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Conceptualizing water bankruptcy in forbidden plains of Iran (Case study: Mahidasht plains)

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ABSTRACT

Objective: The purpose of this case study was to conceptualize WB as perceived by irrigated farmers and agricultural experts in Mahidasht township.

Method: In recent years, climate change has caused a significant decrease in rainfall compared to the long-term average in Iran. In addition, mismanagement of water resources in the agriculture sector has caused the reduction of renewable water, destruction of the ecosystem, and local and regional water disputes. In such a way that there is a reservoir deficit of 350 BCM in Iran's underground water resources, which is about a quarter of the total reserves of underground water resources. According to the statistics of the country's water resources balance, the total amount of water harvest is equal to 96.37 billion m^3, of which 85.6 billion m^3 is related to the agricultural sector. As a consequence, water management experts have called for the state of "water bankruptcy" in the plains of the country, including the Mahidasht Plain in western part of Iran. However, any measures taken by water management experts need to conceptualize water bankruptcy (WB) as perceived by experts and farmers. Because environmental crises, including water bankruptcy, are rooted in human behavior. Since the correct perception of a problem is a prerequisite for behavior; therefore, conceptualizing "water bankruptcy" perceived by stakeholders can reveal the root causes of this phenomenon in the region. Thus, it should also be considered as the first step in solving the conflicts caused by this issue. This study used exploratory qualitative method using case study approach. This research, purposeful sampling through "critical case method" was used as a sampling frame of the study. The population of this study comprised 25 participants, including Experts in Agricultural Organization, Regional Water Company, faculty members in College of Agriculture, and farmers in Mahidasht Plain in Kermanshah Province. Individual interviews and group discussion sessions were used to collect data. Qualitative field notes were collected and coded using thematic analysis.

Results: The results of thematic analysis process revealed that the main concepts of WB are: excess water harvesting (EWH), reduced surface water (RSW), reduced ground water (RGW), condensation and change of aquifer (CCA), negative water balance (NWB), over harvesting of renewable water (ORW) and engaging in non-agricultural activities (ENA).

Conclusions: Policymakers and researchers can benefit from the results of this research in providing dynamic models of water allocation in common basins.

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Introduction

Water management has become a fundamental problem and its dimensions and complexities are increasing. According to the United Nations report, by 2030, only 60% of the world's population will have access to safe water. FAO has also forecasted that water withdrawal from reservoir will be 1.7 times faster than population growth. It is also estimated that by 2050, agricultural water demand will increase by 60% compared to 2006 and 2007 (Amiri et al., 2020).

The water crisis has become an important issue for people and policymakers for several decades, causing water conflict among stakeholders (Islami & Rahimi, 2019). In addition to climate change, inappropriate water management has exacerbated the water crisis. This problem is especially evident in the agricultural sector, which is closely related to water resources. Iran, which is located in an arid and semi-arid sector, is known as the most water-scarce country in the region, and its water reserves are running out. In addition, out of 609 water plains in Iran, 404 plains are in a prohibited or critical condition, and the total volume deficit of Iran's plains reservoir is estimated at 4867.8 MCM (Ministry of Energy Protection and Operation Deputy, 2019). Among these plains, Mahidasht, located in the western part of Iran, has been announced as a forbidden plain introduced as a Plain since 2007. The average yearly rainfall for 2022-4 was 144.9 mm in the Mahidasht Plain. This amount was reduced by 31% compared to the long-term average (Ghamarnia, 2023). In addition, continuous droughts and over-harvesting of water by farmers have reduced the reservoir volume in Mahidasht Plain by 260.20 MCM (Ghamarnia, 2023). Other researchers have clearly shown the critical situation of the plain in terms of aquifer depletion and water poverty (Veisi et al., 2021; Zarafshani & Sadvandi, 2017).

Thus, water resource experts have made an alarming sound and declared “water bankruptcy” as a post-crisis stage for water situation in Iran. They believe, the country is facing WB because the "liabilities" (water withdrawals) exceed the "reasonable value of assets held" (rates of aquifer recharge and recharge by surface water) (Collins, 2017). Water bankruptcy seems to place Iran in the most unprecedented historical challenges. A challenge that can make significant parts of the ancient geographical-political territory uninhabitable and be a prelude to political-social crises that endanger territorial integrity (Fattahi, 2018). Therefore, the increasing demand for water on the one hand and reduced access to water resources on the other hand has created conflict among users in the allocation of common water resources. Moreover, it has also attracted the attention of researchers and policymakers to adapt effective water management strategies (Sadat et al., 2018). Some researchers (e.g., Shahraki et al., 2024; Yazdian et al., 2022; Pournabi et al., 2022; Jalili Kamju & Khochiani, 2020; Jamalomidi & Moridi, 2020; Tayebzadeh Moghadam and Malekmohammadi, 2020; Abrahe et al., 2019; Sadat et al., 2018; Oftadeh et al., 2016) have used WB models to resolve water conflict, which in turn helps proper allocation of water among users. In addition, dispute resolution (bankruptcy) and game theory approaches have been used to resolve groundwater disputes (Abraha et al., 2019; Jamalomidi & Moridi, 2020). However, they failed to consider diverse concepts held by water users as well as water experts as to how they conceptualize (WB) before they consider a best model for water allocation. In other words, as pointed out by Wickramage (2019) Selection of the best allocation rule depends on how beneficiaries conceptualize the WB. Moreover, since there is no exact model or method to choose the best, it seems that the best model would be to utilize concepts held by beneficiaries. Therefore, this study attempts to fill this gap by providing concept of WB as perceived by water stakeholders.

Thus, a first step in effective water management is to conceptualize WB as perceived by end users as well as water policy experts in Iran. Conceptualization of WB has practical implication for water management policies in Iran in that any intervention made by policymakers starts with bottom up resulting in efficient use of water resources and thus resolves any water conflict among water end users. Therefore, this qualitative study sought to conceptualize WB as perceived by farmers and water management experts.

Access to safe water, sanitation and hygiene is the most basic human need for health and well-being. Billions of people will lack access to these basic services in 2030 unless progress quadruples. Demand for water is rising owing to rapid population growth, urbanization and increasing water needs from agriculture, industry, and energy sectors. In December 1992, the United Nations General Assembly adopted resolution in which 22 March of each year was declared World Day for Water with a focus the Sustainable development Goal 6 (Qanadi, 2023).

In Sustainable Development Goal 6 in 2023 declares the importance of achieving "clean water and sanitation for all". It is one of the 17 Sustainable Development Goals established by the United Nations General Assembly to succeed the former Millennium Development Goals (MDGs). According to the United Nations, the overall goal is to: "Ensure availability and sustainable management of water and sanitation for all" (UNDP, 2015). Some of these targets are: Substantially increase water-use efficiency across all sectors and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity; Protect and restore water-related ecosystems, including forests, wetlands, rivers, aquifers, and lakes; and Support and strengthen the participation of local communities in improving water management (Kufeoglu, 2022).

However, the reports and field surveys of the United Nations show that the world has still failed to achieve this goal and billions of people, businesses, health centers, farms and factories still do not have access to proper water services (Qanadi, 2023).

In the meantime, around 70 percent of global freshwater resources are used for agriculture (Ingrao et al., 2023). In developing countries such as Iran, water use in agriculture accounts for 90 percent of all water withdrawals (Doungmanee, 2016). Therefore, water shortage causes the greatest damage to the agricultural sector and farmers' livelihood.

In addition, Iran, which is located in arid and semi-arid regions, consecutive droughts have severely affected natural resource dependent sectors such as agriculture, causing huge economic losses (e.g., loss of food and feed production, increased livestock mortality, declining household farm incomes, and rising food prices) in this sector. It has also caused irreparable damage, including biodiversity loss, water security risk, reduced soil fertility, increased wind erosion, reduced plant fertility, increased disease incidence and pest invasion, increased fires, and lost canopies (Sharafi et al., 2020).

On the other hand, according to the report of the Water Research Institute of the Ministry of Energy in Iran, the amount of water harvesting from the total renewable water sources in normal periods is estimated to be 95%. Meanwhile, the normal percentage of harvesting renewable water sources is defined as 40-50% (Bazrafshan, 2021).

Therefore, all the evidence indicates that Iran is far from achieving sustainable development goal 6. Thus, water crises in recent years have caused the discussion of WB to be raised by some experts.

Water bankruptcy (WB) is raised when common and divisible property (E) is going to be divided between (i) the claimant and the amount of claim (Ci), so that the amount (E) is less than the total claim of the claimants (C). In bankruptcy, resources must be divided between a group of claimants, while the amount of claim is not enough to satisfy all the claims (Herrero

& Villar, 2001). Yet in another definition, WB is considered as a new approach to solve water conflicts among different stakeholders from shared water resources. Bankruptcy theory is a subset of game theory that examines the problem of redistribution of limited common resources between claimants in several ways. For example, this approach uses the common methods of Proportional bankruptcy (P), Adjusted Proportional (AP), Constrained Equal Loss (CEL), Constrained Equal Award (CEA), Piniles (PIN) and Talmud (TAL) (Abraha et al. al., 2019; Zare Farjoudi, et al., 2019; Jamalomidi & Moridi, 2020).

There are limited practical studies in the field of WB due to its novelty. These studies have mainly focused on technical aspects of WB such as economic and mathematical methods to better develop water allocation models in different national and international basins (Shahraki et al., 2024; Yazdian et al., 2022; Pournabi et al., 2022; Tian et al., 2021; Jalili Kamju and Khochiani, 2020; Jamalomidi and Moridi, 2020; Tayebzadeh Moghadam and Malekmohammadi, 2020; Abrahe et al., 2019; Nafarzadegan et al., 2019; Sadat et al., 2018; Oftadeh et al., 2016; Mulugeta Degefu and He, 2016; Madani et al., 2014; Zarezadeh et al., 2012; Herrero and Villar, 2001). However, limited attention has been paid to conceptualization of WB. While conceptualizing WB is as a first step in resolving water conflicts between the outsiders (policy makers) and the insiders (farmers).

