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Why Do Farmers Over-Extract Groundwater Resources? Assessing (Un)sustainable Behaviors Using an Integrated Agent-Centered Framework

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Abstract: This study uses an Integrated Agent-Centered (IAC) framework to investigate the socio-psychological drivers of Iranian farmers' unsustainable groundwater management practices. Empirical land use change analysis of US Geological Survey Landsat satellite images of the Jaz-Murian wetland region for 1990, 2010, and 2022, is combined with community surveys conducted with randomly selected farmers in five townships within the region (n = 356). Visual analysis reveals dramatic increases in agricultural land coverage, diminished water bodies, and increased salt lands over the 32-year sampled period. We use survey data to explain the socio-psychological drivers of unsustainable groundwater use that lead to these adverse environmental changes. In the IAC survey analysis, we find that variables for "expectation" and "subjective culture" have a negative influence on pro-environmental "intention". "Intention" and "habit" have a positive influence and "contextual factors" have a negative influence on the drivers of "unsustainable water use behavior". We conclude that situational influences, habitual process, intentional process, and normative processes must be considered together to alleviate pressure on wetland ecosystems. Policy makers must provide effective agricultural extension training, deliberative dialogue amongst farmer networks, well-governed local water markets and financial support to shift farmer short-termist economic gain-thinking towards socially-supported pro-environmental habits over the longer term.

Keywords: Integrated Agent-Centered framework; sustainable water behaviors; groundwater extraction; land-use change

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1. Introduction

Water resources face unprecedented challenges, globally. Population growth, changes in living standards, and social practices of consumption, alongside changes in climate variability, including more frequent extreme weather events, lead to diverse and complex challenges of diminished water quality, availability, and security [1,2]. Under conditions of climate change, agricultural intensification and land use changes, water scarcity and drought are critical sustainable development concerns for supporting a growing urban population [3]. The United Nations reported that water scarcity affects more than 40% of the world's population [4,5], and this figure is likely to increase due to global population growth (to an estimated 9.8 billion by 2050), more than half of which will live in urban areas [6]. The combination of population expansion, climate change, and economic growth across the developing world means that sustainable water governance is now an urgent and ongoing environmental management priority for policy authorities and practitioners [7].

Water-stress is of specific significance to the arid and semi-arid regions of the world, not least due to the impact of climate change altering temperature, humidity, precipitation patterns, and extreme weather exposure for vulnerable communities. Iran is a notable example of this challenge [2,8]. For example, the severe drought that occurred in Iran from 2007 to 2014 significantly dried wetlands and major lake systems, significantly reducing river flows and depleting groundwater resources, with concomitant impacts to ecosystem services and overall environmental health [9]. Iran has experienced more droughts than all of Europe, and since 1998, drought conditions have exceeded anything experienced in the previous nine centuries [5]. However, despite this ongoing environmental pressure, the agricultural sector of Iran has not significantly adapted its farming practices, which currently consume more than 92% of the available water resources [10–12]. Paradoxically, as freshwater supplies become scarce, demand for irrigation increases, further depleting aquifers and groundwater sources and increasing the precarity of agricultural livelihoods. Efficient agricultural water management practices are therefore essential to long-term Iranian sustainable development and an urgent issue for agricultural extension providers and policy institutions.

The combination of climatic changes and anthropogenic impacts to ecosystems, biodiversity, and natural resource availability, present key barriers to sustainable agriculture [13–15]. Climate change stimulates dangerous interference in precipitation patterns. In arid regions, such as the case study region of Iran, climate change results in reduced overall precipitation (leading to progressively drier environmental conditions) whilst simultaneously increasing the frequency and intensity of extreme precipitation events, resulting in a higher risk of fluvial and pluvial flooding and water pollution [16–18]. Other factors, such as dam construction (including for reservoir creation and, in some cases, hydroelectricity) further exacerbate detrimental effects upon water management systems [19]. Up until the 1950s, Iranian agricultural lands were primarily irrigated using springs and Qanats (a system that carries water from an aquifer to the surface through an underground aqueduct). Semi-deep and deep well water extraction has become more common in subsequent decades. Well water extraction has led to short-term gains in agricultural productivity and profitability; however, high-volume groundwater extraction has resulted in chronic water resource depletion [20] which presents a long-term risk to water and food security across the country.

Despite governmental efforts to curtail water extraction, agricultural practices remain groundwater intensive. Unsustainable extraction of groundwater, where the rate of depletion exceeds that of replenishment, is the root cause of many negative social, economic, and environmental consequences. Negative impacts include the subsidence of the plains (so called "silent earthquakes") [21], breaking of constructed wells (leading to increased operating costs), reduced water supply within wells, springs, and Qanats, increased pollution of groundwater sources [22] (including increasing water salinity), the drying of surface water wetlands and loss of the associated biodiversity and ecosystem services [23,24], and ultimately, the reduction in the quantity and quality of cultivated land over the longer term [25]. Agricultural system stability and sustainability are thus negatively impacted by the short-term motivations of farmers rooted in unsustainable behaviors and social practices [26,27].

Influencing stakeholder behaviors to promote long-term pro-environmental action is a complex process. It requires action to address a combination of cultural, institutional, technological, and normative restructuring and reconfiguration [28,29]; alongside intervention strategies, and stronger governance systems at multiple institutional and spatial scales, to foster a sustainable agricultural transition [30,31]. A sustainable agricultural strategy therefore requires complex multi-scalar systems-thinking, within which heterogeneous networks of water use actors become directly involved in the processes of change [32,33]. Water governance and agricultural management bodies therefore need to better understand farmer behavior within such multi-scalar systems, putting farmers front and center within sustainable water system transformation [34].

As a social scientific challenge, sustainable water management is increasingly understood as a problem of hydrosocial relations: a set of complex interactions between natural, psychological, social, and political processes through which society and water use create, recreate, and shape one another. Hydrosocial thinking pays specific attention to how water becomes known to various stakeholders, how social relations of power, cultural capital and social control are expressed through networks of water use, and how this in turn influences water management practices and behaviors [35]. In agricultural hydrosocial relations, Willis, Stewart [36] argue that farmer-user demand-driven water management becomes a key concern for sustainable practice. Mirchi, Madani [37] state that all aspects of the water scarcity problem (including ecological, socio-economic, biological, hydrological, environmental, and cultural concerns) require a comprehensive, integrated, and adaptive management approach to achieve long-term resource sustainability. For Iran, the adoption of such a conceptual framework would represent a radical paradigmatic shift in the water practices [38] through which economic and technological investments are considered alongside structural social and behavioral dimensions [39].

