Farmers’ Adaptations to Groundwater Scarcity in the Rafsanjan Plain, Iran

by

Seyyed Mahmoud Hashemi

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved April 2021 by the
Graduate Supervisory Committee:

Ann Kinzig, Chair
Charles Perrings
Joshua Abbott
Hallie Eakin
Reza Sedaghat

ARIZONA STATE UNIVERSITY

May 2021

ABSTRACT

Groundwater depletion is threatening the livelihoods and welfare of millions of people living in rural and urban areas worldwide. As had been the experience with many countries, aquifers in Iran have been rapidly depleted over the past decades. The Rafsanjan Plain, Iran (a global center for pistachio cultivation and production) is the study area for this dissertation. The Rafsanjan Plain exemplifies a region where a mismatch between ‘economy’ (socio-economic growth) and ‘ecology’ (water resources’ carrying capacity) has resulted in unsustainable development. Besides groundwater scarcity, Rafsanjani pistachio growers are currently dealing with other stressors, notably declining agricultural profitability.

Using a social-psychological lens and employing both qualitative and quantitative social science research methods, I explored adaptation to groundwater scarcity among pistachio growers in Rafsanjan. Through adopting an integrated approach combining vulnerability and resilience frameworks, a theoretical framework was developed as a diagnostic tool for conceptualization and measurement of adaptation of a groundwater-dependent farmer to groundwater scarcity. The framework consists of five components: ‘Social-ecological stressors’(Stressor), ‘Groundwater-dependent livelihood system’(Livelihood), ‘Response options’, (Response) ‘Background variables’, and ‘Structural factors.’

While heterogeneity exists, the majority of pistachio growers’ perceptions and subjective norms on the Livelihood, Stressor, and Response components strongly favor the human element (short-term pistachio production) over the water element (groundwater conservation for future use). Based on the results from two path models, I also found that pistachio growers who had more pessimistic perceptions of the groundwater resources in Rafsanjan were more likely to increase groundwater extraction; however, these growers were also more likely to seek external employment (income diversification). In addition, a general structural equation model was developed to analyze socio-psychological factors that affect the intentions to adopt and the actual adoption of income diversification in response to groundwater scarcity. The developed model includes affective attitudes, instrumental attitudes, and self-efficacy. This model explains 55% and 36% of the variance in intentions to pursue and the actual pursuit of income diversification among farmers, respectively. Results of this dissertation can inform policies for conserving groundwater resources and maintaining pistachio growers' livelihoods.

DEDICATION

To my parents

ACKNOWLEDGMENTS

First and foremost, my special thanks go to my advisor, Professor Kinzig, for all her endless wisdom, encouragement, and support throughout the development of this dissertation. I truly cannot thank her enough and will be grateful to her forever. I also am grateful to my committee members, Professor Perrings, Professor Eakin, Professor Abbott, and Dr. Sedaghat for their helpful feedback.

I would like to extend my gratitude to the Ecoservices Lab graduate students and faculty, particularly Professor Minteer, Tracie Lorenzo, and Ryan Davila. I am also thankful to the Center for Biology and Society Administration, particularly Professor Maienschein, Dr. Ellison, and Jessica Ranney for their continued support and friendliness.

This dissertation would not have been possible without unconditional support from my parents and brothers. I am eternally indebted to my parents, Fakhri Rahimi and Seyyed Ahmad Hashemi for all their prayers, unconditional love, and lifelong dedication. I also owe deeply to my brothers, Mehdi Hashemi, Seyyed Mohammad Kazem Hashemi, and Seyyed Mohammad Hadi Hashemi for believing in me and encouraging me to start and finish my Ph.D. degree.

Lastly, I would like to acknowledge the financial support received from the UNDP Asia–Pacific Human Development Academic Fellowship. The views expressed in this Ph.D. dissertation are those of the author and do not necessarily represent those of the United Nations, including UNDP, or the UN member States.

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CHAPTER 1

INTRODUCTION

GROUNDWATER OVERDRAFT IN IRAN AND THE WORLD[1]

Globally, reliance on groundwater is increasing, primarily due to the growing demands for food production (Dalin et al., 2017; Megdal, 2018). For example, in the USA, groundwater abstractions, as a percentage of total water abstractions for irrigation, have risen from 23% in 1950 to 42% in 2000, and in India groundwater-reliant irrigated area increased about four times from 1962 to 1997 (from 7.4 million ha in 1962 to nearly 30 million ha in 1997; Birkenholtz, 2009). In many regions worldwide, groundwater resources are being abstracted faster than they are being recharged, resulting in water scarcity and quality related issues (Gleeson et al., 2020; Megdal, 2018). In China, for example, severe groundwater depletion (through an estimated 53.8 million wells in 2011) is threatening food production, industrial and domestic water supplies, and sustainable development (Jia et al., 2019). Moreover, in Pakistan, groundwater abstraction increased from 9,000 to 51,000 million m^3/year from 1965 to 2002 (Qureshi et al., 2010). Over almost the same time span, the number of wells increased from 10,000 to 600,000 from 1960 to 2002 in Pakistan (Qureshi et al., 2010). This excessive groundwater use has

[1] - A version of this section has appeared as Hashemi, S. M., Kinzig, A., Abbott, J. K., Eakin, H., & Sedaghat, R. (2020). Exploring farmers' perceptions about their depleting groundwater resources using path analysis: implications for groundwater overdraft and income diversification. *Hydrogeology Journal*, *28*(6), 1975-1991.

resulted in continuous water-table falls, rising pumping costs, and increasing groundwater salinization in Pakistan (Kirby et al., 2017).

In the years between 2000 and 2009, as shown in Figure 1.1, Iran was among the top five groundwater exploiters in the world; it was also among the top three countries in the world in terms of groundwater depletion rates (with an annual average of 10 km^3 groundwater depletion rate). Figure 1.1 also shows that about 30% of total annual groundwater consumption in Iran comes from nonrenewable groundwater. From the 1970s to 2014, Iran witnessed about a fourfold increase in the use of groundwater, mostly (with more than 81%) for agricultural purposes, and an annual average decline of around 0.51 m in the water table (Emadodin et al., 2019; Taghipoor Javi et al., 2020). While in Iran there were about 45,000–50,000 wells in use in the 1970s, there were some 500,000 registered wells throughout the country in 2006 (Karimi et al., 2012). According to the latest statistics, all 609 plains in the country are experiencing falling water tables, of which 408 plains are being designated as “prohibited plains” for digging new wells (Elahi et al., 2018; Tabnak, 2019; Tasnim, 2019). Extraction of groundwater resources through wells beyond recharge rates has threatened the sustainability of the livelihoods of groundwater users. Falling water tables, drying up of wells, deteriorating groundwater quality, declining yields, and farmers’ poverty are some of the problems that have been caused or exacerbated by overdraft of the groundwater resources by farmers in Iran (Hashemi et al., 2017; Madani, 2014; Nabavi, 2017; Scott & Shah, 2004; Valizadeh et al., 2019).