It is worth mentioning that as far as the authors searched, no study has been done on the conceptualization of water bankruptcy, therefore, in the following, studies that develop water allocation models in the conditions of water bankruptcy have been done.

Using the theory of games and the MODFLOW model, Yazdian et al. (2022) in Iran, presented an optimal model for minimizing the reduction of groundwater level. The results revealed that farmers with clear foresight are in better position to avoid any cost endured by water mismanagement. Jamalomidi & Moridi (2020) conducted a study in Hormozgan province using bankruptcy models in order to manage groundwater resource conflicts. These researchers first simulated the groundwater flow model using MODFLOW software. Then, using the collaborative method (one of the bankruptcy methods), they calculated new aquifer withdrawal values and entered them into the simulation model and compared the results with the current situation. In their study, five bankruptcy methods were used in order to manage the extraction of production wells. The results showed that the aquifer’s groundwater level increased which in turn resulted in improvement of aquifer.

Sadat et al. (2018) examined the optimal redistribution of water resource allocation in the Aras watershed (the common border of the four countries of Turkey, Armenia, Azerbaijan and Iran) using the combination of bankruptcy dispute resolution methods and Particle Swarm Optimization algorithm. Results revealed the superiority of the method bound to the same loss (CEL) over other bankruptcy methods. In other words, the average supply of water needs in the basin in 2020 scenario will increase by almost two billion cubic meters and in 2050 scenario by almost 1.5 billion cubic meters compared to other bankruptcy methods. Interestingly, the applicant with the lowest amount of demand (Turkey) is given the last priority given that Turkey is located in upstream of the basin. Thus, further application of this method requires consideration of alternative facilities and satisfaction of the stakeholders.

In another study, Mulugeta Degefu and He (2016) examined different scenarios for water scarcity in the Nile River Basin. In their study, they applied bankruptcy allocation rules to predict available water allocation of the river basin. Their study contributes to allocation of water scarcity in the Nile River basin and other border river basins in order to prevent water conflicts and ensure the sustainability of fresh water resources. In another study, Zarezadeh et al. (2012) investigated Qazluzan-Sefidroud river basin in Iran. This river basin is located across eight provinces of the country which during the past a few years has suffered from social economic development projects leading to diverse water conflicts. They used four bankruptcy methods, i.e., relative, modified relative, equal profit bound, and equal loss bound in order to provide a fair allocation for different scenarios. The results showed that the plan based on the same profit constraint is the most acceptable allocation under all scenarios.

Madani et al. (2016) investigated the roots of WB by applying socio-economic perspective during drought in Iran. The authors found seventeen factors that influenced WB in Iran: rapid population growth, migration and expansion of urbanization, inadequate infrastructure for water distribution, deterioration of water quality, unsustainable agriculture, unrealistic self-sufficiency of food security, increasing water demand, cheap price for water and energy, indiscriminate dam construction, illegal deepening of wells, drought recurrent, occurrence of floods, climate change, bottom up development projects, economic sanctions and instability, inappropriate structure of water governance, and low level of environmental awareness. In another research, Moradian & Behvar (2018) found that the water crisis in Iran has multiple causes. For example, they showed that structural and physical view of development practitioners, the laws and regulations of water sector, and establishment of water activities affected water crisis in the region. They also identified inappropriate cultivation patterns, incorrect policies, invaluable perception of water price influenced water scarce in Iran. The study also highlighted several procedures to increase water use efficiency. For example, modernizing irrigation systems, correct timing of irrigation, and land leveling.

Overall, we can conclude that most WB researchers have used quantitative and technical approach to understand WB. However, more study is needed to take a qualitative non-technical approach to better understand the concept of WB. Moreover, quantitative researchers have neglected the emic views as pointed out by Chambers (1983). For example, conceptualizing WB as perceived by end users would help researchers in identifying dynamic models in their WB formulas when measuring this phenomenon.

Method

This study employed an exploratory qualitative method using a case study approach. A case study is a detailed study of a specific subject, such as a phenomenon (In this study, the phenomenon is water bankruptcy). Also, this study utilized documentary research in order to achieve research goals and additional information. The documentary research method serves only as a supplement to the conventional social surveys. The use of documentary methods refers to the analysis of documents that contain information about the phenomenon we wish to study (Mogalakwe, 2006).

The population of this study comprised Experts in Agricultural Organization, Regional Water Company, faculty members in College of Agriculture, and farmers in Mahidasht Plain in Kermanshah Province located in western part of Iran. Compared to the quantitative research, purposive sampling is used in qualitative research, as it allows the researcher to focus on specific areas of interest and gather in-depth data on those topics. It is also commonly used in small-scale studies with limited sample size (Gall et al., 2003, Merriam, 2002). In this study, purposeful sampling through “critical case method” was used as a sampling frame of the study. Critical case sampling is a method in which samples are selected because of their extreme importance and are at the center of the subject. People or places that provide the most information are critical cases (Ranjbar et al., 2011). In this study, 15 experts and 10 key informant farmers were interviewed through semi-structured interview (a total of 25 people).

In qualitative studies, data saturation was used to determine the sample size (Francis et al., 2010). Saturation is among the most common guiding principle for assessing the adequacy of purposive samples in qualitative research (Morse, 2015). When the data begin to repeat, so that further data collection is redundant, signifying that an adequate sample size is reached (Francis et al., 2010). In other words, saturation refers to the point in data collection when no additional issues or insights are identified and data begin to repeat so that further data collection is redundant, signifying that an adequate sample size is reached. Saturation is an important indicator that a sample is adequate for the phenomenon studied and thereby demonstrates content validity (Francis et al., 2010). Reaching saturation has become a critical component of qualitative research that helps make data collection robust and valid (O'Reilly and Parker, 2013). Moreover, saturation is "the most frequently touted guarantee of qualitative rigor offered by authors to reviewers and readers" (Morse, 2015, p. 587). Hence, in this study, data saturation was achieved with 25 people; so the researchers stopped interviewing more people.

18 semi-structured individual interviews and 2 group discussion sessions were used to collect data. Data sources in this study include documentation, interviews, group discussions, participatory arrangements. The questions were related to issues discussed in the literature and designed to stimulate verbal reflection on the issue of water crisis in the region: Some questions were raised: Do you think the water situation in the region is in bankruptcy? What does water bankruptcy mean? How is the water situation in the region? Do farmers believe that the water situation in the region is in bankruptcy? Why has the Regional Water Company declared Mahidasht plain as a forbidden plain? What types of crops are grown in the area? How is the rainfall in the region in recent years? Is the farmer allowed to harvest as much water as he wants? What is the status of authorized and unauthorized wells in the region? How are agricultural water decisions taken in the region? Will farmers participate in the decision-making process for agricultural water management? And etc.

The researcher noted and recorded. The interviews lasted, between 20 until 110 minutes, for each person, depending on the time and willingness of the participants to continue the discussion. Interviews were continued until researcher reached saturation in that no new information emerged; then, sampling was stopped. In total, Interviews lasted for 843 minutes (14 hours and 5 minutes) and further documents related to Mahidasht Plain were collected. All interviews were conducted between April and May 2023.

Qualitative field notes were collected and coded using thematic analysis. Thematic analysis goes beyond the counting of obvious words and phrases and focuses on recognizing and explaining explicit and implicit ideas (Naeem et al., 2023). Braun and Clarke (2006) propose three steps for thematic analysis. 1) analyzing and describing the text, 2) describing and interpreting the text, and 3) combining and integrating the text. The first stage includes 3 steps (getting familiar with the text, creating initial codes and coding, searching and recognizing themes), the second stage includes 2 steps (drawing the network of themes, analyzing the network of themes) and the third stage includes 1 step (compilation of the report).

Themes were identified on two levels, semantic and latent. In the analysis of existing themes, the formation and development of themes is an interpretive work, and the analysis is not just a description but a form of theorizing.

In this study, in order to analyze the data, first, interviews text was implemented, word by word. Then, interviews notes and materials were reviewed several times and using open coding, key phrases were extracted. Then, by comparing these codes (phrases), similar codes were categorized and developed a theme (concept).

In relation to uncertainty analysis, it should be stated that this study was done using a qualitative paradigm (Fig. 1). Qualitative analysis is analysis that returns a classification rather than a numerical value. Therefore, in qualitative studies, validation and error is not done with software and statistics like in quantitative studies; instead, data and findings accuracy are checked using trustworthiness criteria (Enworo, 2023; Ahmed, 2024; Merriam, 2002). Trustworthiness of qualitative study is approved through credibility, transferability, dependability, and confirmability (Enworo, 2023; Ahmed, 2024; Merriam, 2002). Trustworthiness of this study was investigated through data sources triangulation and methods triangulation. In this way, the data was collected in several times and in different ways (available documents, individual interviews and group discussions). As a result, an effort was made to consider diversity in the selection of samples, and therefore, several people were interviewed (Thurmond, 2001). In addition, the results were studied and reviewed by the research team, and finally their opinions were applied to the obtained results, and this ensured the validity of the work (peer review) (Merriam, 2002). By implementing these techniques, researchers performed error and uncertainty analysis. The study process is summarized in Fig. 1.