Understanding groundwater as set of overlapping hydrosocial and ecological systems [40] is explored in a range of empirical research studies [41–44]. These studies note the importance of farmer behavior in their role as water managers (i.e., through installing new irrigation technology, changing cropping patterns, wastewater use, etc.). Farmer decision-making has far-reaching consequences for regional water resource management [45,46], and given the scale of agricultural water use in Iran, small changes at the farming community level quickly aggregate to larger impacts on the common pool of water resources in the country. It therefore behooves agricultural extension program managers and farmer education initiatives to raise awareness among agricultural communities about the impacts of water use upon sustainable food production outcomes [47]. Farmers commonly seek to maximize economic benefits through production growth at the expense of the common pool resource of groundwater, thus exacerbating a tragedy of the commons [48]. However, agricultural decision-making is more complex than short-term economic rationality; farmers' decisions depend on a range of cognitive and socio-cultural variables [49]. It is necessary therefore to elucidate the factors that direct farmers' (un)sustainable behavior through case-study specific social-psychological research [50] in order to provide deeper insight into strategies that promote sustainable water management [51].

In this analysis, we build upon the work of Darnhofer, Lamine [52], by adopting a relational approach to understanding the factors influencing the unsustainable farmer water use behaviors. We posit that farmers' behavior is contextualized within the material and immaterial relationships that constitute the social practice of agriculture which, in turn, transform the natural and hydrosocial processes of water sustainability [52]. Within a relational approach, land use becomes the site and focal point for agricultural change, which is, in turn, shaped by changes to cropping systems, microclimate, soil quality, precipitation patterns, point-source pollutants, community composition, demographics, and cultural characteristics [53,54]. It is the interplay of these elements that (re)produces (un)sustainable behaviors. Placing farmers as stakeholders at the center of our research allows us to analyze the diversity of practices within similar structures (farm size, market, geography, politics, etc.) and emphasizes the importance of farmers' values [55]. Recent research into farmer behavior reveals major causes of regional environmental deterioration [56–58]. Of note in the field of farmer stakeholder behavioral study is the focus upon motivation and intention towards pro-social, pro-environmental action. Considerably less research has focused, however, upon motivation and intention towards unsustainable behaviors amongst farmer stakeholder groups. Moreover, there is relatively little research on farmer behavioral intention, specifically towards groundwater use irrigation in key arid and water-stressed regions like Iran [40,59–63]. Understanding the factors that influence farmers' unsustainable groundwater consumption behaviors in a non-Western developing country and high-risk region provides valuable insight into the range of policy options available to the Iranian administration and farming communities. It also provides contextual data relevant to climate-sensitive community development planning in similarly vulnerable locations around the world. To conduct this assessment of hydrosocial relations within Iranian farmer agricultural practice, we employ a novel Integrated Agent Centered (IAC) framework of assessment, as described below.

2. The Integrative Agent-Centered (IAC) Framework

Several competing conceptual frameworks are used to understand and explain pro-environment behaviors and social practices in the social sciences. Kollmuss and Agyeman [64] conceptualize pro-environmental behaviors through a combination of internal factors (incorporating attitudes, values, and feelings) and external factors (incorporating material, economic, institutional and social-structural factors). In practice, this type of framework has been applied in empirical research to issues (such as) water drinking behaviors [65], water conservation, and water reserves [66–68]. What this empirical research reveals is a need for research that shows a testable relationship among variables in the field of water conservation behavior research, i.e., developing an integrative approach that captures feedback [34] and a dynamic decision-making process [69,70]. In developing country contexts, this is important because a lack of understanding surrounding the complexity of farmer decision-making is one of the main causes of water and agricultural policy failure [34]. Decisions that farmers make take place in the broader context of risks (e.g., health, economic, etc.) and livelihood strategies, in which tradeoffs might exist between competing socio-economic objectives [71,72].

The Integrative Agent-Centered (IAC) framework, developed by Feola and Binder [34], addresses the complexity and tradeoffs among perceptions and social objectives relevant to the study of hydrosocial relationships. The IAC framework provides a conceptual model for understanding the behavior of farmers within an agricultural system defined as the socio-ecological "SES" system. IAC research integrates and adapts Giddens' Structuration Theory [73] in which social agency and social structure are co-constitutive and dialectically related, and Triandis' Theory of Interpersonal Behavior [74], through which farmers' choices influence the adaptation of their farms as SESs. To illustrate, Kings and Ilbery [75] assert that farmers act on their environmental choices when they encounter (or perceive) their environment. The IAC framework is rooted in behavioral-theoretic approaches to social-psychological research, specifically critiquing the prevailing behavioral approaches that examine farmers' behavior in isolation from their social environment. In the IAC, social phenomena are construed as products of the actions of individuals, who in turn, function within an array of social structural constraints. It is necessary, therefore, to analyze the physical and symbolic context of macro-social actors within this broader social context rather than just focus upon individual actions or perceptions [76]. For example, Triandis (1977) proffers factors such as influencing tendencies, emotional affect, social habits, and physiological arousal as relevant feedback processes that influence tendency and action [77]. Such feedback processes can enhance or modify existing social structures and occur over different timescales. As such, farmers should not be understood as passive recipients of socio-environmental change shaped solely by external forces; rather, they simultaneously exert their agency by actively engaging in the processes of social and environmental change. The IAC framework is therefore valuable as a conceptual model as it brings together these external (contextual/social structural) and behavioral components into a holistic approach.

As a theoretical model, the IAC incorporates: Contextual Factors (i.e., barriers or favorable conditions), Habits (frequency of past behaviors), Expectations (beliefs about outcomes, their likelihood, and their value), Subjective Culture (social norms, roles, values), and Affect (emotions related to action) [34]. Collectively, these components have been used to study farmer behavior related to production intensity in agricultural systems [34] and also to study farmers' unsustainable behaviors in other contexts [78]. We expand IAC framework analysis here to specifically examine unsustainable water use behaviors as shown in Figure 1. To do so, we formulate the following hypotheses:

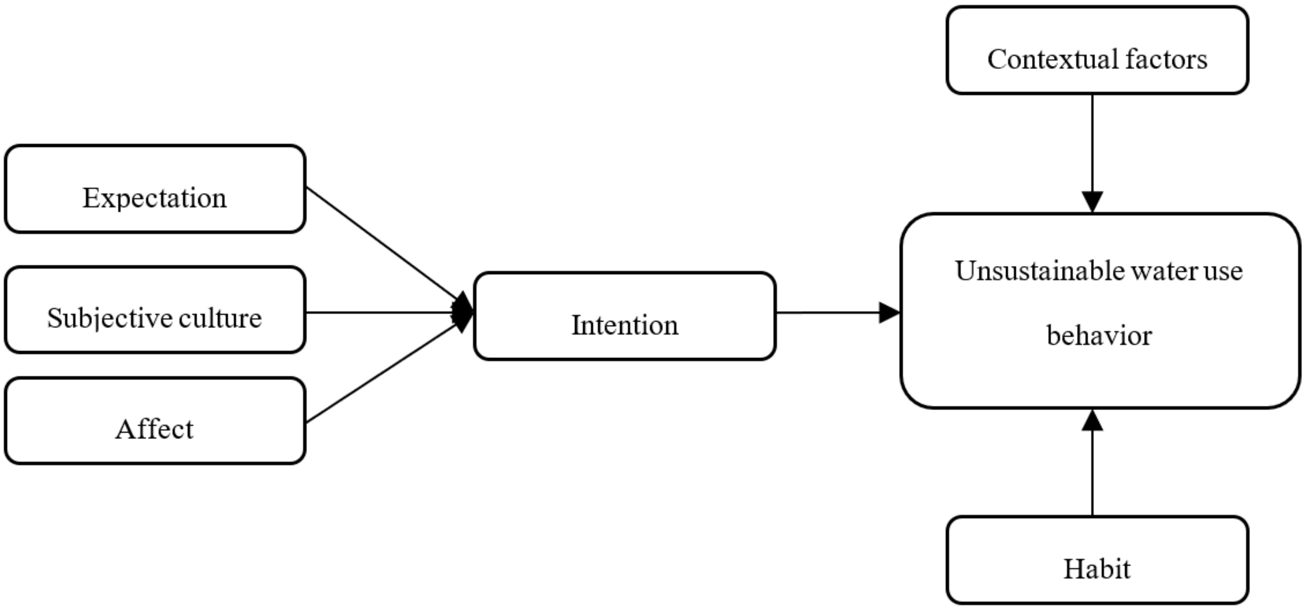

Figure 1. Visual representation of the IAC framework [34].

H1. *The lower the farmers' expectations, the more they desire to over-harvest groundwater resources.*

H2. *The less the farmers perceive the surrounding subjective culture of sustainability, the more they desire to over-harvest groundwater resources.*

H3. *The fewer environmental impacts the farmers perceive, the more they desire to over-harvest groundwater resources.*

H4. *The more they desire to harvest groundwater resources, the more they behave to over-harvest.*

H5. *The contextual factors could have an influence on unsustainable water behavior of farmers.*

H6. *The more ingrained the unsustainable groundwater use habits the more they behave to overharvest.*

3. Methods

Data collection involved two consecutive phases. First, we investigated land use change, paying specific attention to the number of wells dug in the study area using image processing software. Second, we investigated the factors affecting farmers' unsustainable water use behavior in the study area using a survey technique.

3.1. Case Study Area

Image processing and survey research was conducted among agricultural communities of the western area of the Jaz-Murian wetland. The Jaz-Murian wetland is a key wetland habitat in Iran, located between the Makran Mountain range and the Shahsavaran Mountains, enclosed by Jebal-barez Mountains in the north and Bashagard in the south. The wetland is located between the provinces of Kerman, Sistan, and Balochistan (longitude 58°39′ to 59°14′E, latitude 27°10′ to 27°38′N) reaching 300 km east-to-west and 100 km north-to-south. The catchment area of the seasonal lake supporting the wetland environment is 69,000 km^2 with an elevation of 300 m (a.s.l.). The main feeding sources are the Bampur River from the Sistan, and the Baluchestan and Halilrud Rivers that originate from the central high lands of Kerman Province. Figure 2 shows the geographical location of the Jaz-Murian wetland and the dams constructed on the rivers leading into it.

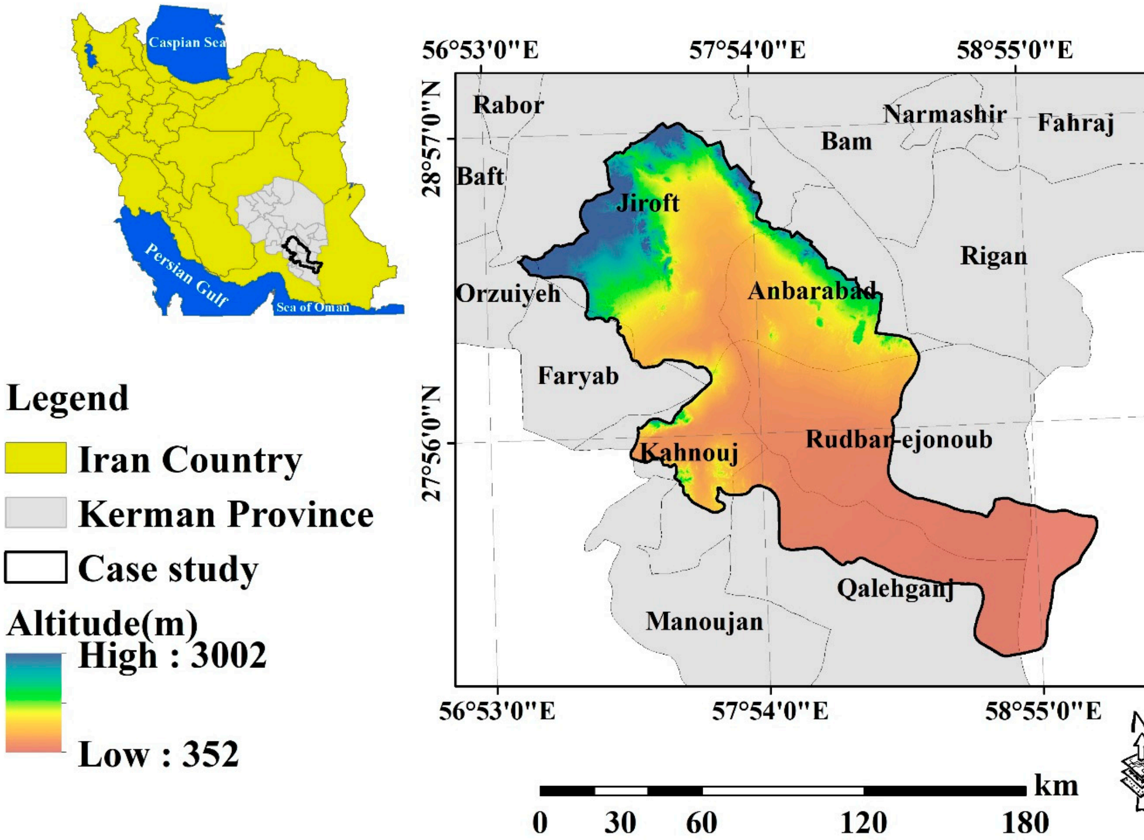

Figure 2. Geographical location of the case study.