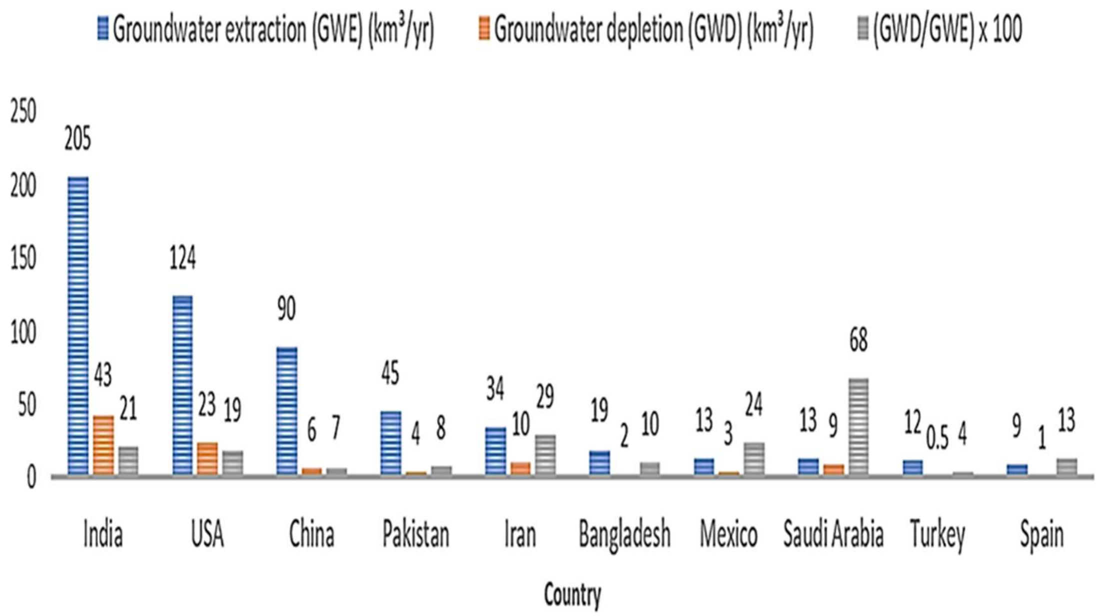

***Figure 1.1.* The average annual groundwater extraction, depletion, and fraction of groundwater depletion over the groundwater abstractions, over the years 2000–2009, by the top 10 countries in the world** (source of data: Doll et al. (2014))

Several factors have contributed to groundwater overdraft in Iran, including very cheap energy for pumping and an ineffective regulation of groundwater resources (Madani, 2014; for a review of the drivers of groundwater depletion in Iran, see Madani et al. (2016)). In many parts of the world, governments support farmers with extensive water and energy subsidies (Fishman et al., 2015; Foster & van der Gun, 2016). Likewise, Iranian farmers pay less than 7% of the costs of electricity consumed for operating pumps, due to the government's highly subsidized electricity prices (Tavanir, 2008 cited in Karimi et al., 2012). As a result, costs associated with groundwater abstraction do not constrain pumping (Madani, 2014). In addition, as with many countries worldwide, groundwater resources are not effectively regulated by the government in Iran (Fishman et al., 2015; Nabavi, 2018). Although, according to the law, groundwater is a public property and groundwater users need to receive permits from the government, there are still many unregistered wells (some 350,000 wells in 2018) across the country (Madani et al., 2016; Mirzaei et al., 2019; Moridi, 2017; Tasnim, 2016).

AN OVERVIEW FROM STUDY AREA OF DISSERTATION: THE RAFSANJAN PLAIN, IRAN

Rafsanjan's Irrigation and Pistachio Production Systems[2]

From Qanats to Pumped Wells

Given the conditions of Rafsanjan Plain, the early farmers of this region had no choice but to rely on groundwater resources for irrigation through using qanats. Qanats[3] are underground channels or tunnels that move water from the interior of a hillside (surface groundwater) downhill. The qanats were used in Rafsanjan until the early 1960s when wells and pumps were first introduced to the region.[4] Since then, qanats have been replaced with an increasingly growing number of pumped wells (Razavi, 1991).[5] In fact,

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[2] - This section mostly draws on Razavi (1991 and 1994).

[3] - There is not much precise information about the history of qanats in the Rafsanjan region (Razavi, 1991). However, qanats first developed in ancient Persia as a groundwater supply technology (Salih, 2006). English (1998, p. 198 cited in Foltz, 2002) considers qanats as "a sustainable system that provides water to settlements indefinitely." and names several advantages for them: they are designed in a way that they bring aquifers' water to the surface in a sustainable way (extraction = recharge), they need no external energy to function as they work only by using gravity, are able to transport groundwater without losing it to evaporation or contaminating the water, and only local materials are used to create qanats. Mehryar et al. (2015) add other (socio-economic) benefits for qanats. Since qanats as (very) large water supply structures usually manage by a large number of users, they encourage users to practice successful cooperation and monitoring in managing their common groundwater resources.

[4]- According to Rafsanjan County Department of Agriculture (2008), there are still 151 qanats (out of which 90 qanats are currently active) in the Rafsanjan County (Fadakar Davarani & Samaram, 2010). These active qanats currently in Rafsanjan supply only 0.1% of the all groundwater outflow (Mehryar et al., 2015).

[5] - The number of deep wells in the Rafsanjan plain has increased from 159 (with an annual well discharge of 215 million cubic meters) to 1392 (with an annual well discharge of 623 cubic meters) from 1963 to 2006 (Mehryar et al., 2015). Although in 1947 the first water pump was put into use in Rafsanjan, it became popular not until 1961. As stated before, in 1974 Rafsanjan aquifer was designated as one of Iran's "prohibited plains" for new wells and water pumps. However, since then and until the Iranian Revolution of 1979, Rafsanjani pistachio growers continued to set up new pumped wells by using legal and illegal procedures. This trend then intensified during the revolutionary years of 1979-1980 because of a decline in the authorities' monitoring (Jamali Jaghdani & Brümmer, 2011).

the adoption of wells undermines the functioning of qanats (explained below), so that abandonment of qanats and adoption of wells have both accelerated in recent decades (Mehryar at al., 2016; Razavi, 1991).

Some factors in this trend relate to the limitations of qanats themselves and some point to the relative advantage of wells. During the 1950s and 1960s, pistachio acreage in this region expanded dramatically, causing higher demands for irrigation water (the reasons for this are explained in greater detail below). Qanats were unable to meet these new demands because they use only the renewable portion of aquifers (English, 1998; Razavi, 1991), and demand began to outstrip aquifer renewal. In addition, with increasing labor wages peaking in the early 1970s, labor-intensive qanats showed lower and lower cost-effectiveness (Razavi, 1991). The increasing number of pumped wells led to the depletion of the Rafsanjan aquifer, rendering the qanats even less efficient (Mehryar et al., 2015). Table 1.1 presents some general information about Rafsanjan.

Table 1.1.

General characteristics of Rafsanjan

Variables	Means
Annual precipitation	90 mm
Crop pattern	Only pistachio orchards
Planting area	Estimated at 80,000 to 120,000 ha
Area of Rafsanjan Plain	6,234 Km^2
Annual extraction volume	743 million m^3
Volume of water used by agriculture	702 million m^3
Groundwater annual safe yield	504 million m^3
Annual drop of water level	64 cm

Source: Jamali Jaghdani and Brümmer (2016); Karamouz et al. (2011); Rahnama and Zamzam (2013).