Study area

The study area is located in the Mahidasht sub-catchment area of the Karkheh River Basin in the middle of Kermanshah Province, Iran (Fig. 1) with a total area of 1,463 Km^2. The maximum and minimum elevations of the region are 2764 and 1310 m, respectively. In the Mahidasht plain, agriculture is the main source of the income of about 19,000 inhabitants. Shallow and deep (~1,500) wells exist in the area with an average annual water extraction of 105 MCM. The large number of wells is the main source of groundwater abstraction, which has increased pressure on the Mahidasht aquifer. The 30-year hydrograph shows a 15.3 m decline in water levels with an average annual reduction of 0.51 m (Fig. 2).
The first time Mahidasht Plain was announced as forbidden plain was in 2005/7/4 (Band-Ab Consulting Engineers Company, 2023).

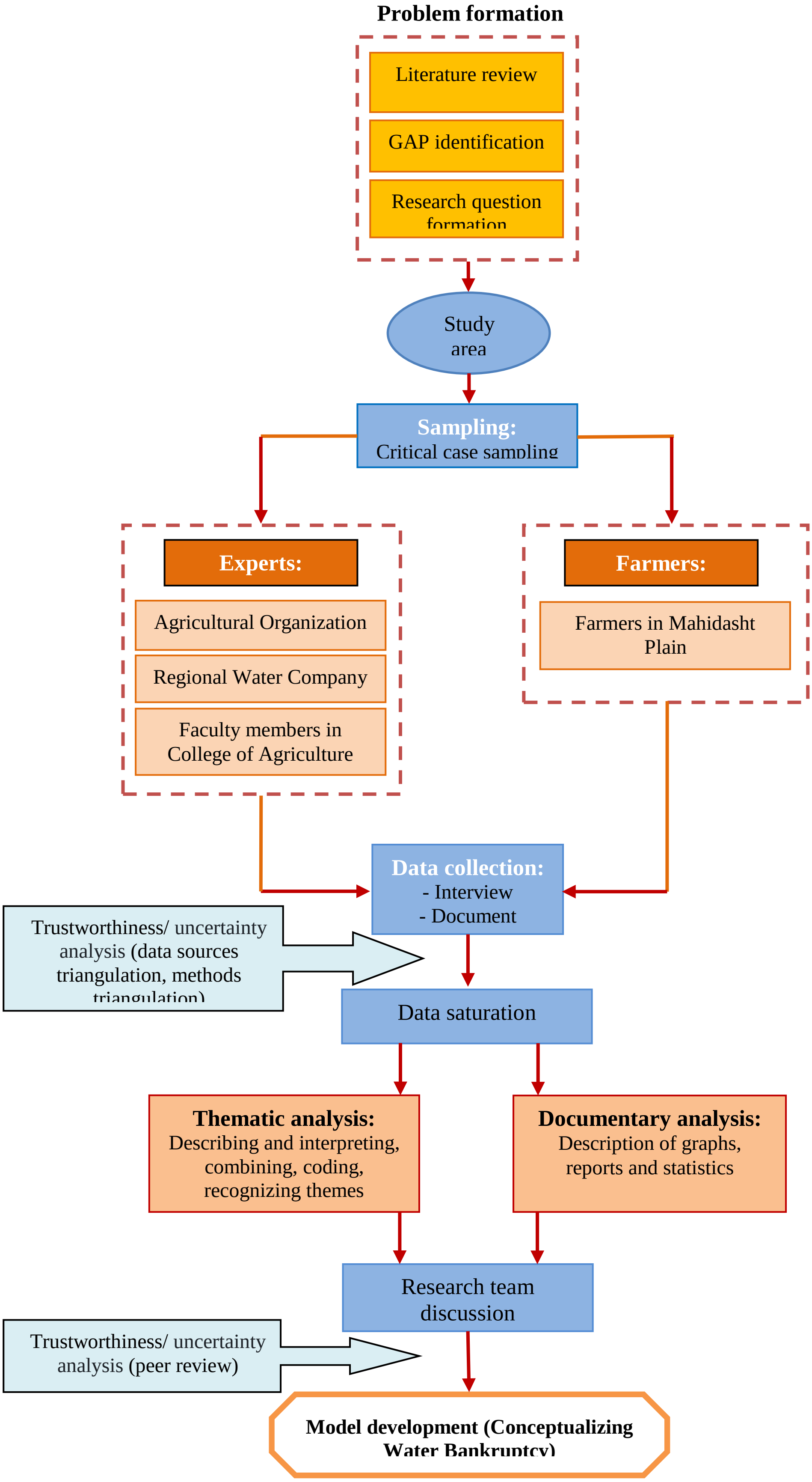

Figure 1. Flow chart of the research process

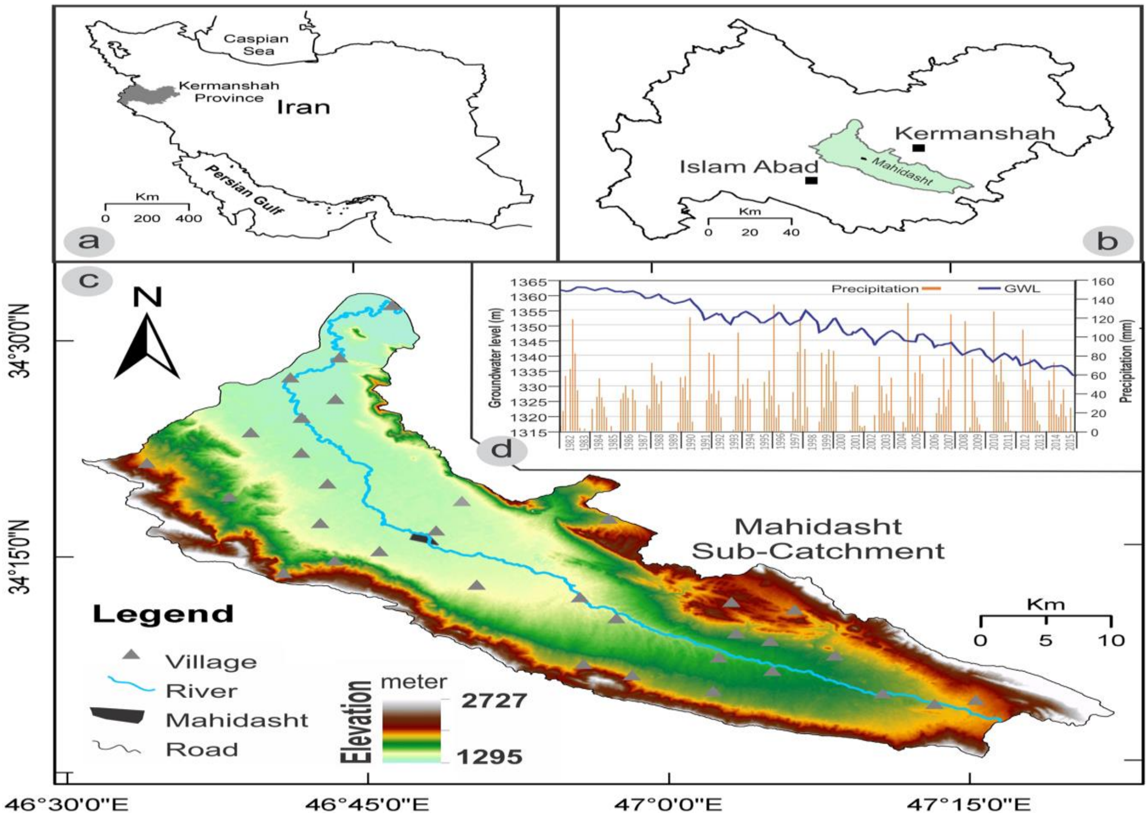

Figure 2. Geographical location of study area: a) Iran; b) Kermanshah province; c) the elevation status of the region based on DEM status map, and d) unit hydrograph of Mahidasht aquifer (Majidipour et al., 2021)

Results

The analysis of water bankruptcy (WB), as perceived by participants, is highlighted in the following sections.

Conceptualization of water bankruptcy as perceived by water experts

The results revealed 60 initial codes that further developed to twelve themes. As shown in table 1 and Fig. 2, excess water harvesting (EWH), reduced surface water (RSW), reduced ground water (RGW), condensation and change of aquifer (CCA), disruption of drinking water (DDW), negative water balance (NWB), over harvesting of renewable water (ORW), reached dead point with water (RDW), reduced water table (RWT), formation of hard pan (FHP), water forbidden (WF), engaging in non-agricultural activities (ENA).

Table 1. Concepts of water bankruptcy as perceived by water experts

Quotes (open coding)	Type of thematic	Theme (axial coding)
Well exploitation permit is not based on real context. We announced certain amount of water harvest permit for normal years not dry years. We do not tell farmers that this amount is not for dry years! Farmers are in competition with one another and they are only concerned with harvesting water. They even irrigate their fields during rainfall season.	Latent	
Linear programing is dominant but not sufficient. Over-water permits to farmers have caused misconception as if there is ample of water to use.	Latent	
Over harvesting of water has to stop otherwise there will be no drinking water in the long run or stop cultivating spring cultivars.	Latent	
They only see short terms by deepening their wells and using irrigated method, they thought everything would be fine and continued over harvesting water without thinking about the future. If they think there is water for the next two years, they'll continue over using water.	Latent	
In general, at least 70% of the water consumed in Iran is used in agriculture. In our province, water consumption is more, because our economy is mostly agriculture. Also, average water consumption is high in Mahidasht Plain.	Latent	
We had 30 years of over harvesting. This is a terrible situation. Even four consecutive rains wouldn't do any good.	Semantic	Excess water harvesting
We can seal off the wells but it would conflict among us. There is no way out.	Latent	
Water resources are not good at all in Mahidasht Plain. Also, they do not have permission to utilize water. They may go towards illegal digging of wells.	Latent	
For example, a farmer has 10 hectares of land, he can make a living with 4 hectares, but he consumes more than he needs.	Latent	
During the past 3 years (from 1995 to 1999), the volume of water withdrawal from Mahidasht Plains has increased by more than 100%.	Latent	
Farmers are not satisfied with what they should withdraw from their wells. They vandalize water meters.	Semantic	
We installed water meters, but we do not have any restrictions on water withdrawals. Now the meters are rechargeable.	Semantic	
We at Regional Water Company do not allow over water harvesting, but farmers start to burglarize.	Semantic	
Water mismanagement without scientific background has caused many burdens on water resources.	Latent	
When demand for water is excessive, bankruptcy occurs.	Latent	
Water harvest is far more than the capacity.	Semantic	