The western area of the Jaz-Murian wetland is dependent on underground water sources due to the prevailing climatic conditions–lack of rainfall and successive droughts, the drying of the Halilrud River due to the construction of the Jiroft dam, and concurrent increases in population density. We identify 5129 deep and semi-deep wells in the study area (Jiroft Plain) in 2014 [79]. According to the last statistics, the number of wells increased to 6112 wells (semi-deep and deep), 1444 springs, and 240 Qanats, which discharge 950 million cubic meters per year to the aquifer of the west basin of the Jaz-Murian wetland [80]. Out of the total amount of discharge, the agricultural sector has the highest amount of evacuation in this region with 94%.

3.2. Image Processing

We obtained open access Landsat satellite imagery to measure land-use change, sampling images from 1990, 2010, and 2022 geological surveys for the analysis. The spatial resolution of the images was 30 m. We cropped each image to the boundary of the study area (Table 1). We performed atmospheric and radiation corrections using the FLAASH module in ENVI 5.3. We obtained the parameters required for atmospheric correction from the text file accompanying the image along with the altitude information from the digital model. We corrected all images to the coordinate system UTM WGS84, North Zone 39. We also used secondary information from the field surveys, pseudo-color composites, existing maps, and Google Earth system to prepare and evaluate the maps. We processed and analyzed the satellite images in the ENVI 5.3 software environment. To prepare a map of land use changes, we applied the maximum likelihood supervised classification method (8). In this method, we calculated the probability of each pixel belonging to each class. Based on the highest probability, we classified and assigned the pixels to the classes. The first step in conducting the supervised classification was to determine the type and number of classes, which required precise knowledge of the desired classifications. To identify each type of land use, we used training samples in data classification [75]. We determined training points for accuracy by combining information from Google Earth data, field surveys, pseudo-color composites, existing maps, and indices from imagery–Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Normalized Difference Build-up Index (NDBI) (see Table 2) [81,82]). Finally, we transferred the obtained layers to ArcGIS 10.8 software to calculate the area of land use and prepare a suitable output map.

Table 1. Landsat Satellite image details.

Images	Years	Spatial Separation	Row/Column
Landsat 5	1990	30	162/39; 162/40; 161/40
Landsat 5	2010	30	162/39; 162/40; 161/40
Landsat 8	2022	30	162/39; 162/40; 161/40

Source: Research findings.

Table 2. Details of indicators obtained from Landsat satellite images used in this study.

Index	Range	Description
$\mathrm{NDVI} = \frac{\mathrm{NIR}-\mathrm{R}}{\mathrm{NIR}+\mathrm{R}}$	Between -1 to 1	Normalized difference of vegetation index [83]
$\mathrm{NDWI} = \frac{\mathrm{NIR}-\mathrm{SWR}}{\mathrm{NIR}+\mathrm{SWR}}$	Between -1 to 1	Normalized difference water index [84]
$\mathrm{NDBI} = \frac{\mathrm{SWR}-\mathrm{NIR}}{\mathrm{SWR}+\mathrm{NIR}}$	Between -1 to 1	Normalized difference build-up index [85]

(NIR = Near Infrared, R = Red band, and SWR = Short red band). Source: Research findings.

The accuracy of classifying images from the three datasets was evaluated using the confusion matrix. Calculated user accuracy, producer accuracy, overall accuracy, and Kappa index were used in the evaluation [86].

The overall accuracy was calculated from the sum of the elements of the main diameter of the error matrix over the number of pixels according to Equation (1) (50).

$$OA = \frac{1}{n}\sum_{i=1}^{n} Pii \tag{1}$$

In this relationship, OA is the overall accuracy, n is the number of pixels, and $\sum Pii$ is the sum of the elements of the main diameter of the error matrix.

The kappa index accounts for the misclassified pixels and calculates the accuracy of the classification relative to a completely random classification. The kappa index was calculated using Equation (2).

$$Kappa = \frac{P_0 - P_c}{1 - P_c} \tag{2}$$

In this relationship, P_0 is the observed correctness and P_c is the expected agreement (50).

3.3. Farmer Survey Using the Integrated Agent-Centered Framework

In parallel to the image-analysis, social surveys were designed using the IAC framework to identify the factors influencing the unsustainable water use behavior of farmers to better explain the changing patterns observed from the satellite data. The survey was conducted in the western area of Jaz-Murian wetland. Our key case study population is composed exclusively of farmer stakeholders. The survey was conducted in 2022 in the townships (the following townships were included: Jiroft, Anbarabad, Kahnuj, Qalehganj, and South Rudbar) in the west wetland. Using a random sampling method, a sample of 383 farmers was randomly selected based on Cochran's formula (margin error = 0.05). The sample was randomly selected from the list of farmers in the townships received from the

Agricultural Management Office of the Township. Data collection occurred in 2022. Based on pre-prepared questionnaires, we set times and locations for interviews with farmers at home or at work. Farmers were free to refuse or discontinue data collection at any point during the research process. No financial incentives were offered. All responses were checked for completeness and incomplete surveys were discarded. The completed survey had a response rate of 356, which is an acceptable response rate of 89% [87].

The research instrument is a fixed two-part questionnaire. The first part contained demographic characteristics of the respondents, including agricultural experience, age, gender, marital status, and education level. Respondent demographics are presented in Table 3. Reflecting broader gender trends in the sector (specifically the demographics of the case study area), we obtained 338 responses from men (94.9%) and only 18 from women (5.05%); this was a limitation of the field of study. The average age of the respondents was 45.32 years old and 28% had a post-secondary level diploma. The average farming experience of the respondents is 19.65 years.

Table 3. Respondent Demographics.

Demographic attributes	Categories	Frequency	Percent
Gender	Men	338	94.95
	Women	18	5.05
Marital status	Single	23	6.46
	Married	333	93.53
Education	No literacy	48	13.48
	Elementary	39	10.95
	Secondary school	89	25.00
	Diploma	100	28.08
	Bachelors' degree	20	1.68
	Masters' degree	45	12.64
	Doctorate	15	4.21
Age (year)	Mean	St.D.	Range
	45.32	8.71	18–65
Agricultural experience (year)	Mean	St.D.	Range
	19.65	10.08	5–52
Land area (hectare)	Mean	St.D.	Range
	8.65	3.21	3–65

Source: Research findings.

Seven social-psychological factors were constructed in the Section 2, i.e., expectation, subjective culture, affect, intention, contextual factors, habit, and unsustainable water use behavior. Farmers were asked about their level of agreement or disagreement with the items using a 5-point Likert scale (Strongly disagree = 1 to Strongly agree = 5). The items in the research questionnaire are presented in Table 4. The questionnaire was conducted in Persian (Farsi) and all items were later translated into English (as shown in Table 4).