From Subsistence Agriculture to Pistachio (a Cash and Export Crop) Production

According to findings of Razavi (1991, 1994), before the early 1940s in Rafsanjan basin (in villages located within an approximate distance of 5 km from Rafsanjan city) pistachios were grown by some of the Rafsanjani landlords as a minor crop to be consumed outside of the county. Major crops (with the largest area under cultivation), on the other hand, were of either subsistence nature like wheat, barley, and millet, or cash crops such as cotton. However, close to half the village lands were devoted to the production of pistachios by the mid-1950s. By the late 1960s pistachios were cultivated as the single dominant crop in almost all the villages of the basin.

Razavi (1991) interviewed landlords and villagers in 1988 and 1989 to reconstruct the reasons for this historic expansion of pistachio cultivation. Landlords and villagers identified both environmental and economic factors driving the transition. Pistachios are well suited to the climate and soil of Rafsanjan's desert-like condition. Pistachios need only 1/8th of water needed for growing wheat. At the same time, while agricultural jobs in Iran are generally low income, pistachio farmers and people living in Rafsanjan have enjoyed relatively high profits from the pistachio industry (Mehryar et al., 2015). Jamali Jaghdani and Brümmer (2011) state that pistachios' price rises after 1931 motivated pistachio production expansion. In addition, development of water pumps and land reform in 1962 helped induce a more gradual expansion of pistachios, until the Rafsanjan cropping pattern became a monoculture of pistachios. Table 1.2 shows some variables describing pistachio production in Rafsanjan (i.e., the production costs, and water, wells, and farm-related variables).

Table 1.2.

Some descriptive variables of pistachio production in Rafsanjan

Variables	Mean	SD	Max	Min
Fertilizer, Manure, and sand Divisia price index[6] (Rials/kg)	1,018.60	1,522.00	11,007.30	23.70
Water pumping costs (Rials/cubic meter)	357.90	318.30	1,503.00	59.70
Labor price index (Rials/day)	101,833.80	16,602.70	144,383.00	58,052.50
Machinery price index (Rials/hour)	59,926.70	43,316.80	352,214.60	14,095.20
Pesticide price index (Rials/kg)	124,255.00	205,923.10	1,406,325.30	19,096.80
Pistachio harvest (kg)	11,963.60	34,045.30	285,000.00	0.00
Well capital stock (million Rials)	169.00	397.40	2,892.00	2.50
Water salinity (Electrical Conductivity(µmhos/cm)	6,453.50	3,885.00	21,000.00	1,314.00
Density of trees in farm (number of trees)	9,362.70	26,128.40	276,840.00	112.50
Farm size (ha)	9.60	25.20	224.90	0.10
Age of gardens	25.70	9.00	65.00	5.00
Number of fragmented farms	3.50	2.60	15.00	1.00
Water quota per ha (cubic meter/year)	8970.30	4272.40	22425.00	2307.40
Water use per ha (cubic meter/year)	9,083.60	3,970.60	20,981.60	2,325.90
Water level (meter)	62.20	30.60	138.70	8.10
Well depth (meter)	194.00	79.60	400.00	69.00
Tree density per ha (number of trees)	1,216.60	863.80	5,117.30	357.10

Source: Jamali Jaghdani and Brümmer (2011).

[6] - To calculate the Divisia price index for Fertilizer, Manure, and sand use for each farmer, an aggregation formula was used (Jamali Jaghdani, 2011).

Rafsanjan's Pistachio Farmers

From Landlords' Monopoly over Water and Lands to More Diversified Water and Lands Ownership

In Rafsanjan, traditionally the (urban-based) absentee landlords have been the sole owners of water and therefore land.[7] However, this complete monopoly eroded first during the 1970s —initially due to land reform first initiated in 1962[8] —with a more pronounced change in property rights after the Iranian Revolution of 1979 (Razavi, 1991). [9] This historic legacy has contributed to inequitable assets among pistachio farmers (Jamali Jaghdani & Brümmer, 2011). Table 1.3 shows how four different categories of pistachio producers (based on land area size) differ in terms of their liquidity (pistachio production's revenue minus pistachio producers' cost of living). As shown, while category 3 and 4 farmers enjoy a profit, category 1 and 2 farmers are generally in debt. Lastly, Table 1.4 contains a summary of a history of main events/drivers of change and their impacts on Rafsanjani pistachio growers' livelihoods.

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[7]- Due to water being the constraining factor in Rafsanjan, the landlords' ownership of (entire) villages (individually or together with other landlords) was determined (and described) based on their possessed proportion of the village's water supply (Razavi, 1991).

[8] - Since (pistachio) orchards lands were exempted from redistribution and given the large area of the pistachios under cultivation in that time in Rafsanjan, the 1962 land reform did not result in a significant change in the land ownership (Razavi, 1991; Jamali Jaghdani & Brümmer, 2011). In fact, as a result of the reform, only 8% of all the land owned in two villages in Rafsanjan in 1989 was obtained during this period (Razavi, 1991).

[9] - Here, it should be mentioned that the (absentee) landlords were still the largest owners of water and lands in two villages explored by Razavi (1991). Based on agricultural experts' estimations, 87% of water and lands under cultivation in the two villages belonged to a small number of absentee landlords (this figure was almost 93% in the early 1970s) (Razavi, 1991).

Table 1.3.

Pistachios' cropping area distribution and farmers' liquidity in Rafsanjan

Category	Lands area size (ha)	Frequency	%ages of farmers	%ages of land ownership	Liquidity (Rials)
1	Less than 1	237	43.7	8	-123,437,61
2	1-2.5	147	27.3	19	-402,001,1
3	2.5-5	51	9.4	14	929,798,9
4	More than 5	105	19.4	59	342,692,39
Total		540	100	100	

Source: Sedaghat, 2002; 1 US Dollar = 7,927 Iranian Rials in 2002.

Table 1.4.

Rafsanjani pistachio growers' groundwater-dependent livelihood system: timeline of main events and the scale of drivers of change

Year(s)	The scale of driver of change	Event(s)
1931	National and international	Pistachios price rise
1947-1961	Regional	Pistachio growers' adoptions of water pumps: in 1947 the first water pump was put into use in Rafsanjan, it became popular in 1961.
Late 1960's	Regional	Pistachio monoculture
1974	Regional	Rafsanjan Plain was determined as a prohibited plain for digging new wells by the Iranian government. However, since then and until the Iranian Revolution of 1979, Rafsanjani pistachio growers continued to set up new pumped wells (Jamali Jaghdani & Brümmer 2011).
1979	Regional	During initial years after the revolution of 1979, Rafsanjan witnessed a significant increase in cultivated area.
1988-	National and International	Pistachio growers' revenue and livelihood improved in the years after the war (1988-) because of an increase in

		the price of pistachios along with other reasons (e.g., agricultural subsidies).
2005-2006; 2000-2011	Regional	Conditions changed significantly with groundwater scarcity as well as the fact that the Iranian Rial remained relatively stable against the US dollar from around 2000 up until late 2011. This means that the price of pistachios was more or less the same; however, the pistachio producing costs increased because of high inflation rates. Consequently, many smallholder pistachio growers had no choice but to sell their orchards.
2010	National	Eliminating the most of agricultural subsidies (e.g., water and energy)
2011-2013	International	The Iranian Rial devalued against international currencies (Iranian Rial lost two-thirds of its value within two years); as a result, the price of pistachios increased by about three folds, making pistachio farming very profitable for pistachio growers.
2015-2018	International	Lifting of international sanctions against Iranian economy resulted in the relative stability of the Iranian Rial and therefore the price of pistachios.
2018-	International	Restoring U.S. sanctions against Iranian economy caused dramatic devaluation of the Iranian Rial and therefore surge in the price of pistachios.