Continue of table 1. Concepts of water bankruptcy as perceived by water experts

Quotes (open coding)	Type of thematic	Theme (axial coding)
There used to be other water resources such as river and rainfall. But now theses resources have depleted. The permits we issued are no longer useful and farmers continue to over use water from their wells.	Semantic	Reduced surface water
Current precipitation only compensates a certain amount of water shortage. In the wet season, water rises and in dry season water falls. The situation in Mahidasht is far more devastating to be compensated with current rainfall.	Latent	
Mahidasht Plains is a large area and there is no surface water to replenish so we are only dependent on groundwater.	Semantic	
It is true that during the past two years of drought, the capacity of water increased by about 300 mm, but two years later, a drought occurred and caused a further decrease water capacity. .	Latent	
Severe drought caused water shortage. On the other hand, we over harvested and this has caused shortage of water.	Latent	
In my opinion, Mahidasht Plain is 100% water bankrupt and with this amount of precipitation, the situation will never return.	Latent	
In general, Iran is water bankrupt because the average rainfall is 250 mm.	Latent	
Mahidasht Plains has no surface water. Only the Mereg River has dried up.	Semantic	
Farmers don't believe that there is no water. Also, with 10 mm of rain they think that the lack of water has been compensated. Although the have deepened their wells and created series of problems but they don't care at all.	Latent	Reduced groundwater
In Mahidasht Plain, during the past 30 years, we could reach less than 3-4 meters of water. We cultivated any type of crop we wanted but now the water table is way down with restrictions of digging wells.	Semantic	
In Mahidasht Plains, groundwater has reached way below and it takes time for water to reach below the surface. In the short term, this rainfall will not have much effect on discharge of the wells.	Semantic	
In Mahidasht Plains, we experienced water drop of 50-60 cm per year. Therefore, in the last 30 years, we had a water drop of 15 to 20 meters. Farmers clearly see what is going on.	Semantic	
Farmers know that there is no water due to dry wells. But they still deepen their wells due to their poor livelihood.	Latent	
We have been in crisis for many years now. The groundwater tables have reached salinity which in turn reduced yields.	Latent	
The water level has dropped between 20, 30, and 40-meters causing aquifer to reach the state of crisis.	Latent	
Believe it or not, we have wells that are 120 meters deep.	Latent	

Continue of table 1. Concepts of water bankruptcy as perceived by water experts

Quotes (open coding)	Type of thematic	Theme (axial coding)
Water holding capacity has decreased in the plain thus We cannot harvest the same amount of water as before. Soil pores were coarser before and the harvesting capacity has decreased. Special hydration has changed.	Semantic	Condensation and change of aquifer
The groundwater has reached way below and the soil structure is broken causing soil cracks and sinkholes.	Semantic	
In Mahidasht Plains, water holding capacity has decreased (for example, it has decreased by 20 cm). Topsoil has destroyed and cannot be regenerated.	Semantic	
Mahidasht Plains used to be fertile and wide with excessive rainfall and there was no need to dig a well. Now, water holding capacity has extensively reduced.	Latent	
Many years have passes by and this aquifer is no longer as effective as before due to changing characteristic of the aquifer. I don’t think things will return as before.	Semantic	
If the aquifer is compressed with no point of return, water bankruptcy emerges.	Semantic	
Corn farmers admit that the wells are not sufficient and they have to irrigate with irrigation tapes even though is not enough.	Latent	Disruption of drinking water
We needed drinking water but we only had 12 liters.	Semantic	
We are also faced with health problems due to water shortage. Only if we reach famine, farmers would believe.	Semantic	
Mahidasht Plains has a serious problem with drinking water. The groundwater table is low and the hydrograph is strongly negative.	Semantic	
The groundwater level has decreased. In 2001 till now, the groundwater has reduced tremendously.	Semantic	
A large local company dug a well but reached zero water.	Latent	
The aquifer has decreased by 260 million m^3 (negative balance). The groundwater level has also decreased by year 1400. A local company asked me to find a place for him to dig a well but I refused.	Semantic	Negative water balance
Iran's water balance is bankrupt, especially in Mahidasht because of over crop harvesting. Rainfall in Mahidasht Plain is also limited, which is below Iran's annual average. The Plain has a large area with extensive crop cultivation with situation getting worse each year.	Semantic	
The water balance is negative and is getting worse year by year. It will never be compensated. With this amount of rains, the balance will never reach positive.	Semantic	
Every year, the balance between produced water to consumed water is negative. We have reached water bankrupt.	Semantic	

Continue of table 1. Concepts of water bankruptcy as perceived by water experts

Quotes (open coding)	Type of thematic	Theme (axial coding)
The aquifer has decreased by 260 million m^3 (negative balance). The groundwater level has also decreased by year 1400. A local company asked me to find a place for him to dig a well but I refused.	Semantic	Negative water balance
Iran's water balance is bankrupt, especially in Mahidasht because of over crop harvesting. Rainfall in Mahidasht Plain is also limited, which is below Iran's annual average. The Plain has a large area with extensive crop cultivation with situation getting worse each year.	Semantic	
The water balance is negative and is getting worse year by year. It will never be compensated. With this amount of rains, the balance will never reach positive.	Semantic	
Every year, the balance between produced water to consumed water is negative. We have reached water bankrupt.	Semantic	
Three indicators such as Falkenmark, Institute of Water Resources Management, and Institute's index are used to measure water status. The Falkenmark index is based on annual volume of renewable water resources per capita indicating individual water use. Deficiency index happens when an annual per capita volume of water is equivalent to 1000 cubic meters. Stress index occurs when an annual per capita volume of water is equivalent to 1700 cubic meters. Countries with annual per capita less than 1000 cubic meters are considered water scarce. However, countries with less than 500 cubic meters per capita per year are imposing pressure on people.	Latent	Over harvesting of renewable water
According to the United Nations, if we consume 40% or more of renewable resources, we are in the critical state. We now have 100 billion cubic meters of renewable water. According to the Ministry of Agriculture, about 62 billion m^3 is used in agriculture. However, Ministry of Energy states otherwise (80 billion m^3). A clear contradiction at policy level. We are better of importing some agricultural products (virtual water).	Latent	
We have no right to harvest renewable water needless to say we did.	Semantic	
For example, one year of wet season causes delay in groundwater drop. Nature helps by providing rain thus delays groundwater drops. All projects such as aquifer restoration, increased performance and efficiency of irrigation systems is word of mouth. We hardly survive.	Latent	Reached dead point with water
We have reached dead end (over water harvesting and huge number of wells). There might be a solution but not with this type of management.	Semantic	
We might be able to control the situation but we cannot save the Plain.	Latent	
There are about 1000 legal wells and 200-300 illegal wells in Mahidasht Plain. The water table of water has gone way below.	Semantic	Reduced water table
In sandy soil water is stored. If water table goes below 20 cm, the soil to settle. It would never be the same.	Latent	
The hard pan is formed in the surface horizons of the soil. How do you expect rainwater penetrates to the lower level and groundwater aquifers?	Semantic	Formation of hard pan
Excessive use of chemical fertilizers, especially urea, hardens the soil and creates hard pan.	Semantic	

Continue of table 1. Concepts of water bankruptcy as perceived by water experts

Quotes (open coding)	Type of thematic	Theme (axial coding)
Mahidasht Plain as one of our worse Plain is known as critical forbidden Plain so that it has been adjusted to certain measures. This helps to allocate minimum amount of access water to farmers. However, other Plains in the province has received improvement factor. Let us say water forbidden Plain.	Semantic	Water forbidden
Farmers are no longer cultivating because there is no water.	Semantic	Engaging in non-agricultural activities

"Excess water harvesting" (EWH) has been proposed as the first concept of WB by experts. This concept consists of 16 representative phrases that express the expert's consensus regarding this concept. In other words, the emphatic statements about this concept all indicate that farmers in the region are extracting excessive water from the plain' capacity, with no legal restrictions on water harvesting. Therefore, EWH is considered as WB.

The second concept that the experts frequently raised regarding WB is "reduced surface water" (RSW) and "reduced ground water" (RGW) which each of these was characterized by 8 representative terms. From the experts' point of view, rainfall has decreased in recent decades, which leads to the decrease of surface water sources such as rivers. To the extent that the most important river in the region (Mereg River) has dried up. On the other hand, water harvesting continues to rise, which has caused the groundwater aquifers to drop sharply, with recent rains having no significant impact on water flow. Therefore, experts consider this issue as WB.

Other important concepts of WB in the studied area were "condensation and change of aquifer" (CCA) and "disruption in drinking water" each with 6 primary quotes. Water and soil experts believe that the significant decline in groundwater levels has condensed the soil structure, breaking down soil particle pores (creating micropores), thereby reducing water-holding capacity. This situation arises because, despite adequate rainfall, water cannot be stored due to the compression and condensation of the aquifer. Therefore, water and soil experts introduce WB as CCA.

Regarding the disruption in drinking water, some experts said that the water situation in the region is critical and the authorities are facing problems in providing drinking water and sanitation. Therefore, this situation shows that the plain is facing a severe water shortage and is bankrupt. Thus, experts consider the disruption in drinking water as an indicator of WB.