The validity of the researcher-developed questionnaire was checked prior to the start of the study. Specifically, the questionnaire was reviewed by a variety of disciplinary experts who were involved to ensure validity. Pre-checks and piloting assessed question interpretation, questionnaire length, question interpretability, and clarity. Reliability was assessed through a pilot study (fieldwork) conducted in Kerman Township. A total of 30 pilot questionnaires were collected, and the Cronbach alpha coefficient was calculated, showing a coefficient above the acceptable value (greater than 0.7) on all scales used in the study (Table 4). Additionally, convergent and discriminant validity was established for all constructs. Composite reliability for all constructs is at a threshold of 0.7, as suggested by Hair, Anderson [88]. In this way, Average Variance Extracted (AVE) for all constructs is greater than a threshold of 0.5 [88]. Based on Hair, Anderson [88], discriminant validity statistics, i.e., ASV (Average Shared Squared), and MSV (Maximum Shared Variance) Variance), should be less than AVE. All four constructs of this study have good discriminant validity.

Questionnaire data input to SPSS allowed descriptive statistical analysis. Evaluation of frequency, skewness, and kurtosis values did not reveal significant violations of normality, as all coefficients were less than ±2. Finally, we applied an SEM [89] analysis through AMOS 20 software to test the model.

Table 4. The items included in the study questionnaire and the Cronbach's alpha for the main scales of the study (translated from Persian).

Factor	Alpha's Coefficients	Conceptual Definition	Code [1]	Items	Skewness	Kurtosis
Expectation	0.79	Expectations correspond to expected outcomes of actions, their probabilities, and their values [90,91].	E1	Continually saving and monitoring water usage is time consuming and tedious.	0.65	0.81
			E2 *	Reduce water costs by reducing excessive water use.	0.52	0.75
			E3	It takes me a lot of extra effort to avoid excess water consumption on my farm.	1.02	0.75
			E4	I think it is not necessary to participate in saving water.	0.85	0.79
Subjective culture	0.81	Subjective culture "refers to a human group's characteristic way of viewing the human-made part of the environment" and "consists of ways of categorizing experience" [92]. The subjective attribute emphasizes the fact that social structures exist only within each agent. Within the framework, subjective culture is the product of three main components: roles, social norms, and values.	SC1	It isn't easy to protect water resources without the involvement of community members and other stakeholders.	0.98	1.40
			SC2 *	My family accepts that I should endeavor to secure and conserve water.	0.38	1.15
			SC3 *	My family considers that I ought to take an interest in water-saving exercises.	0.85	1.01
			SC4 *	My family will acknowledge my interest in water-saving practices.	1.20	0.85
			SC5	If I take action to save water, I will be criticized by friends and associates.	0.84	0.15
Effect	0.73	Effect refers to the emotional system of an individual, i.e., "the feelings associated by an individual with a particular act" [34,90].	A1	Taking part in water preservation is vital during dry season conditions.	0.73	0.68
			A2 *	Saving water makes me feel like a good person.		
			A3	I think that cooperation in water preservation is pointless.		
			A4 *	Conserving water resources makes me feel like a good person.		
Intention	0.75	Intentions are "instructions that people give to themselves to behave in certain ways" [93].	I1 *	I will use low-tillage techniques.	0.84	0.23
			I2 *	I will be looking for non-agricultural jobs.	0.32	1.17
			I3	I wouldn't use drought-tolerant cultivars.	0.70	0.18
			I4	I will try increasing the depth of the well.	0.54	0.86
			I5 *	I will use products that require less water to cultivate.	0.36	1.11
			I6	If my agricultural land needs water, I will definitely extract more groundwater.	0.63	0.70

Table 4. *Cont.*

Factor	Alpha's Coefficients	Conceptual Definition	Code [1]	Items	Skewness	Kurtosis
Contextual factors	0.81	The contextual factors are "objective factors, "out there" in the environment" [90]. They can make an action easy (facilitation) or difficult (barrier) to perform. They can be distinguished into socioeconomic, agro-ecological and political [94]. The examples of the contextual factors are environmental characteristics of the system, the social context of the agent, the processes occurring in the agricultural system (e.g., climatic conditions and etc.), as well as the power relationships, and allocation resources [73].	C1 *	I have experience in reducing agricultural water consumption.	1.44	1.75
			C2	I do not have the financial ability to use high efficiency irrigation systems.	1.14	1.41
			C3	Weather conditions have led to drought and water consumption by farmers has no effect on drought.	1.18	1.42
	-		C4	Age (Farmer's age (years)	1.39	1.05
			C5	Agricultural experience (Years)	1.52	1.46
			C6	Land area (The area of cultivated land)	1.82	1.12
Habits	0.83	Habits are "situation-behavior sequences that are or have become automatic so that they occur without self-instruction" [95]. Habit describes the level of routinization of the behavior.	H1	I struggle to reduce water use under today's conditions.	0.22	1.40
			H2 *	We work with other farmers to save water.	0.02	1.48
			H3 *	I am motivated to deal with the risk of climate change.	0.58	0.68
			H4 *	I am capable of dealing with the risks of climate change.	0.85	0.95
Unsustainable water use behavior	0.75	Behavior means any action that a person performs [96]. Behavior is seen as the response and visible action of a person in a specific situation and context with regard to a specific goal and at a specific time [97].	U1	I do not share water-saving ideas with other farmers.	0.80	0.27
			U2	I do not encourage other farmers to participate in saving water.	0.69	0.12
			U3	I have increased my crop production over the past three years, this is more important than participating in saving water.	0.70	0.18
			U4	I am not using a water resource protection system.	0.54	0.86

* Negative Items. Source: Research findings. [1] Hereafter, we use these codes to show each question.

4. Results

4.1. Image Processing

Classification Analysis of 1990, 2010, and 2022 Landsat Images

Agriculture, barren lands, dams, wetland vegetation, river, salt lands (salt flats), built-up (urbanized), water body, and mountain lands were mapped for the period from 1990 to 2022 (Figure 3). According to Table 5, the overall accuracy of the use maps for 1990, 2010, and 2022 are 85%, 90%, and 89%, respectively, and the Kappa coefficient for these uses are also 0.84, 0.88, and 0.86. Images of the study area were divided into eight classifications (Figure 2). Visual examination of the case study region reveals drastic transformation of the landscape over the 32-year study period. Notable in Figure 2 is the disappearance of large standing water bodies in the south-eastern region, the expansion of salt lands, increased densification of built-up areas, and the expansion of agricultural lands at the expense of wetland vegetation.

Table 5. Overall accuracy and Kappa coefficient.

Year	Accuracy	Kappa Coefficient
1990	85%	0.84%
2010	90%	0.88%
2022	89%	0.86%

Source: Research findings.