Source: interviews with key informants in Rafsanjan; literature review, e.g., Jamali Jaghdani & Brümmer, 2011; Razavi, 1991.

GROUNDWATER MANAGEMENT LITERATURE[10]

Based on the review of the literature on the management of groundwater in the agriculture sector, five distinct disciplinary approaches to addressing groundwater depletion are identified (Table 1.5). These five types of research do not represent a comprehensive survey of the literature but are demonstrative of some typical studies in the field.

[10] - A version of this section has appeared as Hashemi, S. M., Kinzig, A., Eakin, H., Abbott, J. K., & Sedaghat, R. (2020). Developing a socio-psychological model explaining farmers' income diversification in response to groundwater scarcity in Iran. *International Journal of Water Resources Development,* DOI: 10.1080/07900627.2021.1879029.

The first disciplinary approach is based on hydrology, with research focusing on the characteristics and behavior of groundwater (Mukherji & Shah, 2005). These studies have received the most attention among the five types of research given in Table 1.5 (Mitchell et al., 2012). Research in this area primarily proposes supply-based solutions (e.g., artificial recharge schemes, water transfer projects) to overcome groundwater resource problems. Scholarship in this area also promotes water-efficient irrigation technologies because of their anticipated positive impacts on water savings, water quality and farmers' welfare, among others (Ward & Pulido-Velazquez, 2008). However, the higher irrigation efficiency obtained by using water-conserving technologies can trigger, for example, the expansion of irrigated acreage by farmers in the long-run and with a resulting increase in total water use (Expósito & Berbel, 2017; Kumar, 2018; Ward & Pulido-Velazquez, 2008). Furthermore, increased irrigation efficiency lowers the irrigation return water flow (and therefore groundwater recharge; Adamson & Loch, 2014; Perry et al., 2017; Ward & Pulido-Velazquez, 2008). Therefore, given that the impact of water-saving technologies is highly context dependent, it is necessary to proactively project and prepare for any potential unintended impacts of such technologies (Kumar, 2018; Pérez-Blanco et al., 2020; Sears et al., 2018).

Table 1.5.

Summary of the groundwater resources management studies by the academic discipline.

Example academic discipline	Subsystem of interest	Main focus	Solutions for achieving groundwater management	Nature of the solutions
Hydrology	Ecological system	Groundwater resources	Technological solutions (e.g., artificial recharge schemes)	Supply and demand-based strategies
Economics	Social system	Economic structure	Changing farmer behavior (e.g., elimination of water and energy subsidies)	Demand-based strategies
Political sciences	Social system	Institutions	Changing farmer behavior (e.g., changing rules)	Demand-based strategies
Development studies	Social system	Resource users	Changing farmer behavior by focusing on socio-demographic variables	Demand-based strategies
Psychology	Social system	Resource users	Changing farmer behavior by focusing on social-psychological variables	Demand-based strategies

The remaining four types of studies in the literature primarily focus on the reduction of groundwater use through changing farmers' behaviors (Table 1.5). In economic studies, researchers recommend appropriately pricing water and energy to achieve socially optimal groundwater use (Aeschbach-Hertig & Gleeson, 2012). In many countries such as Iran, groundwater and energy have been underpriced relative to the social optimum (Kumar, 2013; Momeni et al., 2019). In practice, however, politicians are often reluctant to increase costs to socially efficient levels (Fishman et al., 2015). In addition, according to Balali et al. (2011), there is mixed evidence concerning the effectiveness of water pricing to manage agricultural water demand. For instance, Balali et al. (2011) showed that water pricing is an effective tool for reducing agricultural water demand in the Hamadan-Bahar Plain of Iran. In contrast, Momeni et al. (2019) concluded that raising agricultural water price alone is not an effective measure to reduce the water consumption in the West and East Azerbaijan provinces of Iran without being accompanied by other tools, such as improving water distribution systems or educating farmers.

Similarly, the effectiveness of energy pricing to reduce agricultural water demand is mixed and differs from region to region. Kumar (2005, 2013), for example, suggest that if there is a shift from a flat rate to pro rata for groundwater energy pricing in India, multiple objectives can be achieved – including conserving groundwater resources, reducing the demand for energy and improving farmers' livelihoods. However, Qureshi et al. (2010) argue that energy pricing policies do not effectively control groundwater overdraft in Pakistan. Qureshi et al. (2009, 2010, 2020) contend that given Pakistani farmers' dependence on groundwater for irrigation, raising energy prices results in shifts from electric to diesel engines by farmers, which subsequently leads to only a small reduction in groundwater use.

The literature centered in the political sciences focuses on formal and informal institutional arrangements and explores the likelihood of community self-organization and collective action to manage their common groundwater resources (e.g., Ostrom, 2009). The main premise of these studies is that access rules must be compatible with local conditions, and there must be a monitoring and enforcement of those rules to achieve long-term sustainable use of the common resource (Ostrom, 2009). Generally, however, the regulation of groundwater resources can be politically costly and even infeasible in the short term (Patil et al., 2019).

This brings the discussion to the last two remaining types of studies on groundwater management: development studies and social–psychological studies. These two research traditions, particularly research grounded in psychology, have received the least attention among the five research traditions given in Table 1.5 (Mitchell et al., 2012). With a focus on farmer and farm characteristics ('livelihood assets'), work in development studies has found, for instance, that groundwater users in Australia with smaller areas under irrigation were less likely to adopt spray irrigation (Sanderson & Curtis, 2016). In psychological studies, behavioral variables (e.g., attitudes, perceptions) are postulated as the determinants of an individual's behavior (Fishbein & Ajzen, 2011). This dissertation primarily draws on insights from the last of two approaches and especially the last one (social–psychological studies) in order to provide some insights into the long-term sustainability of groundwater resources and livelihoods in the Rafsanjan Plain.

RESEARCH QUESTIONS AND SIGNIFICANCE

1. How do Rafsanjani pistachio growers perceive their groundwater-dependent livelihoods, the stressors that threaten their livelihoods, their responses to those stressors, and adaptation obstacles? What adaptation strategies have been adopted by them? How do Rafsanjani pistachio

growers' knowledge of the groundwater system differ from those of scientists? (Chapter 2)

2. What explains groundwater overdraft among pistachio growers in Rafsanjan? (Chapter 3)
3. What explains the pursuit of income diversification in response to groundwater scarcity among pistachio growers in Rafsanjan? (Chapter 4)

This research has theoretical, methodological, and practical significance:

In regard to the theoretical significance of this study, there is no certainty that adaptation to water scarcity is sustainable, and new approaches are needed to assess current adaptation trajectories (Eriksen & Brown, 2011; addressed in Chapter 2 of this dissertation). Understanding the perceptions of different players about the groundwater-based livelihood system is critically important, both for conserving groundwater (Bekkar et al., 2009) and for sustaining rural livelihoods (addressed in Chapter 2 of this dissertation). In addition, this research (Chapter 2) acknowledges the importance of other stressors in addition to climate change as exposure to multiple stressors is a true challenge, particularly in developing countries (Eakin, 2005; O'Brien & Leichenko, 2000). Unlike research on adaptation to surface-water scarcity among farmers, few have done so for groundwater use using behavioral research (Mitchell et al., 2012; Sanderson & Curtis, 2016). This study (Chapters 2, 3, and 4) explores psychological factors affecting adoptions of strategies to cope with groundwater scarcity. Understanding human behavior and decision-making are considered an important part of the social-ecological systems' dynamics research, and it is crucial in developing sustainable agriculture and increasing adaptive capacity (Feola et al., 2015; Schlüter et al., 2017).