Another key concept that was raised by some water experts is "negative water balance" (NWB) with 4 emphatic codes. According to them, water harvesting is more than the water input to the plain, resulting in a negative water balance that cannot be offset by recent rainfall. In fact, experts consider WB to mean a NWB.

Concepts such as "over harvesting of renewable water" (ORW) and "reached dead point with water" (RDW) each include 3 primary quotes. Regarding ORW, the experts admitted that currently, over 40% of renewable water resources are utilized in Iran, reflecting the country's critical water situation. Therefore, experts interpreted the bankruptcy of Mahidasht Plain as an ORW.

Some experts also used the term RDW for WB. They believe that the excess water harvesting and the existence of several wells in the region have caused the water situation to reach a dead end, and nothing can be done.

Among the other concepts of WB that were mentioned by the experts, there were concepts such as "reduced water table" (RWT) and "formation of hard pan" (FHP), each of these topics is also mentioned with 2 initial terms.

Excess water harvesting (EWH) and the existence of several wells in the region have caused the reduce water table. As a result, this issue has made it more difficult to access groundwater. Hence, sometimes re-excavation is required to reach the groundwater tables. This issue leads to saltwater intrusion into groundwater aquifers. Therefore, some experts believe that RWT indicates the WB in the region.

Some soil experts consider the FHP on the soil surface as a reason for WB. They explained that overuse of chemical fertilizers (e.g., urea) hardens the soil, forming a surface crust. In this case, it is not possible for rain water to penetrate to the lower layers, and considering that the only water input in Mahidasht Plain is rain water, this problem causes a severe shortage of groundwater in the region, and WB occurs.

"Water forbidden" (WF) and "engaging in non-agricultural activities" (ENA) with 1 initial phrase are other concepts raised by experts in relation to WB in Mahidasht Plain. Water experts stated that the Mahidasht Plain is one of the critical forbidden plains that well-drilling permits should not be issued, and water-intensive crops should not be cultivated. They use the forbidden water concept for WB.

Some experts also believe that the severe lack of water in the region has caused many farmers to stop farming and engaging in non-agricultural jobs. These experts consider engaging in non-agricultural jobs as an indicator of the critical water situation and WB in the region.

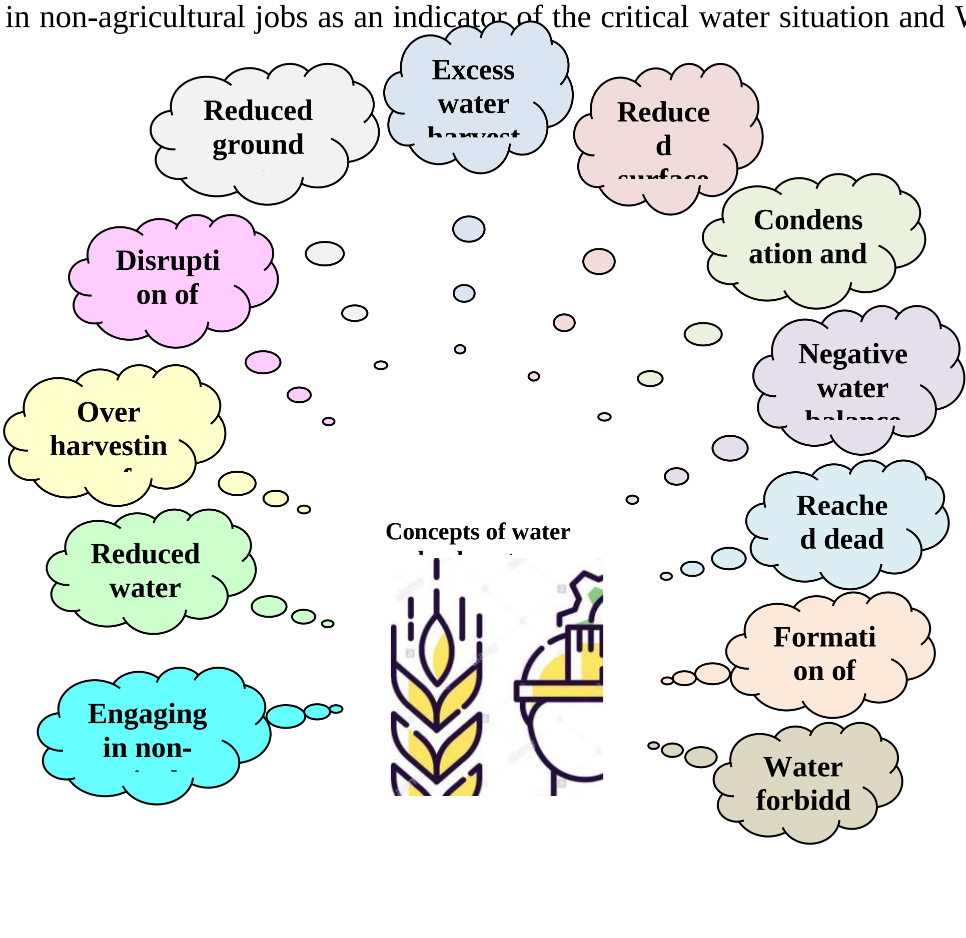

Figure 2. Conceptualization of water bankruptcy as perceived by water experts

Conceptualization of water bankruptcy as perceived by water farmers

The results revealed 47 initial codes, which were consolidated into five themes. As shown in table 2 and Fig. 3, excess water harvesting (EWH), reduced surface water (RSW), agricultural bankruptcy (AB), reduced ground water (RGW), and water forbidden (WF).

Table 2. Concepts of water bankruptcy as perceived by farmers

Quotes (open coding)	**Type of thematic**	**Theme (axial coding)**
We should use floating pump equal to size of our land and not more. Most think its their right to do so.	Semantic	Excess water harvesting
Mahidasht Plain has water problem. There is excessive exploitation among legal wells. Deep wells are also drying up.	Semantic	
Farmers dug their wells without restrictions and in close distance. An unknown middleman asked me to pay x for him to give me a permit to dig a new well.	Semantic	
Farmers use water as much as they can with this in mind that if he doesn't someone else would.	Semantic	
Smart meter is useless for farmers. I know someone who uses 8 sprinklers without anyone complaining.	Latent	
I know a x factory who is draining all the water with his two wells (250 meters) that is located in Sarab Niloufar Lake.	Latent	
All crops grown in the region are water-bearing crops. If water experts had informed us about impact of high-water bearing crops and even penalize us, we would have stop cultivating such crops.	Latent	
Unfortunately, farmers are not allowed to over collect water, but they do anyway.	Semantic	
I am allowed to use 2 liters of water per second, but I use 30 liters of water per second. I am willing to pay for the extra.	Semantic	
Even If farmer knows that there will be no more water in 5 years, he would still over collect water without thinking of next generation.	Latent	
Land tenants and some owners install strong floating pump and extract 20 inches of water per second.	Semantic	
There are 32 wells in our village and if placed on any dam, it will dry it up.	Latent	
A Factory X in my area consumes 50 liters of well water per second for 12 months.	Latent	
Farmer is allowed to harvest as much water as he wishes. Thus far no one has stopped it.	Semantic	
There are illegal wells in Mahidasht Plain and farmers over collect from them.	Semantic	
We wanted to plant corn, but we saw that the water was decreasing day by day.	Latent	
In Mahidasht Plain, there are plenty of wells.	Latent	
A Factory X in the Plains has several wells and they pump water day and night.	Latent	
We do multi cropping with all restriction on water harvest.	Latent	
Farmers recklessly harvest a large amount of water.	Semantic	
550 square meters of land is located next to Mereg River. Mereg is one of the dead rivers which has water only autumn. I suggested that they put a dam on the river so that we can use it whenever there is a flood. The fields have become infertile due to lack of water.	Semantic	Reduced surface water
Water has decreased with concurrent drought for the past a few years. It's a mistake to think that this year was a wet season. In Kermanshah alone there was 120-130 mm. The land is dry.	Semantic	
During wet season, we cultivated variety of crops. But during dry season we only do rain fed farming.	Semantic	
Rainfall has reduced by 100%. This year we had 330 mm and last year we had 250 mm. Any rainfall below 700-800 mm is onset of drought.	Semantic	
When I was a kid we used to swim in Mereg River because it was full of water but it has dried due to drought for the past a few years.	Semantic	
Rainy season has disappeared and it is getting worse. If we have a good wet season, we can expect to have a good year in the next 10 to 12 years.	Latent	
Rainfall has decreased a lot and it is 100% due to water loss.	Semantic	
Droughts have also caused dehydration.	Latent	
The Mereg River has no water.	Semantic	