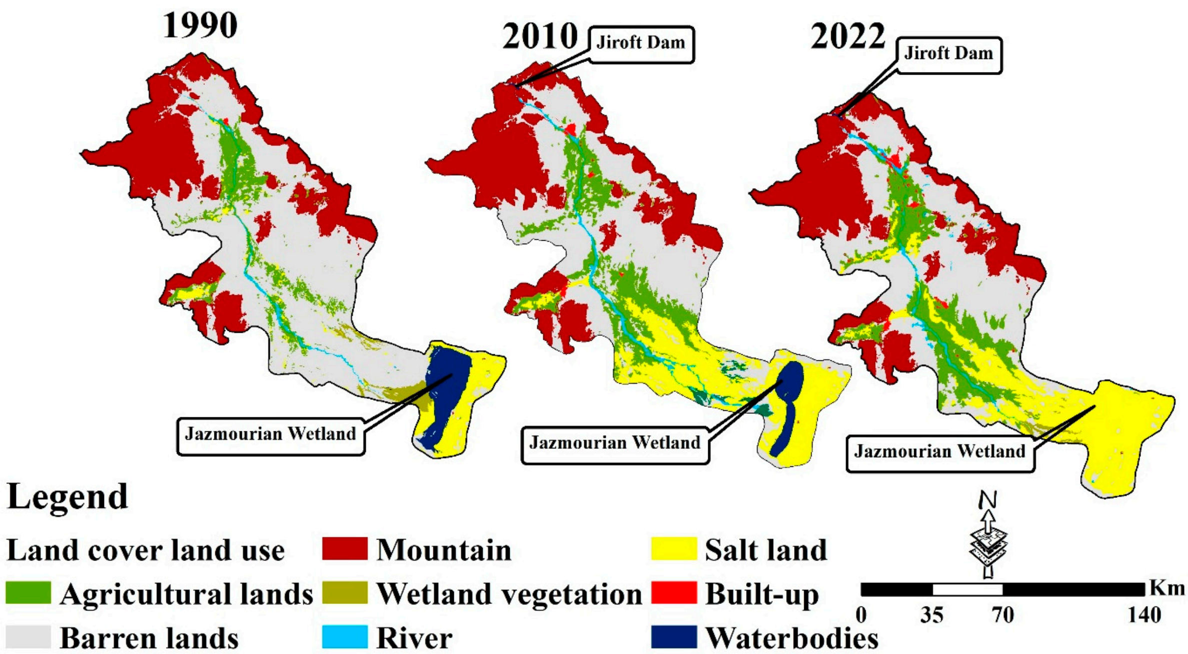

Figure 3. Classified land use land cover maps from 1990 to 2022.

In 1999, agricultural land use covered 1143.448 km^2 ha (8% of the study area, see Table 6). Uncultivated arid (barren) land occupied 7391.71 km^2 (51%). Wetland vegetation covered 288.15 km^2 (2%). Salt land covered 905.86 km^2 (6%). Built-up lands accounted for 9.10 km^2 (0.1%), and water bodies covered 692.22 km^2 (5%). By 2010, barren land, despite its dominance in the landscape, declined to 5200.26 km^2 (36%). Wetland vegetation decreased to 150.09 km^2, representing only 1% of the study area. Salt lands expanded roughly three-fold to 2631.95 km^2 (18%), as did built-up land, which grew to cover 54.94 km^2 (0.4%); this was an increase of about 503% in comparison to 1990. Agriculture covered 1925.59 km^2 (13%), which increased by about 68% in comparison to 1990. Wetland standing water body coverage decreased to 355.77 km^2 (2%) by 2010, which was less than half of its area in 1990. By 2022, the water body disappeared completely. Built-up land had grown to 108.58 km^2 (0.8%), nearing 1092% more than its 1990 extent. Uncultivated (barren) land decreased to 4583.42 km^2 (32%), nearly 37% less than its 1990 coverage. Wetland vegetation decreased to 94.92 km^2 (0.7%), and agriculture increased to 2078 km^2 (15%). Salt land increased to 3092.03 km^2 (22%), more than 241% of its 1990 extent (Figure 3).

Table 6. Area statistics for classified images.

LUC Class	1990		2010		2022		Changes (%)	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	1990–2022	2010–2022
Agriculture	1143.44	8	1925.59	13	2078	15	81.73	7.91
Barren land	7391.7	51	5200.26	36	4583.42	32	−37.99	−11.86
Dam *	0	0	5.92	0.04	6.67	0.05	-	12.74
Wetland vegetation	288.15	2	150.09	1	94.92	0.7	−67.05	−36.75
River	110.69	1	216.67	1	195.63	1	76.73	−9.70
Salt land	905.86	6	2631.95	18	3092.03	22	241.33	17.48
Built-up	9.10	0.1	54.94	0.4	108.58	0.8	1092.06	97.62
Water body	692.22	5	355.77	2	0	0	−100	−100
Mountain	4033.75	17.82	4033.75	17.82	4033.75	17.82	0	0
Total	14,574.97	100	14,574.97	100	14,574.97	100	-	-

* The Jiroft dam was constructed in 1991. Source: Research findings.

4.2. Farmer Survey

The confirmatory measurement model was tested using AMOS software (V20). Confirmatory Factor Analysis (CFA) was used to examine whether a factor's estimations were compliant with its factor properties [98]. Using CFA ensures the uni-dimensionality of the scales on which each factor is measured. Several commonly used fitness indices were used to assess the overall model fitness, as shown in Table 7 [99]. The comprehensive goodness-of-fit indices produced a Chi-square of 112.3, and Chi-square/DF = 1.63 [99]. The CFI value of 0.90, the IFI value of 0.90, and the TLI value of 0.91, were deemed good fits to the model according to [100], whereby, for these indices, a value of 0.7 and above is satisfactory, 0.8 and above is good, and 0.9 and above is very good. The RMSEA value was 0.042, and an RMSEA threshold below 0.10 is considered an indication of fair fit [101]. Therefore, the measurement model results show an acceptable fit.

Table 7. Confirmatory Factor Analysis.

Items	Chi Square	Chi Square/DF	IFI	TLI	CFI	RMSEA
Indices	1128.3	1.63	0.90	0.91	0.90	0.042

Source: Research findings.

All standardized factor loadings should be ≥0.5 and statistically significant. Loadings of this size indicate that the observed metrics are strongly related to the relevant factors. They also contribute to construct validity [102]. All standardized factor loadings are significant in the model. All factor loadings are above 0.5 (as shown in Table 8). Taken together, the findings indicate that there was a good fit between the proposed model and the data. Additionally, convergent and discriminant validity was established for all factors. As shown in Table 8, composite reliability for all factors met the threshold of 0.7, which was suggested by Hair, Anderson [88]. Average Variance Extracted (AVE) for all factors was greater than the threshold of 0.5 [102]. Based on the suggestion of [88], discriminant validity statistics, i.e., MSV (Maximum Shared Variance) and ASV (Average Shared Squared Variance), should be less than AVE. As seen in Table 8, all factors had good discriminant validity. Finally, skewness and kurtosis values showed no significant violation of normality (Table 4).