From a methodological point of view, this research addresses socio-psychological and economic questions using statistical techniques, including path analysis and structural equation modeling. Rafsanjani farmers and residents are totally reliant on groundwater resources for irrigation and drinking purposes (Karamouz et al., 2011; Mehryar et al., 2015). Therefore, this dissertation's results can also be of practical importance, considering the importance of sustainable adaptation of Rafsanjani farmers to groundwater scarcity.

DISSERTATION SUMMARY

In general, from the methodological point of view, the first substantive chapter of this dissertation (Chapter 2) is more qualitative than the rest of the dissertation. Chapter 2 introduces the dissertation main problem and provides insights and baseline information that inform the entire dissertation. On the other hand, Chapters 3 and 4 are more quantitative, building on the insights derived from the previous chapters.

Chapter 2: Exploring Farmers' Perspectives on Social-Ecological Stressors, Causes, and Solutions[11]

This chapter draws on data from questionnaires administered to pistachio growers in Rafsanjan, a focus group with pistachio growers, and interviews with key informants in Rafsanjan. This chapter argues that farmers' rationales behind their decisions about their groundwater use often can be understood in terms of their perceptions of the groundwater system in which they are embedded. To this end, I explore how pistachio growers see (1) their groundwater-dependent livelihoods (Livelihood); (2) the stressors that threaten their livelihoods (Stressor); and (3) their responses to those stressors (Response). This chapter finds that, while showing heterogenous views, the majority of pistachio growers' perceptions and subjective norms on the Livelihood, Stressor, and Response strongly favor the human element (short-term pistachio production) over the water element (groundwater conservation for future use). Furthermore, I find that pistachio growers' knowledge (or more correctly misperceptions, misinformation, and/or lack of knowledge) of the groundwater system is an additional factor that influences their decisions to increase groundwater use. In addition, most pistachio growers generally think that the strategy of "increasing groundwater extraction" and strategies involving income diversification are the most and least effective livelihood strategies to address livelihood stressors, respectively.

[11] - A version of this chapter has appeared as Hashemi, S. M., Kinzig, A., Eakin, H., Sedaghat, R., & Abbott, J. K. (2020). Embedding farmers' groundwater use in the context of their livelihoods: farmers' perspectives on social-ecological stressors, causes, and solutions. *International Journal of Sustainable Development & World Ecology*, 1-15.

Chapter 3: Exploring Farmers' Perceptions about Their Depleting Groundwater Resources: Implications for Groundwater Overdraft and Income Diversification[12]

Given that Chapter 2 finds that pistachio growers in Rafsanjan think that strategies involving "increasing groundwater extraction" (as a maladaptive strategy) and income diversification (as a transformational strategy; Wise et al., 2014) are the most and least effective livelihood strategies to deal with water scarcity in Rafsanjan, Chapters 3 and 4 focus primarily on groundwater overdraft and income diversification, respectively. Chapter 3 has a focus on groundwater overdraft, using path analysis and logistic regression. In this chapter, I examine whether Rafsanjani pistachio growers' perceptions of their depleting groundwater resources leads to the conservation of the resource and/or income diversification. The results indicate that pistachio growers who are more pessimistic about the current state of groundwater resources in Rafsanjan are more likely to increase groundwater extraction. On the other hand, these farmers are also more likely to seek jobs outside the Rafsanjan Plain (income diversification).

Chapter 4: Understanding Income Diversification in Response to Water Scarcity Among Farmers Using Socio-Psychological Factors[13]

While previous chapter focuses on the perceptions of the state of depleting groundwater resources in Rafsanjan to explain farmers' groundwater overdraft and

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[12] - A version of this chapter has appeared as Hashemi, S. M., Kinzig, A., Abbott, J. K., Eakin, H., & Sedaghat, R. (2020). Exploring farmers' perceptions about their depleting groundwater resources using path analysis: implications for groundwater overdraft and income diversification. *Hydrogeology Journal*, *28*(6), 1975-1991.

[13]- A version of this chapter has appeared as Hashemi, S. M., Kinzig, A., Eakin, H., Abbott, J. K., & Sedaghat, R. (2020). Developing a socio-psychological model explaining farmers' income diversification in response to groundwater scarcity in Iran. *International Journal of Water Resources Development,* DOI: 10.1080/07900627.2021.1879029.

income diversification behaviors, Chapter 4 concentrates on farmers' perception of income diversification as a determinant of the adoption of these strategies. Chapter 4, using the Theory of Planned Behavior (Ajzen, 1991), develops a general structural equation model that analyzes socio-psychological factors that affect intentions to use, and use of, income diversification strategy in response to groundwater scarcity among pistachio growers in Rafsanjan. The developed model explains 55% and 36% of the variance in intention to use and the use of income diversification behavior among Rafsanjani pistachio growers, respectively.

Chapter 5: Summary and Conclusions

Finally, Chapter 5 concludes the dissertation. This chapter has two sections. First, a summary of major conclusions of each preceding chapter is provided. Then, the overall conclusions of the dissertation are given.

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CHAPTER 2

EXPLORING FARMERS' PERSPECTIVES ON SOCIAL-ECOLOGICAL STRESSORS, CAUSES, AND SOLUTIONS [14]

ABSTRACT

With a focus on farmers, using a behavioral approach, I explore how the groundwater system, which consists of human and water elements, is seen by pistachio growers in Rafsanjan, Iran (a major pistachio-production region in the world). I advocate that farmers' rationales behind their decisions about their groundwater use – including their reactions to policies implemented to conserve groundwater– often can be understood in terms of their understanding and knowledge of the groundwater system in which they are embedded. To this end, I explore how pistachio growers see (1) their groundwater dependent livelihoods (Livelihood); (2) the stressors that threaten their livelihoods (Stressor); and (3) their responses to those stressors (Response). In addition, I document some differences between pistachio growers' knowledge of the groundwater system and those of scientists. I find that, while showing heterogenous views, the majority of pistachio growers' perceptions and subjective norms on the Livelihood, Stressor, and Response components strongly favor the human element (short-term pistachio production) over the water element (groundwater conservation for future use). Furthermore, I find that pistachio growers' knowledge (or more correctly misperceptions,

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misinformation, and/or lack of knowledge) of the groundwater system is an additional factor that influences their decisions to increase groundwater use. I discuss the implications of the results for conserving groundwater resources and maintaining pistachio growers' livelihoods.