Continue of table 2. Concepts of water bankruptcy as perceived by farmers

Quotes (open coding)	Type of thematic	Theme (axial coding)
I had 10 hectares of irrigated farming. I have decided to let go of 5 hectares and plant spring or autumn peas so that I don't have to water a lot.	Semantic	**Agricultural bankruptcy**
We are now faced with the lowest water level in the last 20 years. In summer, the water reaches 1 inch. We did not cultivate half of the land due to lack of enough water.	Semantic	
I used to cultivate 10 hectares, but now I cultivated 4 hectares by sowing spring cultivars. I had no choice otherwise I had to let go of farming and find some other jobs.	Semantic	
We have limited water in the Plain and we are going bankrupt and have to leave farming.	Semantic	
I have sowed 4 hectares of sugar beet but before I had 11 hectares because I had access to more water.	Semantic	
Agriculture is not profitable and is on the verge of bankruptcy. While it is profitable in anywhere else.	Latent	
We have to cultivate less land. There is no water.	Semantic	
We do single cropping because we don't have access to sufficient water.	Semantic	
Tenants engage in multi cropping. They sow potatoes that need water every other day. They pump water from February to October. The tenants pay 60000 dollars and take advantage of owner's well. The result is empty groundwater resources.	Semantic	**Reduced groundwater**
The groundwater level has gone down or its very scarce. We have to go below 70 meters to see any water but before we saw water below 3 meters. I know a friend who dug a well below 201 meters but couldn't get 6 inches of water.	Semantic	
Water is running out and groundwater layers are disappearing. The layers are no longer able to store water and therefore we are facing environmental disaster.	Latent	
Many wells have been dug and groundwater sources have gone down. In the past we used to collect water from 3-4 meters deep but even now 40-50 meters deep doesn't give us any water.	Semantic	
Water has decreased a lot and compared to the previous years we had a 50-meter water drop (10-12 years ago).	Semantic	
One of the water Karstic resources is located under the Mahidasht plain, most of which is empty.	Semantic	
All this rain has come (last year and this year), but it has not penetrated enough and therefore the wells are dried.	Latent	
Although Mahidasht Plain is known as forbidden Plain, water experts still issue permission to harvest.	Semantic	**Water forbidden**
I know that the plain has been forbidden for the past 15-20 years and I also know that there is no water.	Semantic	

The first key concept that farmers conjured from the term WB was "excess water harvesting" (EWH). This concept with 20 emphatic phrases expresses the farmers' emphasis on this concept. Farmers are also aware of the fact that water exploitation is done indiscriminately, so that deep wells are also drying up. Meanwhile, there is no serious lever to prevent EWH, and if the farmer uses too much, he is only required to pay a fine. Therefore, from the point of view of farmers, EWH means WB.

Among the other concepts that farmers raised after hearing the term WB, were "reduced surface water" (RSW) and "reduced ground water" (RGW), each of these concepts is specified with 9 representative expressions in Table 1. From the point of farmers, the amount of rainfall has decreased over recent years and this situation is getting worse year by year. The lack of rain has led to consecutive droughts, which has resulted in the drying up of the Merg River. On the other hand, due to the fact that the amount of water in the region depends on the amount of precipitation, the water level of the groundwater aquifers in the region has dropped sharply, so that the wells are drying up and the farmers have increased the depth of their wells to access water. Therefore, farmers consider the RSW resources and the decreased groundwater as the WB in the region.

"Agricultural bankruptcy" (AB) with 9 primary codes is one of the influential concepts expressed by farmers regarding WB in Mahidasht Plain. They stated that due to the lack of water, they did not cultivate a part of their land and farming is not profitable for them. Some farmers also decided to abandon farming.

Some of the farmers were aware that Mahidasht Plain has been declared as "forbidden plain" (FP) and pointed out that the Regional Water Company should not permit excessive exploitation of water and drilling wells, because the region has a severe water shortage. Meanwhile, many lands in the region rented to farmers in other provinces and they have also cultivated water crops such as potatoes and corn. These farmers use the term water forbidden (WF) for WB.

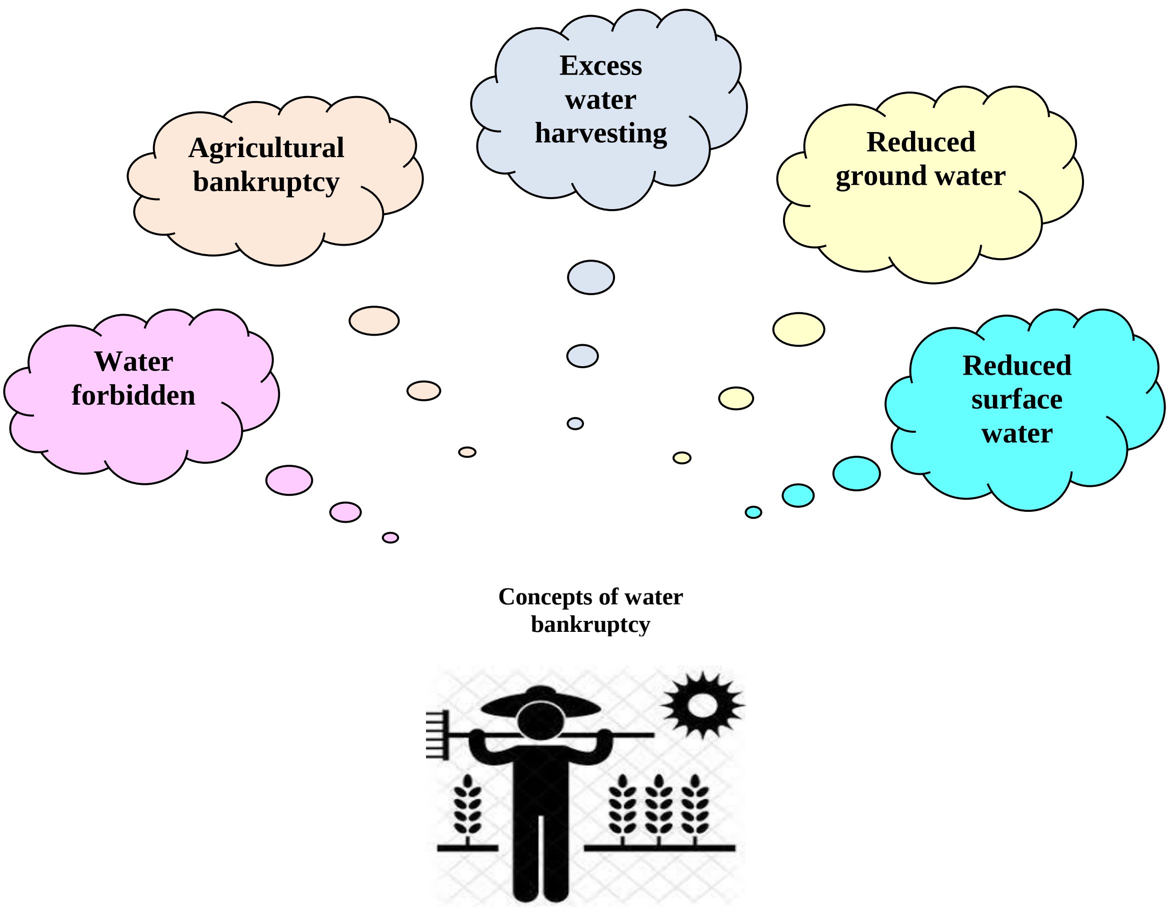

Fig. 3. Conceptualization of water bankruptcy as perceived by farmers

This qualitative study sought to investigate how Iranian farmers conceptualized WB in forbidden Plain of Mahidasht in western Iran. Moreover, this study uncovered water experts' perception of WB. Results revealed that water experts conceptualize WB as excess water harvesting (EWH), reduced surface water (RSW), reduced ground water (RGW), condensation and change of aquifer (CCA), disruption of drinking water (DDW), negative water balance (NWB), over harvesting of renewable water (ORW), reached dead point with water (RDW), reduced water table (RWT), formation of hard pan (FHP), water forbidden (WF), engaging in non-agricultural activities (ENA). Moreover, farmers conceptualize WB as excess water harvesting (EWH), reduced surface water (RSW), agricultural bankruptcy (AB), reduced ground water (RGW), and water forbidden (WF). Interestingly, both groups shared similar concept in five themes but differed in other seven themes. This difference may be due to technical concepts shared by water experts. In the following paragraph we will discuss each and every theme in detail.

Excess water harvesting (EWH)

As mentioned in result section, "excess water harvesting" (EWH) is the first concept of water bankruptcy as perceived by water experts. This concept was quoted 36 times in which 16 quotes belonged to water experts and the remaining belonged to farmers. This clearly indicates that water experts and farmers are fully aware of excess water harvest by farmers. The excess water harvesting may be due to unauthorized wells, the presence of water-bearing crops, economic and livelihood pressure, competition and collusion of farmers with each other. However, water experts had enforced legal issues concerning unauthorized harvesting but farmers had not paid attention to policies regarding untheorized. Because they are aware that dealing with farmers are one of the most significant factors affecting conflict in the region and have unfortunate consequences in the society. Several studies in water field (Tatar et al., 2019; sefidgar et al., 2023; Naderi et al., 2024) show that most of the conflicts between the local community and organizations are related to water issues. These conflicts cause that society security to be endangered and it leads to high economic consequences, such as reduction in production and employment at the community level, and the country needs to import foreign products in relation to strategic products. As stated by one of the experts:

> "Se*aling of unauthorized well may lead to unemployment, social insecurity and food security, and lowers production. Therefore, the government does not seek to seal the wells*."

On the other hand, the regional water company does not have enough manpower to monitor the actions of farmers and cannot directly monitor these issues (illegal well drilling and Excess water harvesting). In addition, licensing more water harvesting for farmers and charging their cards will provide a high source of income for the water organization, and in fact, selling more water makes more profit for the organization, and this is contrary to water scarcity situation in the region. This issue has caused experts not to follow up on the sealing illegal wells or the restriction of harvesting in legal wells. Therefore, the weakness in the implementation of institutional and legal frameworks for water distribution is clearly seen in the organization, which leads to excess water harvesting and water bankruptcy.
Another farmer protested to water organization management said:

> *Now that we are in water crisis, authorities should seal unauthorized wells rather than just imposing penalties. For example, the administration can penalize 1100 dollar for 10 hectares of water cultivation, which is a good source of income for the administration".*

According to the Ministry of Energy, 45% of all wells in the country are illegal. In Kermanshah province, 36% of wells are illegal (Ghamarnia, 2023). However, there is no information on Unauthorized wells since they are not registered; therefore, farmers take advantage and utilize water as much as they can from these unauthorized wells. Consequently, water harvest from these unauthorized wells is not considered in the balance of water resources. Therefore, some experts believe that issuing permits to unauthorized wells causes water harvesting is calculated more realistically and more accurate statistics of the water condition in the region are obtained.