The comprehensive goodness-of-fit indices for the path analysis, as shown in Table 9, are the Chi square = 3.98 and Chi square/DF = 1.99 (smaller than 3) [99]. The other goodness-of-fit indicators i.e., NFI (Normed Fit Index), CFI, IFI, and TLI, are below the threshold (according to [100]), values from 0.90 indicate an acceptable fit, and values from 0.95 indicate a good/close fit). Also, the RMSEA is within the acceptable threshold. Taken together, the results show that there is a good fit between the proposed model and the data.

Table 10 shows the direct and indirect impacts of all variables on the study's endogenous variables (Unsustainable water use behavior). Table 10 also shows that the variable 'expectation' has a significant negative effect on farmer 'intention to unsustainable water use'. We find that the variable 'subjective culture' negatively impacts 'intention to unsustainable water use'. 'Intention to unsustainable water use' and the factor 'habit' have a significant positive influence on 'unsustainable water use behavior'. Finally, the factor 'contextual factors' has a negative influence on 'unsustainable water use behavior'. Overall, the variables influencing 'unsustainable water use behavior' explain 46% of the variance within the model.

Table 8. Factor loadings and convergent and discriminant validity in Confirmatory Factor Analysis.

The Codes of Items	Expectation	Subjective Culture	Affect	Intention	Contextual Factors	Habits	Unsustainable Water Use Behavior
E1	0.71 [a]						
E2	0.73 **						
E3	0.71 **						
E4	0.70 **						
SC1		0.75 [a]					
SC2		0.75 **					
SC3		0.77 **					
SC4		0.65 **					
SC5		0.81 **					
A1			0.66 [a]				
A2			0.79 **				
A3			0.88 **				
A4			0.80 **				
I1				0.79 [a]			
I2				0.78 **			
I3				0.71 **			
I4				0.74 **			
I5				0.75 **			
I6				0.71 **			
C1					0.77 [a]		
C2					0.74 **		
C3					0.72 **		
C4					0.75 **		
C5					0.71 **		
C6					0.65 **		
H1						0.83 [a]	
H2						0.63 **	
H3						0.65 **	
H4						0.71 **	
U1							0.71 [a]
U2							0.74 **
U3							0.89 **
U4							0.81 **
CR	0.80	0.86	0.87	0.88	0.87	0.80	0.87
AVE	0.51	0.56	0.62	0.56	0.52	0.51	0.62
MSV	0.27	0.16	0.25	0.18	0.12	0.09	0.10
ASV	0.17	0.12	0.11	0.10	0.07	0.07	0.07

Source: Research findings. [a]: The square roots of AVE estimate **: Correlation is significant at the <0.01 level.

Table 9. Measures of the research framework model fit.

	Items	Chi Square	Chi Square/DF	NFI	IFI	TLI	CFI	RMSEA
Path analysis	**Indices**	3.98	1.99	0.97	0.98	0.92	0.99	0.053

Source: Research findings.

Table 10. The standardized direct and indirect effects.

Path	Direct Effect	Indirect Effect
Expectation → Intention	−0.268 **	-
Subjective culture → Intention	−0.321 **	-
Affect → Intention	0.171	-
Intention → Unsustainable water use behavior	0.336 **	-
Expectation → Unsustainable water use behavior	-	0.090
Subjective culture → Unsustainable water use behavior	-	0.075
Affect → Unsustainable water use behavior	-	0.022
Contextual factors → Unsustainable water use behavior	−0.212 **	-
Habit → Unsustainable water use behavior	0.302 **	-

Source: Research findings. **: Correlation is significant at the <0.01 level

5. Discussion

The Jaz-Murian wetland is an ecosystem at high risk of water scarcity and diminished water quality, located in the southeast of Iran. The wetland ecosystem has been negatively impacted by the development of redirection and hydroelectric dams (Halilrud and Bampur) on the main feeder rivers. As with many aquatic ecosystems, sustainable dam construction requires adaptations to downstream water management. However, satellite images show that, in the period of 32 years, the Jaz-Murian wetland has dried up almost completely, and across the same period, the proportion of agricultural land in the study area has significantly increased. At the same time, the level of barren lands in the region has also decreased. Our investigation shows a significant increase in the number of agricultural wells, leading to excessive pressure upon groundwater systems. The increasing pressure on water resources occurs despite the Ministry of Energy declaring Jiroft Plain to be a prohibited plain for such extraction. When combined with the infrastructural control of river systems through the Jiroft dam, the reduction of water entering the wetland has resulted in significant drying of the habitat, exacerbated by unsustainable water use behaviors by farmer stakeholders in the region. A combination factors including lack of training and support programs for agricultural stakeholders, continued dam construction, and climate change-induced water stress, creates conditions in which farmers seek short-term profit to meet cost-of-living needs and, therefore, create an unsustainable hydro-social system that further diminish water resource sustainability [24]. Our satellite data analysis supports the conclusion that such a vicious cycle of unsustainable water management is established in this region, leading to declining water quantity and quality within the Jaz-Murian wetland ecosystem.

The Integrated Agent-Centered (IAC) framework applied in our study is used to assess unsustainable water use behavior as an explanatory model for the growing water crisis in the Jaz-Murian wetland as well as the changes needed to halt this common tragedy. The IAC framework combines six factors to map complex human behaviors, and these are used as variables in the survey study: Expectation, Subjective Culture, Affect, Intention, Contextual Factors and Habits.

We found that the estimation model based upon the ICA fits well and is therefore predictive of farmer unsustainable water use behavior. The IAC is thus applicable to different cases of agricultural development and suitable for broader investigation of the underlying factors influencing farmers' unsustainable water use behavior in different regional contexts. We suggest that the IAC would prove useful to local and central government agencies in helping to identify key barriers to adaptive practices at the farm and rural level, and thus shape water management policies and practices according to local context.

In terms of specific variables, our results first revealed the negative impact of the 'expectation' variable on 'intention towards unsustainable water use'. Expectations correspond to the expected outcome, probability of occurrence, and relative value of an action [74], as well as the belief that the proposed response is effective in protecting oneself or others from the threat and the expected effect of the response in mitigating the threat [103]. Expectations relate to the effectiveness of adaptive responses to mitigate or avoid existing risks [104,105].

In the context of this study, expectation relates to the effectiveness of adaptive behaviors in mitigating the adverse effects of regional drought on agricultural productivity. The findings mirror those of other IAC framework cases [106,107], namely that the more that the farmers in the study area understand the value and impact of their actions, the more willing they will be to change their behavior.