INTRODUCTION

Millions of farmers worldwide rely on depleting groundwater resources for meeting irrigation water needs (Mukherji & Shah, 2005). It is estimated that about 15–35% of the irrigation withdrawals from groundwater resources in the world are unsustainable (WBCSD 2006 cited in Singh et al., 2021). In many parts of the world, groundwater depletion (and its resulting water scarcity and quality issues) is threatening significant economic growth, food security, and human welfare, which have been created by the development of groundwater irrigation (Katuva et al., 2020; Wang et al., 2020). Hence, addressing water scarcity and implications for world food systems is a priority of the Sustainable Development Goals (SDGs), which were adopted by all United Nations Member States to be achieved by the year 2030 (UN, 2015). Achieving the SDGs in the agriculture and water sectors requires actors (e.g., farmers, water authorities, scientists) to consider both SDGs (e.g., SDG1, SDG 2, SDG 8) that promote sustaining farmers' livelihoods ('economy') and those (e.g., SDG 6, SDG 15) that advocate for conserving groundwater resources ('ecology') (Rasul, 2016; Sanderson et al., 2017; van Zanten & van Tulder, 2020). This is especially important in arid regions located in countries like Iran where farmers are dependent on depleting groundwater resources (Sanderson et al., 2017; Varela-Ortega et al., 2011). In this chapter, I explore how the groundwater system, which consists of human and water elements, is seen by farmers in Rafsanjan, Iran.

As with many countries worldwide, Iran's policies and measures have largely failed to control the depletion of groundwater resources by farmers (Moench, 2007; Nabavi, 2018). Overdraft of the groundwater resources by farmers in Iran has resulted in water scarcity, deteriorating water quality, declining yields, and farmers' poverty (Hashemi et al., 2020a). In this chapter, I advocate that farmers' rationales behind their decisions about their groundwater use—including their reactions to policies implemented to conserve groundwater— often can be understood in terms of their understanding of the groundwater resource, which is in turn embedded in the broader context of their livelihoods.

In Iran, the government has usually blamed the current (ground)water scarcity problem on droughts (Madani, 2014). Therefore, the Iranian government has often tried to fix the problem through implementing water supply-oriented policies, such as constructing dams, desalination, and water transfer (Balali et al., 2009; Madani, 2014). Researchers (e.g., Alborzi et al., 2018; Foltz, 2002; Hosseinifard & Aminiyan, 2015; Madani, 2014; Madani et al., 2016; Nabavi, 2018), on the other hand, while acknowledging the importance of climate change impacts (e.g., drought), argue that the groundwater scarcity is the result of other factors, including expansion of the cultivated areas, farmers' inefficient water use (caused by highly subsidized water and energy), and illegal pumping. Thus, researchers have often called for policies/plans that entail strong demand-side measures (decreasing groundwater extraction) to sustainably manage the groundwater resources in Iran.

Farmers' understandings and perceptions of the groundwater scarcity problem, its causes, and solutions can be quite different from those of other actors (e.g., policy-makers, scientists) in part because peoples' knowledge and perceptions of the environment are shaped by their different socio-economic characteristics and experiences (Hommes et al., 2009; Otto-Banaszak et al., 2011; Sumberg et al., 2003). For instance, in India, farmers considered the long-term declines in the annual rainfalls as the reason behind the falling water tables/drying up of wells, and they did not seem to see any roles for the groundwater withdrawals (Kumar & Singh, 2008). To give another example, Ethiopian farmers thought that deforestation, God's wrath, human activities, or weakened indigenous practices and values were responsible for climate change (Hameso, 2018). Additionally, farmers' farming objectives, interests, values, and norms influence their perceptions of groundwater scarcity problem, its causes, and solutions and therefore their decisions to increase or decrease groundwater use. For instance, results of a study examining groundwater irrigators' values found that egoistic (self-interest) values were negatively associated with the implementation of adaptive strategies, such as modifying flood irrigation or switching to spray irrigation (Sanderson & Curtis, 2016). According to Hommes et al. (2009), two learning processes of *cognitive* and *strategic* are involved in the development and change of actors' perceptions. Cognitive learning takes place through an increase in actors' knowledge of causes and effects of groundwater resources' problems and the potential solutions. On the other hand, strategic learning occurs as a result of interactions between different actors through which actors become aware of other perceptions, and consequently they may change their perceptions or develop new ones (Hommes et al., 2009; Koppenjan & Klijn, 2004).

With a focus on groundwater scarcity, this chapter presents results vis-a-vis how Rafsanjani pistachio growers see their groundwater-dependent livelihood systems, the stressors that threaten their livelihoods, and their responses to those stressors. An attempt is also made to highlight the differences between Rafsanjani pistachio growers' local perceptions/knowledge of the groundwater system and those of scientists. Understanding the perceptions/knowledge of different actors about the groundwater system can help to bridge the gaps and increase the mutual understandings (Kuruppu & Liverman, 2011; Otto-Banaszak et al., 2011; Walker et al., 2010). The mindset of the different actors is critically important, not only for conserving groundwater resources (SDG 6, SDG 15) (Bekkar et al., 2009), but also for sustaining rural livelihoods and eradicating poverty (SDG1; SDG 2).

BACKGROUND: RAFSANJAN PLAIN

The Rafsanjan Plain, Iran, the study area of this dissertation, was declared as a prohibited area for digging new wells in 1974 by the government, at which point there were 585 wells. However, this could not stop an increase in the number of wells being dug in Rafsanjan. In fact, due to several conditions, including subsequent changes/repeals in the law that prohibited drilling new wells in Rafsanjan (and in Iran as a whole) as well as the lack of law enforcement, farmers in Rafsanjan have continued to drill new wells since 1974 (the number of wells reached 1,445 in 2014; Jamali Jaghdani, 2011; Mirnezami et al., 2018; Nabavi, 2018; Zeraatkar & Golkar, 2016). To respond to groundwater scarcity, in addition to increasing groundwater extraction (e.g., by deepening wells), in recent years, some Rafsanjani pistachio growers have diversified their livelihoods.

The Rafsanjan Plain/Rafsanjan Study Area, the study area of this dissertation, is located in the northwestern part of Kerman Province, Iran. The Plain has three sub-basins, namely Rafsanjan, Nough, and Anar. Pistachio cultivation constitutes the most important economic activity in Rafsanjan (Hosseinifard & Aminiyan, 2015). Rafsanjan is a major pistachio-production region in Iran and the world (Khalilabadi et al., 2014). Groundwater is used in domestic (3.5%), agricultural (96.4%), and industrial sectors (0.1%) in Rafsanjan (Hosseinifard & Aminiyan, 2015). This arid plain receives an average precipitation of less than 100 mm annually, and it loses more than 3,000 mm to evaporation annually (Sayyaf et al., 2014).

The Rafsanjan Plain exemplifies a region where a mismatch between 'economy' (socio-economic growth) and 'ecology' (water resources' carrying capacity) has resulted in an unsustainable development (Madani, 2014). In other words, an unsustainable management of groundwater resources in Rafsanjan, caused primarily by a rapid and dramatic increase in pistachio production, as described below, has threatened the sustainability of pistachio production and pistachio growers' livelihoods. Rafsanjan suffers from socio-economic drought (Mishra & Singh, 2010), meaning that the amount of extraction of groundwater resources (mostly for irrigation purposes) is over 200 million m^3/year more than the amount of recharge of groundwater resources (Karamouz et al., 2011). An annual average of 83 cm/year drawdown of the water table, water quality issues, and land subsidence have been some of the negative impacts of the groundwater overdraft in Rafsanjan over the past decades (Karamouz et al., 2011; Sayyaf et al., 2014).