One of the water experts impatiently stated:

> "*Filling the well is costly. No matter how they fill the well, farmers will dig a well from another place because it's their job. Therefore, government does not interfere because they do not wish to cause social tension*".

A concept that emerged from the data among farmers was overuse of water that can be related to his perception in that if he doesn't take advantage they will be overrun by others. This is the reason why there are no restrictions on water harvesting by farmers. In this regard, the findings of the study by Amiri and Mirkzadeh (2022) showed that farmers in Mahidasht are not willing to install smart meters so that they can easily harvest water.

On the other hand, farmers who use this technology charge it after they reach the allowed amount of water. Therefore, it is worth considering that the experts have banned drilling and more water harvesting in the region, while it is possible to excess water harvesting by paying a fine! Hence, the farmer has agreed to pay fine for cultivation of water crops in the area, because it is very economical for the farmer.

According to one of the farmers in the region:

> *"... The Regional water charges our usage card and we pay for it no matter how much it is. There is a conflict of interest, the more water the administration delivers (sells), the better."*

As shown in Tables 1 and 2, most water-based crops such as potatoes, corn, beets, and tomatoes are cultivated in the region. This clearly indicates that although Mahidasht Plain has been introduced as a critical prohibited plain for many years, there is limited monitoring and restrictions the Agricultural Jihad Organization and the Water Affairs Department. This in turn has encouraged farmers to engage in over use of water. Moreover, the problem seems to be more complicated when a few lender farmers decided to lease their property to other farmers of the region. One of the farmers stated:

> *"The tenants do not care about their boundaries and restrictions. They cultivate without considering the amount of water they are allowed to use."*

For farmers who have rented land, water, environment and resource sustainability conservation are not important. For the farmers who have leased their land, the same thinking prevails and the concern of their subsistence life prevents them from makeing a right decision for future generation. In confirmation of this analysis, the findings of Majidipour et al. (2021) and Fattahi Chaghabaghi et al. (2023) regarding the groundwater sustainability of Mahidasht aquifer showed that most parts of the region are in an unstable state in terms of groundwater and the application of the management scenario of 30-40% reduction in groundwater extraction will not stabilize the central areas of the aquifer. In fact, on the one hand, the environmental awareness of farmers is low, and they are not fully aware about climate change, and they hope that the water situation will improve in the coming years; on the other hand, economic benefit is the first priority for them.

In line with concepts emerged, Ghamarnia (2023) showed that drought and over-harvesting caused the groundwater reservoirs in Kermanshah province to have a cumulative deficit of one billion and 34 MCM. In addition, 300 MCM are also overdrawn from all the aquifers in the province. In another study, Visi et al. (2021) estimated water poverty index in the plains of Kermanshah province. Results revealed that Mahidasht Plain is in a state of severe agricultural water poverty by using water poverty indicators in terms of aquifer stability (the total volume of discharge from the aquifer to the volume the whole supply to the aquifer). This result meant that Mahidasht Plain is in worse condition in compare to other plains in Kermanshah Province. In a similar study, Zarafshani and Sadvandi (2017) also concluded that the Mahidasht Plain is in a state of severe agricultural water poverty by using water poverty indicators. Madani et al. (2016) also point to the lack of environmental information in Iran and they believe that awareness among the people is increasing as a result of the environmental trend that has been created in recent years; For example, in this study, some farmers mentioned climate changes and droughts and the reduction of surface water in the region.

It can be concluded that both farmers and experts are in accordance in terms of WB concept as well as in line with theoretical rendition of reality.

Reduced surface water (RSW)

A second concept that emerged from the data by both groups was "reduction of surface water" (RSW). This concept was quoted 17 times by participants (8 phrases by experts and 9 phrases by farmers).

Both groups of participants stated that the amount of rainfall in Mahidasht region has decreased for several years and this has led to consecutive droughts. In other words, considering the amount of rainfall as well as the flow from Mereg River, we can conclude that Mahidasht Plain is faced with critical status. The amount of water entering Mahidasht Plain is negligible, while the amount of water extracted is significant causing unacceptable water feeding.

In this regard, the global statistics and evidence also show that the climate has changed. In terms of the average surface temperature of Earth, these indirect estimates show that 1989 to 2019 was very likely the warmest 30-year period in more than 800 years; the most recent decade, 2010-2019, is the warmest decade in the instrumental record so far (since 1850) (McNutt and Ramakrishnan, 2020)

Therefore, the evidence of climate change is compelling: sea levels are rising, glaciers are retreating, precipitation patterns are changing, and the world is getting warmer (Adedeji et al., 2014). Meanwhile, countries such as Iran, which are located in arid and semi-arid regions, are very sensitive to climate change (Silva et al., 2023).

The issue of climate change in Iran can be seen concretely, including the decrease in rainfall and successive droughts. In this regard, the head of the National Center for Climatology in Iran announced that over the next 40 years, the Middle East region, including Iran, will face severe drought for 30 years. This growing threat has started in recent years and in the next 90 years, the amount of rainfall will decrease, the temperature will increase and the groundwater table level will disappear (Sharafi et al., 2020). In various studies in the world and in Iran, the decrease in rainfall in recent decades has been confirmed (Sharafi et al., 2020; McNutt and Ramakrishnan, 2020; Mianabadi and Davary, 2023).

In this regard, Kermanshah province has also experienced drought with different intensities in several time periods.

In this regard, Ghamarnia (2023) evaluated changes of surface flows in Kermanshah province. He concluded that during drought period in 2017, the average annual runoff volume of Kermanshah province has decreased by more than 40%. Moreover, rainfall during wet season in 2022-3 was 21% lower than the long-term average rainfall. In a study conducted by Sharafi et al. (2020) for one-year meteorological drought changes (SPI) in the rain gauge stations of Kermanshah indicated that Mahidasht rain gauge station faced 17 years of meteorological drought in a 30-year period (1986 to 2014). This result shows a significant decrease of surface water in the region. Since rain is the only source of water entering the plain, we can conclude that this phenomenon has had a significant impact on reduction of the water source of the plain and the drying up of the Merah River.

The debatable point is that if the decrease in rainfall continues for many years, due to the direct effect on water resources, it will cause agriculture crisis. The continuation of meteorological and hydrological droughts in the region has caused insecurity in the economy of rural household. For this reason, many farmers in the region have irrigated their lands (drilling wells and setting up irrigation systems) and start cultivating water crops. As a result, the extraction of water from the well has increased and this problem, as a serious challenge, aggravates the water shortage in the region.

Interestingly, many experts and farmers pointed out that although rainfall has been unsatisfactory for two consecutive years, the Plain has not been fed enough is not fed and there is still a shortage of water.

Therefore, it is evident that both groups of experts and farmers are fully aware of the reduction of rainfall and surface water in the region. Therefore, according to these alarming conditions, the participants understand water bankruptcy as the reduction of surface water. In fact, experts and farmers believe that one of the concepts of water bankruptcy is the reduction of surface water, which is consistent with the reality of society.

Reduced ground water (RGW)

Another concept that was raised by both groups of farmers and water experts was "reduced ground water" (RGW). This concept was derived through 15 phrases (8 phrases by experts and 7 phrases by farmers). As previously mentioned, the existence of many authorized and unauthorized wells in the region has led to a large drop in groundwater. Farmers and water experts believed that depletion of groundwater resources is due to the reform that was passed in parliament stating that any wells that was dug illegally before 1385 in plains across Iran and was identified by Ministry of Energy and that followed legal distance from other wells in the region equipped with sprinkler irrigation is subject to exploitation license (Center Researches of the Islamic Council, 2010).

Moreover, reduction of rainfall and consecutive droughts are also the cause of reduced ground water resources. As stated by one of the farmers: "*It takes time for these rainfalls to penetrate to lower layers and thus has limited impact on the discharge of current wells*". According to data provided by Iran's water information Center (https://mrsi-g.ir), from 1959 to 2023, the groundwater of Mahidasht Plain has decreased by about 0.5 meters every year. This reduction of water resources is very clear and can be seen by farmers causing them to illegally deepen their wells. In this regard, Gorgani et al. (2017) predicted that in the upcoming year, the groundwater level will intensively continue to decrease in the future. In other words, the annual trend will continue in the future in such a way that the average water level of most piezometers will decrease until 2031 since general trend of these piezometers in the last 20 years confirms this phenomenon. Also, Hosseini et al. (2019) assessed the sustainability of groundwater resources in 30 aquifers in Iran using environmental indicators. Their results demonstrate that state of ground water quantity and quality is unsustainable. Moreover, Emaduddin et al. (2020) showed that groundwater level trend in Mahidasht Plain has a downward direction, which follows a gentle downward trend from 1981 to 1998 and a steep slope from 1998 to 2015. In addition, in 2015, the level of groundwater is at the lowest value during the studied period. The survey of Mahidasht Plain water level during the mentioned period shows a drop of about 23 meters in aquifers. Furthermore, Khalilpour et al. (2018) also indicated that water level of wells in Mahidasht Plain has dropped during a 16-year period (1998-2015). Overall, current evidence shows a significant decrease in groundwater in the region showing consistency between farmer's conceptualization of WB and the realities of the studied region.

Majidipour et al. (2021) evaluated the stability of Mahidasht aquifer groundwater based on socio-economic and environmental indicators. The results of their study showed that in most areas are in the unstable category, so that 62% of the area has had a drop in water level of more than 10 meters.

