again. As a result of this scenario, mismanagement decreased by 4%, agricultural conditions improved by 14%, and farmers' economic conditions improved by 17% in the following year. Finally, the migration rate decreased by 6%.

Table 9. Summary of scenario 3 input and output parameters

***Scenario 3**: A hypothesised scenario where climate change has less severity than reality*	
Input conditions	**Simulated outcomes**
Climate change: decrease to 2%	Migration: decrease by 6%
Drought: decrease to 2%	Economic condition of the farmers: increase by 17%
	Agricultural condition: increase by 14%
	Mismanagement: decrease by 4%

Summary of the three scenarios

The first of these three scenarios, with less industrialization in Isfahan Province, has the greatest change in migration rate. with The asymmetry of power, and the top-down approach, the most of the water is dedicated to this section. Assuming that this section consumes less water or that the province of Isfahan becomes less industrialized, the drought decrease by 67%, and there is finally better economic condition and less migration. For the second scenario, which is not changing the management boundaries to the provincial level, the amount of water transferred to other cities and the number of stakeholders decreased. As a result, the drought was reduced by 41% and migration was reduced by 11%. Changes in basin management have a smaller impact on migration rates than in scenario one. The final scenario is climate change, which reduces the impact of drought by 14% and the migration rate by 6%. Climate change has a lesser effect on migration than the other two scenarios.

5. Discussion

In this chapter I first discuss what has changed in the previous situation of Kafran village and Zayandeh-rud River and the current situation, based on the application of the SES framework. Following that why different users cannot self-organize their current usage from the Zayandeh-rud River. Next, based on the IAD framework, I will investigate why farmers chose migration.

A system collapses when the users of that resource are different and cannot communicate well and have open access. The applied rules and policies fail to answer the diverse users' needs (Ostrom, 2009). The Zayandeh-rud River flowed through the Kafran village at the time. Following the SES framework, the river's actors were residents of the villages surrounding this basin, including farmers, and locals who used water on a daily basis. Despite the fact that water resources were among the government's assets, the people had access to water because water was available in both surface and ground water resources. Farmers had an irrigation pattern, and each had a specific water quota that was sufficient for them all without consuming the quota of the other farmer. People in the village drink and wash with water from the river, and wells that fed by the river.

Following the Iran-Iraq war, large agricultural lands were dedicated in Isfahan to cultivate various crops to provide food using the Zayandeh-rud River and wells fed by this river, which was introduced as inefficient agriculture. Later, during Hashemi Rafsanjani's presidency, with the development plans for becoming more industrialized, the Zayandeh-rud River, with a certain capacity, became the host of many manufacturing industries. This industrialization required a workforce, which drew people to Isfahan, increasing urbanization. Dam construction occurred as urbanization and industrialization increased. People in the village (some of whom were farmers), industries, and newcomers to Isfahan province were now the users of the Zayandeh-rud River. As the number of users increases, it becomes more challenging to make decisions about resource management (Ostrom, 2009). Even though the administration is done by one organization, resource management has not yet been solved. In cases where the water resource grows at a slow speed, but the number of consumers grows at a high rate without regard to the capacity of the water resource, this resource might collapse (Ostrom, 2009).

In the first case, the government was the one who issued a certificate that allowed farmers to use wells and surface water. And the farmers themselves were the ones who managed the water usage among themselves. In the second case, after the dam construction, the water stopped flowing, and with time the wells dried out. In this case, the governmental organization was the only one to allocate water to different sectors and farmers in the Kafran village. With the passing of each year, the profit of the industries is prioritized by other sectors and the local community. Following this, having the energy ministry in charge of water rights and allocation gave more power to industries to have the right to harvest the water. Also, agents from the local side are not strong enough to express the community's needs and defend them in the parliament.

In the following, the construction of the Koohrang tunnel and the routing of water to the Zayandeh-rud from other springs made the belief that there was enough available water access, and there the emergence of more industries, more agricultural lands, and urbanization occurred. The water management changed from the basin level to the province level. Water from the Zayandeh-rud allocated to other cities, such as Kashan. This belief caused the water dedication to cities in Yazd province, such as Meibod city and Yazd city. All the factors above contributed to the exhaustion of the resource. This exhaustion can cause problems in the system's productivity and, in time, decrease the need to keep the resource for future generations (Ostrom, 2009).