During the 1950's and 1960's, as pistachio acreage expanded dramatically in this region, it caused increasingly higher demands for irrigation water, and as a result, the groundwater extraction outstripped the Rafsanjan's aquifer renewal (Jamali Jaghdani, 2011). Razavi (1991) interviewed pistachio growers in Rafsanjan to understand the reasons for this historic expansion of pistachio cultivation. Pistachio growers stated that both environmental and economic factors contributed to this transition. Pistachios are well suited to the climate and soil of Rafsanjan's desert-like conditions. Pistachios need only one-eighth of the amount of water needed for growing wheat (Razavi, 1991). The price rise of pistachios after 1931 also motivated the pistachio cultivation expansion (Jamali Jaghdani, 2011). In addition, the development of water pumps in this region helped the expansion of pistachios until the Rafsanjan's cropping pattern became a monoculture of pistachios in the late 1960's (Jamali Jaghdani, 2011).

In addition to challenges associated with groundwater scarcity, Rafsanjani pistachio growers are currently dealing with other stressors resulting in the declining pistachio-cultivation profits (Karamouz et al., 2011; Oraei et al., 2014; Sedaghat, 2002). Since 2010, for instance, the government has been actively considering eliminating most agricultural subsidies, such as subsidized pricing for energy and water. Removing subsidies could result in declining profits even further, particularly for small pistachio growers who are already struggling with maintaining the profitability of their businesses due to, most notably, groundwater scarcity and groundwater quality issues (Karamouz et al., 2011; Oraei et al., 2014; Sedaghat 2002, 2019). Another future uncertainty Rafsanjani pistachio growers face concerns the exchange rate for the Iranian currency, the Rial. Over the course of almost 12 years, from 2000 to 2012, Rial exchange rates showed relative stability; at the same time, pistachio growers were experiencing double-digit inflation rates for pistachio production inputs, substantially reducing the profitability of pistachio production, as most of the Iranian production is sold in international markets. In 2013 and 2018, however, the Rial was significantly devalued over a short period of time because of international sanctions, creating higher profitability for pistachio production. The lifting of sanctions may result in the future stabilization of the Rial; pistachio profitability will then depend on national inflation rates and the level at which the exchange rate equilibrates.

METHODS

Theoretical Framework

Figure 2.1 illustrates this study's theoretical framework that was designed based on experience with previous projects and published literature on related topics (Carpenter et al., 2001; Chapin et al., 2009; Resilience Alliance, 2010). It was also based on a framework for conceptualizing farmers' sustainable adaptations to climate change (for more details, see Hashemi et al., (2017)). With a focus on the groundwater scarcity problem, the theoretical framework (see Figure 2.1) considers three components for adaptation of a groundwater-dependent farmer to stressors that threaten his/her livelihood, namely: (1) Stressor; (2) Groundwater-dependent livelihood system; and (3) Response options.

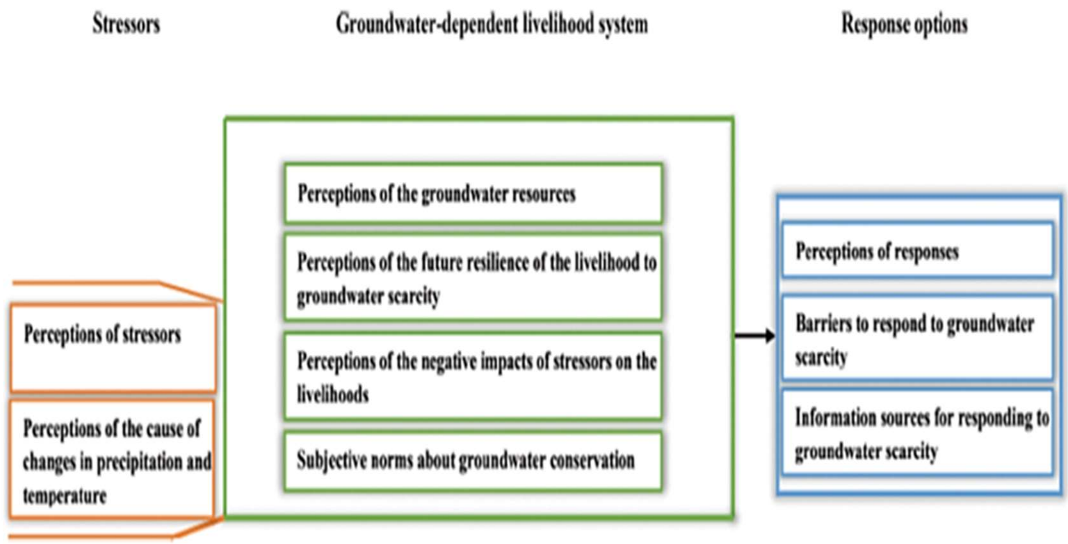

***Figure 2.1*. The study's theoretical framework.** It considers three components for adaptation of a groundwater-dependent farmer to stressors threatening his/her livelihood; they are 'Stressors', 'Groundwater-dependent livelihood system', and 'Response options'. Source: adapted from Chapin et al. (2009) and Hashemi et al. (2017).

As shown in Figure 2.1, the 'Stressor' component consists of the variable perception of social-ecological stressors that threaten farmers' livelihoods. Of particular interest was to explore whether Rafsanjani pistachio growers consider the drivers of groundwater overdraft in Rafsanjan (e.g., ineffective groundwater regulation and heavy subsidies for pumping energy) as the stressors threatening their livelihoods. It was also explored how the groundwater scarcity-related stressors are compared to other stressors influencing pistachio growers' livelihoods in the view of Rafsanjani pistachio growers. In addition, the 'Stressor' component (Figure 2.1) includes a variable that measures perceptions of groundwater scarcity-related stressors in Rafsanjan (perceptions of the cause of changes in temperature and precipitation).

The ‘groundwater-dependent livelihood system’ component has three sub-components: (1) perceptions of groundwater resources: including (i) perceptions of the state of the groundwater resources; (2) perceptions of livelihoods, including: (i) perceptions of the negative impacts of stressors on the livelihoods and (ii) perceptions of the future resilience of the livelihood to groundwater scarcity; and (3) perception of ‘governance system’ (Ostrom, 2007; 2009), including subjective norms about groundwater conservation (Figure 2.1). I was, in particular, interested in understanding how Rafsanjani pistachio growers see groundwater conservation compared to pistachio production profitability by exploring their ‘subjective norms about groundwater conservation.’

Lastly, the ‘Response options’ component includes perceptions of effectiveness of five responses, which have been commonly used to cope to cope with groundwater scarcity by Rafsanjani pistachio growers: (1) ‘Improving irrigation water efficiency’; (2) ‘Increasing groundwater extraction’ (e.g., by deepening wells); (3) ‘Earning revenue outside the Rafsanjan Plain’; (4) ‘Earning non-agricultural revenue inside of the Plain’ and (5) ‘Reducing pistachio planting area’. Furthermore, this component includes farmers’ proposed solutions for conserving groundwater resources in Rafsanjan. Finally, the ‘Response options’ component is comprised of perceptions of barriers to respond to groundwater scarcity and information sources used by farmers for responding to groundwater scarcity (Figure 2.1). As above, my particular interest was to examine how Rafsanjani pistachio growers see the importance of the water element compared to the human one by exploring their perceptions of effectiveness of their responses and their views on the solutions for conserving groundwater resources in Rafsanjan.