We find that the variable 'Intention' has a positive influence on unsustainable water use behaviors. Intentions are "instructions that people give to themselves to behave in certain ways" [74]. As Bandura [108] argues, most individual actions are directly guided by the goal or intention of the action. This study reveals that 'intention towards unsustainable water use' is the most important determinant of behavior overall. The greater the intention to over-harvest water, the more their behavior is consistent with this behavior. Intention is therefore the most important behavioral control that we identify. However, intention is, in turn, mediated through other variables within the model.

Of note is that the variable 'subjective culture' had a negative impact on 'intention to unsustainable water use'. This finding shows that the higher the subjective culture of water saving among farmers in the region, the less desire individuals show for over-harvesting of groundwater resources. This result is consistent with similar studies [109], adding to existing evidence that subjective norms influence farmers' intentions to conserve water [110]. Subjective cultural norms within a social network of agricultural stakeholders are therefore powerful predictors of (un)sustainable water management practices and, thus, a point at which external authorities can intervene, as discussed in the conclusions below.

The results also show that broader contextual factors—the "objective factors 'out there' in the environment" [74]—also play a role in mediating water use behaviors. For example, if an external factor, such as a new technology or practice (e.g., drip irrigation, water capture and storage, or conservation tillage), makes a pro-environmental activity less demanding to perform, then this provides a favorable context for behavior change. Conversely, if an external factor (such as climate related loss or damage) creates boundary conditions which limit sustainable action, then this, in turn, acts as a barrier to long-term change. A combination of social, financial, agro-ecological, and political drivers and barriers therefore play roles in mediating behavioral intentions and subjective norms [94] and can determine the outcomes of attitudes and values on behavior more broadly [111], even when intention to change is strong.

Finally, farmer awareness about the impact of water resource degradation plays an important role in influencing personal water conservation behaviors, as shown in other agricultural behavioral studies [112–114]. Awareness relates to reflection upon personal 'habits', i.e., the "situation-behavior sequences that are or have become automatic so that they occur without self-instruction" [74]. Habits are key variables in explaining how often a behavior is performed. If broader changes from environmental impacts, such as changing financial circumstances and social unrest, alter routinized behavioral patterns [115–117], then this is a key challenge for agricultural extension organizations and water management authorities to meeting long-term sustainable development goals within the region. Conversely, if raising awareness amongst agricultural stakeholder groups can shed light on unsustainable habits and highlight the mechanisms to break such habits, then this too will have a positive impact in moving away from unsustainable water use behaviors.

6. Conclusions and Policy Recommendations

This study researched motivation and intention towards unsustainable water use behaviors amongst farmer stakeholder groups, with a specific emphasis upon groundwater use for irrigation. Understanding the factors that influence farmers' unsustainable groundwater consumption behaviors in Iran—a high-risk developing nation—provides valuable insight into how to approach water governance across rapidly developing and populous arid regions, alongside contextual data relevant to climate-sensitive community development planning in similar locations across the world.

Our analysis of satellite data shows declining water quantity and resource quality across the Jaz-Murian wetland over time. Due to the interplay of land use change and climate change, water resources are increasingly scarce in the case study region, as seen across diverse arid and semi-arid regions across the world. As an adaptive response to such drastic environmental change, farmers' psycho-social characteristics play an important role in the ensuring the sustainability of remaining groundwater. However, we find that farmer action on sustainable water management is influenced by two competing intentional demands. On the one hand is a short-term profit motive that creates a common tragedy for the wetland; on the other is an ethical stance motivated by subjective cultural conditioning of normative goals and intentions [118]. Unfortunately, the contextual factors of climate-induced drought currently exacerbate unsustainable water management practices by promulgating short-termist thinking, i.e., sacrificing long-term drought adaptation planning for unsustainable agricultural production.

Given the strength of financial motives in influencing behavioral intention, we suggest that policy mechanisms to develop stronger internal markets for water governance that incentivize sustainable practices would prove environmentally beneficial. As reported by Razzaq et al. [119,120], groundwater markets that categorize farmers as either buyers, sellers, or self-users of water resources and then allow sustainable trade amongst differentiated tiers of water need have proved effective in reducing unsustainable practices. In Iran, there are already similar systems for the market governance of water resources used by indigenous farming groups that could be implemented more broadly across the country. In the southwest of the country, there exist indigenous water governance systems that categorize different users (including, for example, differentiating "pumpers", who extract river water into traditional reservoirs, from other water-using farmers) [121]. Differentiated internal water governance markets would allow regulatory authorities and user groups to reallocate water in a way that incentivizes user action through profit while maintaining the carrying capacity of the water resource. The creation and development of formal and/or informal institutions for a groundwater market would then shape the behavior of farmers, which in turn requires more detailed investigation in future studies.

While short-term profit motives are the most strongly expressed value in our case study and may be alleviated by groundwater market approaches, other normative goals also complement adaptive and sustainable behaviors. We find that actions that lead to positive and self-rewarding emotional outcomes are likely to be effective in initiating positive pro-environmental behavioral change. Raising awareness of the need for sustainable water management through information provision, agricultural extension, and targeted social and/or print media campaigns promoted by central agencies and agricultural advisory centers is also likely to prove to be beneficial, especially if it emphasizes the collective benefits of water management changes for farmer communities. The content of this messaging should be specific to groundwater management and provide information on how modern irrigation methods and appropriate cultivation patterns can conserve water and energy, which can in turn enhance our understanding of the effectiveness of outcomes and make them important for potential intercession strategies.

We also conclude that awareness raising activity should be coupled with shared dialogue to bring farmers together to discuss ways to foster socio-cultural change through a shaping of social and ethical norms that influence the subjective culture of the region, as this would lead to longer-term change in farmer habits. Agricultural extension services professionals are well situated to intervene in these critical socio-environmental settings [122], creating a meeting space where the potentially antagonistic or uncooperative groups can jointly develop solutions through shared dialogue and deliberative decision-making between researchers, extension workers, and farmers, and thus shift the subjective cultural norms within a community of agricultural practitioners. As Oskamp, Harrington [123] argue, farmers will likely find such dialogues between peers to be useful in terms of time and financial investment. Farmers that then adopt new pro-environmental behavioral strategies should be given opportunities and encouragement to discuss the use and practice of water technology freely and openly with their peers as well as social networks to establish changes in collective norms of water use practice; this would allow them to share their findings within and among such groups. It is in this way that the subjective culture of sustainability is created, shared, and strengthened over time.

7. Study Limitations

Due to the self-reporting method used, farmer-reported unsustainable water use behaviors may be subject to social desirability bias given the nature of the subject. Given the emphasis on farmer worker populations, there are limitations in gender presentation within the sample. Future studies in different geographic and cross-cultural studies, especially those that better capture the responses of female agricultural workers in water-stressed areas, would be beneficial. It would be useful in future studies to also investigate the direct link between awareness and sustainable behaviors in greater detail. The model explains 46% of farmer unsustainable water management behavior; adding other factors to the model would increase the explanatory power of future studies.

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