According to the factors above, the water users can no longer self-organize the Zayandeh-rud River as an open access system, with different sectors using the water. This is among the duty of the energy

ministry, and the local community has no role in the organizing. This ministry has also failed to organize this resource and is exhausting the river and springs. According to article 7 of the equitable water distribution law, the priority for consumption is drinking water, horticultural water, agricultural and animal husbandry water, and industrial water, respectively. (Center, 1997) But locals from the Kafran village have access to low-quality drinking water, and their access to water for farming has diminished.

As indicated in Figure 6, the exogenous variables consist of the actor status, institutions, and constraints. The actor status is explained in the previous paragraphs for the SES framework. Institutions involved are the ministry of agriculture, ministry of energy and the laws applied by these two ministries that also affect water rights. The constraints are considered based on Ma et al. (2019), which include age, job, annual income, limitations for having an income, and social patterns. As stated, changing the basin boundaries, having the Top-down approach for management, and having the ministry of energy in charge of the water rights caused the winning of the industrial sector to have access to water more than other sectors. Also, the law for constructing the Koohrang tunnels to deviate the water from Karoon resources to the Zayandeh-rud Rover was mainly used for the industries and providing drinking water as urbanization increased. Climate change and its impact on precipitation rate and form was one of the exogenous factors contributing to the drought. The hydrological drought has reduced flow pressure by nearly 33% in resource areas (Rahimi & Mohamadi, 2010). All of these factors contribute to farmers' inability to access water and continue farming. This results in less revenue, which is a constraint. The Ministry of Agriculture, as the ministry responsible for supervising the farmers' affairs, began to assist farmers by providing loans and seeds, as well as providing educational facilities and educating them.

The action arena reflects how actors make their decisions, and consists of situational awareness and an intellectual decision model (Ma et al., 2019). In terms of situational awareness, the interviews revealed that the drought was unpredictable for farmers and that they had not been educated beforehand. Another issue that farmers could not predict was the province's transformation into an industrial hub and the allocation of water to these industries. Based on the reviewed articles (Rezaei et al., 2017; Waha et al., 2017) about people migrating from rural to urban areas, the intellectual decision model in the IAD framework consists of the environmental, economic, health, and social factors that affect farmers' decisions. This model also is affected by the institutions involved and the behavioral outcome.

Actors process the data from the action arena and, based on that, develop their external operational status and make a decision to migrate or not. This status consists of a behavioral outcome that is shaped by a behavioral model and assessment criteria (Ma et al., 2019). As the behavioral model, farmers tried adapting to the new situation and using the facilities provided and keep their occupation or start another one in their own village. Farmers began to experiment with different cultivation and irrigation patterns on a smaller portion of land, as well as changing their crops. using the loans ministry of agriculture gave them to start new business in their village or cultivate new seeds. Some of them were able to use that money and began fisheries or buy tractors to work on other lands and some couldn't. For the assessment criteria, they claimed their income is significant; they need their profit from selling the cultivated crops. The soil they work on should have good quality, which in some parts has been mixed with salt due to water exploitation from deeper wells than usual. Also, drought has caused soil subsidence and caused damage to their houses. The pipe water they use for drinking and washing has low pressure.

However, the behavioral outcome is migration. because farming relies heavily on water availability, farmers have begun to migrate despite all of these changes. When making migration decisions, people put the investment and cost benefits as their priorities (Ma et al., 2019). In the case of Kafran, the

economic reasons have the highest impact on migration, and the next is the environmental and health reasons. The first group is the youth generation which could work for the industries. The second group was the middle-aged ones. Those who couldn't use loans to change their occupation moved to the cities to find new jobs, such as carpenters, plumbers, etc. Still, the elderly group is the most vulnerable since their age is a constraint for finding other jobs, and they rely heavily on the government or their children's help. As a behavioral outcome, migration can provide better economic profit for farmers. Also, they have access to better living conditions, such as better piped water and better schools for their children. The environment they are living in is not affected by drought anymore and does not cause them any health problems. Even though the institutions tried to provide better conditions for living in Kafran, as stated before, migration is still more popular.