According to experts in this filed, one of the reasons for the excess water harvesting from wells, which has led to the drop in groundwater, is that water is extremely cheap in Iran. Water is nearly free in rural areas and in the agricultural sector. Therefore, water cost is never a limiting factor for agricultural activities and only the physical unavailability of water can limit farming. Despite the recent increase in energy prices, energy has also been a relatively cheap resource in Iran. Although groundwater extraction requires considerable amounts of energy, the relatively cheap price of electricity or diesel does not make pumping costs prohibitive. The actions of the government to support farmers have resulted in substantial subsidization of water and energy. While groundwater water is becoming scarcer across the country, the government continues to pay significant subsidies, eliminating any conservation incentive agricultural water users (Madani et al., 2016).

Condensation and change of the aquifer (CCA)

This theme emerged from experts with six basic phrases. They believed that lack of rainfall during the past a few years coupled with excessive harvesting and depletion of groundwater have caused a significant change in the aquifer. This has led to condensation and compression of voids making them less viable in water holding capacity. In other words, not only, the groundwater has been depleted but the aquifer has also been damaged. Some water management experts in Iran believe that Mahidasht Plain has been settled and that the characteristics of aquifer has changed and thus do not function as they used to function.

According to scientific studies, soil compaction can have a number of negative effects on soil quality, water conservation and crop production including the following:

- causes soil pore spaces to become smaller;
- reduces water infiltration rate into soil;
- decreases the rate that water will penetrate into the soil root zone and subsoil;
- increases the potential for surface water ponding, water runoff, surface soil waterlogging and soil erosion;
- reduces the ability of a soil to hold water and air, which are necessary for plant root growth and function;
- reduces crop emergence as a result of soil crusting;
- impedes root growth and limits the volume of soil explored by roots;
- limits soil exploration by roots and decreases the ability of crops to take up nutrients and water efficiently from soil;
- reduces crop yield potential (McKenzie, 2010).

In this regard, Ghamarnia (2023) estimated changes of Mahidasht aquifer as -260.02 million cubic meters indicating a sad situation in terms of water.

A large number of soil science scholars have indicated an ideal condition for any soil is to contain 50% of air and water. In case of excessive water extraction in the basement, the coarse pores of soil particles are broken down creating micro pores. These micro pores cause soil space to block and thus reducing water holding capacity. This in turn develops runoff and flood and consequently washing away soil surface that usually takes 300 years to form 1 cm of soil in dry and semi-arid areas.

It is interesting to note that, in many cases, the agricultural method creates such hard pan. Excessive use of fertilizers and pesticides, long-term use of tillage tools at a fixed depth, the prevalence of flood irrigation, the traffic of heavy vehicles such as tractors, combine harvesters, etc., cause hard soles, which can be solved with proper management.
Apparently, water experts presented an interesting concept of WB because as the water storage tank (aquifer) is destroyed, the Plain will not be able to maintain water.

Agricultural bankruptcy (AB)

The last concept that was derived from interview with farmers and water experts was agriculture being lost or agricultural bankruptcy (AB). This concept was emerged through one phrase by experts and 9 phrases by farmers. Open interview by farmers revealed that many farmers have left part of their land uncultivated or in some cases turned into rain-fed farming with lower income. Therefore, this group of farmers lost their jobs. In this regard, Pournabi et al. (2022) investigated the allocation of water in the Karkhe River in Iran using bankruptcy models. The results showed that, because of climatic conditions and agricultural demands, full wetland restoration was out of reach and led to minimum satisfaction levels for agricultural beneficiaries. In addition, the percentage of the water supply was increased by applying the scenario of crop restriction in the conditions of the full restoration of the wetland; for example, in the Abbas Plain region, this increase was achieved by almost 10–15% in all methods. On the other hand, decreasing the area under cultivation shifted the allocation problem in the basin to a non-bankruptcy one.

A few farmers leased their farm land to other farmers from nearby provinces due to shortage of water. They believed that farming is no longer profitable. However, tenant farmers used soil and water in unsustainable manner.

Considering that there is no special industry such as factories in the region and farmers do not know any other skills (their main occupation is agriculture), they cannot earn the income that provide their livelihood and many family and social problems such as job insecurity, conflict among family members, unemployment, migration, conflict with other villagers, psychological problems, etc. have arisen for them.

As one of the farmers put it this way: "in the past our wells were semi deep but when farmers from other provinces came to lease our land for 2800-3000 dollar per hectare, we were motivated to deepen our wells."

Non-native farmers in the village have created many social and environmental problems in the region. Because the renters pay attention to their economic benefit and use excessive water resources as much as possible to produce more, and make maximum use of chemical fertilizers and poisons. So that according to some farmers, the smell of nitrates has filled the entire area. Also, migrant farmers, in order to produce a marketable product, add acid to the soil to turn the soil into a powder and produce more suitable potatoes in terms of shape. All the mentioned above makes cases for concern and regret.

Ghanbari et al. (2020) confirm that farmers' destructive behavior in Mahidasht Plain that has led to environmental and socio-cultural consequences due to leasing by tenant farmers. For example, soil structure and texture as well as quantity and quality of water resources were ruined by tenant farmers. The soil structure has turned into acidic characteristic due to the overuse of fertilizer and pesticide. Moreover, soil texture and chemical properties, including soil pH, have also been changed.

In his study in Kermanshah province, Ghamarnia (2023) concluded that the main cause of groundwater depletion and pollution is mismanagement and exploitation of groundwater by non-native farmers and immigrants from neighboring provinces. This unsustainable behavior by non-native farmers in one hand and over exploitation of water resources in the other hand have made farmers in Mahidasht Plain to minimize their agricultural activities. Therefore, farmers use the concept of agricultural bankruptcy for WB.

Conclusions

Iran is located in a dry and semi-arid climate (Sharafi et al., 2020). Therefore, drought has become a permanent feature of the country's climate, particularly in recent decades (Rezaei et al., 2024). Consequently, average rainfall in Iran is reported to be lower than the global average (yearly perception average in Iran is 260 mm compared to the world perception average 800 mm). Therefore, there is always critical situation in many plains of Iran. This problem when become more complicated that the management system in Iran follows the "crisis management" strategy. Crisis management is significantly non-productive, untimely, and not economically viable (Gerber and Mirzabaev, 2017; Zhao et al., 2017), because poor management system has caused a disaster (water shortage and water bankruptcy) and after causing huge damages, it seeks to solve problems. The status of 404 forbidden plains out of 610 plains in the country is proof of this claim (Ministry of Energy Protection and Operation Deputy, 2019).

According to this situation, in recent decades, the new concept “water bankruptcy” (WB) presented by some experts in order to water optimal management and conflict resolution. Water bankruptcy (WB) can be conceptualized as a relative concept and can occur at any level of supply or demand. Significantly, bankruptcy can be a social construct, meaning a product of expectations as well as customary behavior.

Water bankruptcy (WB) problems, which are currently observed in most plains of Iran, including Mahidasht plain in Kermanshah province (10 prohibited plains and 2 critical prohibited plains in Kermanshah province), have been formed over decades and cannot be solved immediately. Much of the damage to the country’s water and ecosystem are irreversible within a short period of time. Iran has many interrelated water challenges with complicated root causes. To solve these issues, it is necessary to adopt a comprehensive approach that involves implementing multiple concurrent strategies. The most effective solutions to Iran’s water problems are long term and they are economically and politically costly to implement. Therefore, unless there is a change in public opinion regarding pro-environment actions and policies, Iran’s water management will continue its inertia and will not pursue radical changes in its solutions and regulations (Madani et al., 2016). If the policymaking do not adopt basic strategies for optimal water management, they must pay a significant cost for its unsustainable water management in the near future. Thus, unless major efforts are directed at reduction of the country’s water demand, further deterioration of water resources should be expected.

One noteworthy point is that, various researchers have analyzed the WB based on technical aspects such as economic and mathematical methods to better develop water in different national and international basins. Although, technical indicator, are popular because it is easy to apply and understand but these do not help to explain the true nature of water scarcity. The more complex indicators are not widely applied because data are lacking to apply them and the definitions are not intuitive (Rijsberman, 2006).

Therefore, for examine any new problem, it is necessary to conceptualize problem and analyze understanding stakeholders towards phenomenon, because the correct understanding of the phenomenon reveals the roots of phenomenon and the causes of stakeholder’s behavior (experts and farmers). Hence, the concepts extracted in the present study can be used as the benchmark for social, economic and environmental indicators of WB. Meanwhile, this important issue (conceptualization of WB) has been neglected by researchers and policy makers.

In such a way that the researchers of the present study could not find studies about the social dimensions especially the conceptualization of WB. This issue was raised as a limitation and research gap in this study. Thus, the results of this study can be considered as an important innovation in the development of literature in WB and the identification of variables for measuring this phenomenon; In this way, experts and researchers can consider these concepts in the measuring the WB in region to obtain realistic information. Hence, focusing on the social perspective of WB can lead to practical strategies.

In the end, the following recommendations are suggested:

- Before dealing with the technical issues of phenomenon (water bankruptcy), the social dimensions of the phenomenon should be examined; in such a way that the accurate conceptualization from the point of view of the stakeholders in relation to phenomenon takes place;
- The identified concepts (15 concepts in this research) should be used in the water allocation models so that more complete dynamic models can be provided for the allocation of common water basins.
- Traditional and semi-mechanized agriculture wastes water. By modernizing agriculture, part of this problem can be solved.
- Modifying the cultivation pattern towards the development of less water crops in the region is one of the basic strategies to optimize agricultural water consumption.
- One of the reasons for excessive water consumption is the low price of energy (water, electricity, etc.) in Iran. If the real price of water is calculated, its excessive consumption can be reduced.
- The environmental awareness of farmers is low, so increasing their environmental awareness and education can lead to optimal water use.

Declaration of competing interest

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

Author Contributions

All authors contributed equally to the conceptualization of the article and writing of the original and subsequent drafts.

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