6. Conclusion

The objective of this research is to identify the relationship between farmers' migration and water scarcity in Kafran village in Isfahan city in Iran. To achieve this objective, the factors that can exacerbate or cause water scarcity and have a direct or indirect impact on migration flows are investigated.

Water scarcity in Isfahan, particularly in Kafran, is caused by two major factors: mismanagement and the effects of climate change. The responsibilities and the authority for water management has been assigned to the Ministry of Energy and its affiliated companies, and a top-down approach was established by them. Mismanagement of water has resulted from governors' ambitions to become industrialized and increase economic benefits for the country without considering the capacity of the Zayandeh-rud River and the needs of the local population. As a result, decisions were made that have harmed other rivers, by transferring water from other resources in the Koohrang mountains. This step established the misperception that there was enough water available. Water management boundaries were then changed to the provincial level, and the Zayandeh-rud River was required to supply water to more industries and cities. This industrialization and, as a result, urbanization occurred in the absence of a proper scenario or programme for water allocation. The quantity of available water in relation to the profit that the industrial sector can generate with this quantity has not been studied, and industries with high water demand have been established in Isfahan. This problem is exacerbated by the belief that regions with limited water resources will face the tragedy of the commons for their natural resources because locals cannot organize their usage from the common resources and will overharvest from the common resource, which leads to the government's intervention.

Rising water demand prompted dam construction. Following the construction, water quota happened. This quota is posing a problem for the local community, particularly farmers. This action, combined with the effects of climate change in the region, caused a drought in the region's wells, which are one of the most important sources of water supply in semi-arid regions. Not having the river flow through the village had an impact on the environment, causing severe hot weather, health problems, and a decrease in local income. In this case, steps were taken to mitigate these issues, such as providing farmers with loans and training them to cultivate new crops.

According to the interviews, the farmers that have migrated are mostly young people, who have moved to Isfahan or other cities near their home village, such as Yazd. The majority of them work for industries, and some have started their own businesses, such as Carpentry or plumbing. Those who could have purchased tractors are working on other people's farms, and some have begun fish farming, both of which are supported through the loans from the Ministry of Agriculture. The situation is different for the elderly. They lack both the financial and physical resources required for migration. There are no job opportunities for the elderly. The loans provided are too difficult to apply for due to illiteracy, and they rely on the monthly allowances given to people with low income from government, and also the assistance of their children.

The main reason for farmer migration is economic problems, followed by health and environmental concerns, and finally, living in a more open-minded environment with better facilities in the city. Younger farmers frequently migrate, both temporarily and permanently. Some people leave their families in the village because they cannot afford to live in the city. Some only use their tractor for a few months out of the year. Others move with their entire family permanently. Most of the farmers who have migrated have stated that when the precipitation in the mountain area is good and they have a higher water quota, they return to their village to continue farming.

Based on the scenarios, the first is less industrialization in the province, the second is maintaining the basin management boundaries, and the third is less effect of climate change. Industrialization has the greatest impact on migration rates. The rate of industrialization and its associated concepts has decreased the migration rate dramatically. The second factor in lowering migration rates is maintaining basin management boundaries, followed by climate change, which has the least impact on emigration.

The number of interviewees in this study was limited. One of the interviewees needed to be the manager of industrial parks, specifically the one in Mobarakeh, to ask for the exact usage of their water. Another interview with the Varzaneh city and its villages agent would be beneficial.

The next step in this research is to find successful frameworks and approaches to managing a failed system. How to prioritize needs and different section profits in a way that does not cause large losses and harms to the GDP. new method for water distribution among various sectors. Best solutions for assisting farmers to stay in their village and determine how their needs can be met.

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Appendix 1: Interview Guide for Farmers

Introduction

My name is Yasaman Ahmadi Nejad, and I am a master's student at the University of Twente studying Environmental and Energy Management. This interview is being conducted for the purposes of my thesis.

"The relationship between water scarcity and farmer migration in Isfahan, Iran" is the title of my research project.

I need to record the interview in order to have time to transcript it and select the necessary data. Your name and personal information will be kept private and anonymized during the transcription.

The only thing that will appear in this transcript is your age. So, I want to ask for your permission to start the recording.
This interview will not harm or cause you problems. However, if you feel uncomfortable or unsafe, I can stop the recording. But, I will need time to write down some key points, which will require additional time for the interview.
Because these questions cover a wide range of topics, there may be some that you are unsure about or are you may be uncomfortable answering; in this case, feel free to skip the question and not answer. I would appreciate it if you could answer the questions you know the answers to in a brief but complete and precise manner.

Start of recording

Could you please introduce yourself and describe what did you cultivate?
(for those who are still farming: 1. what did you cultivate? 2. What do you cultivate now?)

- an estimate of amount of water you needed annually?
- Do you measure/meter your water use? If yes, how? If not, why?

Predictability and situational awareness:

1. Given that Isfahan is in a semi-arid region, how predictable was the water availability every year?
    - How was the frequency of the drought?
- Given that Isfahan is becoming an industrial hub in Iran, how likely is it that water rights for agriculture will decrease?
2. What are the long term and short term consequences of Zayandeh-rud drought for your business ?
3. How suitable was this area for growing your crop from the beginning? (the amount of water you consumed wasn't more than the capacity of the resources?)

Number of users from a specific water resource:

4. How does urbanization affect the agricultural water use/consumption?
5. Who are the users of the main water resources in this village?
    - How does their use affect the water needed for agriculture?

Institutions:

6. What are the private institutions and governmental organizations that distribute water among different sectors?
7. What are the organizations that apply rules and regulations for the quantity and quality of water use?
    - What institution do you file your water rights complaints with? How responsive are they?

Actions taken by authorities and farmers:

8. What steps have the responsible organizations taken to address the agricultural problem (water allocation problems)?
    - Does the government provide support, such as loans and facilities, to improve the irrigation system? If yes, are the farmers using it?
9. What educational steps are being taken to train farmers on how to irrigate more efficiently and how to increase their ability to manage the critical situation?
10. Did you consider changing the crop you're growing?
    - How does precipitation affect your crop?
    - If the amount of precipitation in the region were the same as before (climate change), would it still be possible to cultivate this crop?
11. What solutions have been proposed by farmers themselves for equitable water distribution in the way to negotiate with other industries?

- What solutions have been proposed by farmers themselves for equitable water distribution in the way they negotiate among themselves on the amount of existing water ?
- What solutions have been proposed by farmers themselves to deal with the lack of water availability?

Reasons that may encourage farmers to migrate: (intellectual decision model and actor status)

12. How do you think climate change affected your migration/those who migrated to the city?
    - How much has climate change and water scarcity impacted the environment in your area?
    - How much can these environmentally changes motivate you to migrate to other cities?
    - Does drought in this village cause any new diseases? If yes, can this be a reason to migrate? Why?
13. Is it more important to you to work in a field where you are an expert (farming) or is it sufficient to work for factories and earn money?
    - To what extent it is important for you to live in your own village?
    - What effect has the drought and scarcity of water had on the price of your produce? Did it force you to sell your produce at a higher price? If so, could it be a reason to emigrate? why?
    - What are the consequences of drought and water scarcity on your region's economy? And how does this encourage people to migrate?
14. To what extent has the level of disputes over water distribution/use increased?
    - Have these disputes resulted in migration? If yes, why?
    - How can the differences between your culture and those of other cities deter or motivate you to migrate?
    - Do you think water scarcity can increase the cultural differences regarding your decision to migrate?

Closing the interview:

Thank you very much for your time and information that you shared with me; if you are interested, I can send you the research results as well as the transcript. If you have any questions or comments, I would be happy to hear it.

Appendix 2: Interview Guide for Experts

Interview questions

1. Can you please introduce yourself and your occupation?

Resource system (productivity, producibility, equilibrium properties:

2. What are the main water resources for irrigation?
    - Which of these resources are renewable?
    - How predictable are these resources in the sense that people who benefit from them manage the amount of usage by applying rules and policies?
    - What are the policies regarding the discharge and recharge of these resources? (like the amount of usage in different seasons or any policy regarding the water demand or the amount of water that each industry can extract from a particular resource based on its needs)
3. What is the role of Zayandeh-rud River for agriculture in Isfahan?
    - How does the water transport from the Zayandeh-rud River to other cities affect agriculture in Isfahan?

Resource unit (replacement rate, interactions, distinctive marketing) and institutions

4. How is water distributed among different industries that use the same water resource (both surface water and groundwater)?
    - How economically valuable is the agricultural sector in Isfahan? Is it worth the same as other industries (such as textile and steel)?
    - What are the priorities for industries and drinking water over the agricultural water use?
    - What Is the share of water from one watershed resource for drinking water, agriculture, and other industries? (the name of the watershed resource will be added)

Situational awareness

5. What are the agricultural practices in east areas of Isfahan?
    - How suitable are these lands for farming?
    - Was this city designed to handle this volume of agriculture from the start?
    - What types of crops are common in this city (in terms of water demand)?
6. Because Isfahan is located in a semi-arid region, farmers must be aware of the best available techniques and technologies for irrigating their crops to keep their resilience. It is also critical that they understand how to deal with situations where water scarcity is severe in some years, as well as how to manage the available water or have the ability and capacity to switch crops.
    - According to above explanation, what is the degree of farmers' awareness far about water scarcity?
    - What is the degree of farmers' awareness far about climate change?

- What knowledge they have in order to monitor their water consumption and manage it?

Social factors

7. How do culture, customs, and literacy affect the way farmers cultivate and irrigate?
    - How all the above mentioned effects of water scarcity on agriculture, affect the way farmers interact with each other (other farmers) and others (people with industrial business, or people with position in related organizations)?

Governance system

8. What are the most important policies regarding the amount of water dedicated to the agricultural sector?
    - Do farmers have a share of special water rights for farming? Is yes, what are they?
    - What are the laws and regulations applied to water delivered to each sector? (drinking, agriculture, industry)

Action situation (monitoring, policy making, provision):

9. Are there any strategies or plans to reduce water scarcity? if yes, what are their scope and objectives?

- What are the provisions from responsible companies and ministries in the process in order to change the current situation? (to help the agricultural sector)?

10. Are all the farmers the owner of the land they are working on? If not, is there any priority given to investigating the landowners' complaints about their water right?
    - What are the difference regarding to provide with better irrigation systems or dedication of more water resources between farmers who cultivate crops for exports and other farmers?
11. How is the water consumption in agriculture monitored?
    - In what areas is monitoring taking place? (Environmental aspects of basins or also the social aspects such as effects of water scarcity on people)
    - What are the new technologies being considered for irrigating and monitoring the amount of water used in irrigation?

Climate change and migration:

12. What is the role of climate change in water scarcity?

- Do you think if there was enough precipitation, you could prevent the water scarcity? How? (in recharge of the resources)?

13. How important is climate change in economic aspect of farming?

- How important is climate change in social aspect of farming?
- How does climate change affect the migration of farmers form rural to cities?

Appendix 3: Consent Form

You are being invited to participate in a research study titled “The relationship between water scarcity and farmer migration in Isfahan, Iran”. This study is being done by Yasaman Ahmadinejad from the Faculty of Behavioural, Management and Social Sciences at the University of Twente

This research study aims to examine the factors that contribute to farmer migration due to water scarcity. This interview will last between 30 and 45 minutes and will assist in understanding the relationship between elements of the system between migration and water scarcity. There are no political danger in this research

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any question.

I believe there are no known risks associated with this research study; however, since the situation in Iran is a little different, once the evaluation is completed, we will ensure that all data provided by participants is anonymized and deleted.

Contact information: Yasaman Ahmadinejad

Appendix 4: Concepts Used in the FCM

Agr	Agriculture
Asy	Asymmetry in power
CBM	Change in basin management
CC	Climate change
Dam	Dam construction
Drg	Drought
Eco	Economic problems
Env	Environmental problems
Hlt	Health problems
Ind	Industrialization
LIg	Local Ignorance
Mig	Migration of farmers
Mng	Mismanagement
NoF	Not having Flow of the Zayandeh-rud river
PMn	Problems caused by management methods
Soc	Social problems
Stk	Increase in Stakeholders
T-D	Top-down approach
Urb	Urbanization
WTC	Water transferred to other cities
WTR	Water transferred from other resources