Data Collection Methods

In this chapter, my primary data mostly come from questionnaires that were administered to pistachio growers in Rafsanjan. In addition, in this chapter I draw on the data from a focus group with 30 Rafsanjani pistachio growers, who represented diverse socio-economic backgrounds in Rafsanjan (e.g., small and large pistachio growers, old and young pistachio growers) and interviews with key informants (e.g., affiliated with Rafsanjan's Departments of Agriculture and Water) both of which were conducted in Rafsanjan. I used the qualitative data and insights acquired from employing the focus group and interview methods as well as the data collected from the questionnaires to validate each method, reduce bias, and to enhance reliability (Porter, 2014). In particular, the focus group and interview methods were employed to depict a timeline of main events, which happened in the Rafsanjani pistachio growers' groundwater-dependent livelihood system (results given in Table 2.1). A questionnaire was designed to collect data on the variables represented in the study's theoretical framework (Figure 2.1). Table 2.1 contains a summary of the questionnaire. As shown in Table 2.1, the questionnaire was constructed following closely the study's theoretical framework (Figure 2.1). For instance, the stressor component was assessed using two variables of perceptions of the cause of changes in precipitation and temperature and perceptions of stressors. In addition, the following variables were measured using open-ended questions: (1) perceptions of the cause of changes in precipitation temperature, (2) perceptions of stressors, (3) impact of stressors on the livelihoods, (4) perceptions of the future resilience of the livelihood to water scarcity, (5) barriers to respond to groundwater scarcity, (6) information sources for responding to groundwater scarcity, (7) and response. On the other hand, perceptions of the state of the ecological resources and subjective norms about groundwater conservation were measured using Likert scales (Table 2.1).

Table 2.1.

A summary of the questionnaire's sections on factors affecting Rafsanjani pistachio growers' responses to social-ecological stressors threatening their livelihoods.

Component of the theoretical framework used in this study	**Variable**	**Item/question**	**Comment/source**
'Stressors'	Perceptions of the cause of changes in precipitation and temperature	1 open-ended question ('What is the cause of changes in precipitation and temperature in Rafsanjan?')	–
	Perceptions of stressors	1 open-ended question ('What is the most important stressor threatening your livelihood?')	–
	Perceptions of the state of the ecological resources	6 questions (e.g., 'How do you assess the current state of the groundwater resources in Rafsanjan?')	It was measured using a 5-point Likert scale from 'very bad' to 'very good'.
		'Which of the following resource(s) in Rafsanjan needs more attention with respect to its conservation? (1) groundwater resources; or (2) agricultural soils'	–

'Groundwater-dependent livelihood system'	Impact of stressors on the livelihoods	1 open-ended question ('What is the negative impact of stressors on your livelihood?')	–
	Subjective norms about groundwater conservation	2 questions (e.g., 'most people who are important to me think that increasing the amount of water I pump from my well(s) is a good action')	It (level of agreement) was measured using a 5-point Likert scale from 'very low' to 'very high'. Adapted from Yazdanpanah et al. (2014); Farzaneh (2016)
	Perceptions of the future resilience of the livelihood to water scarcity	1 question ('Do you think whether your pistachio cultivation business can continue to operate in the face of water scarcity in future?')	Hashemi et al. (2020a)
	Barriers to respond to groundwater scarcity	1 open-ended question ('What prevents you from coping with groundwater scarcity?')	Adapted from Deressa et al. (2009)
	Information sources for responding to groundwater scarcity	1 open-ended question ('What information source(s) you use to cope with groundwater scarcity')	–
'Response options'	Effectiveness of the response	5 strategies. It consisted of three response categories of income diversification (two strategies[a]), groundwater conservation (two strategies[b]), and groundwater overdraft (one strategy[c]).	It was measured using the question 'How do you rank the effectiveness of following five coping strategies for responding to groundwater scarcity?' ; Farzaneh (2016)

	Solutions for conserving groundwater resources	1 open-ended question (‘What is the solution to the groundwater resources’ problem in Rafsanjan?’)	Farzaneh (2016)

[a] ‘Earning revenue outside the Rafsanjan Plain’; and (2) ‘Earning non-agricultural revenue inside of the Rafsanjan Plain’
[b] ‘Reducing pistachio planting area’; and (2) ‘Improving irrigation water efficiency’
[c] ‘Increasing groundwater extraction’ (e.g., by deepening wells).

Prior to administering the survey, the questionnaire was tested for content validity. One hundred and ten pistachio growing households located in three major regions of the pistachio cultivation in the Rafsanjan Plain, namely Anar, Nough, and Rafsanjan, were surveyed. The data collection methods are further described in Hashemi et al. (2020a).

Data Analysis

After checking the collected questionnaires for completeness, 101 questionnaires (out of 110 completed questionnaires) constituted the analytic sample of this chapter. Using frequency and % values, Rafsanjani pistachio growers’ perceptions of their (1) groundwater-dependent livelihoods, (2) responses to those stressors, and (3) the stressors that threaten the livelihoods were examined. In addition, a logit model was estimated to model pistachio growers’ perceptions of the current state of the groundwater resources in Rafsanjan. The logit model is appropriate for predicting changes in the dependent variable of this research, which was measured at the nominal level with two categories (value 0 if the pistachio grower has assessed the current state of the groundwater resources in Rafsanjan as poor; value 1 otherwise). The independent variables in the logit model were pistachio growers' socio-economic variables, such as land ownership (value 0 if the pistachio grower was not an owner of his/her orchard(s); value 1 otherwise), agricultural organization membership (value 0 if the pistachio grower was not part of any agricultural organizations; value 1 otherwise), annual pistachio cultivation revenue, age, and access to extension services (value 0 if the pistachio grower had access to agricultural extension services; value 1 otherwise). To estimate the amount of variance explained by the model, the Nagelkerke R Square statistics (Nagelkerke, 1991) and Cox & Snell R Square (Cox & Snell, 1989) were computed. All data were analyzed using the IBM SPSS Statistics 25 and Microsoft Excel 2016.

RESULTS AND DISCUSSION

In this section, factors that influence Rafsanjani pistachio growers' responses to social-ecological stressors threatening their livelihoods are explored. This section is organized around the variables represented in this study's theoretical framework ('Stressor', 'Groundwater-dependent livelihood system', and 'Response options'; Figure 2.1).

Perceptions of 'Stressor'

The Most Important Stressors Threatening the Livelihoods as Perceived by Rafsanjani Pistachio Grower

When respondents were asked 'What is the most important stressor threatening your livelihood?', as an open-ended question, the majority of pistachio growers responded that their livelihoods were under the influence of 'drought' (29%), 'water scarcity' (26%), or 'pests[15]' (24%; Figure 2.2). On the other hand, some respondents instead reported socio-economic stressors ('expensive agricultural inputs' (3%), 'high costs of living' (1%), or 'unemployment' (1%)), as the most important stressors negatively affecting their livelihoods (Figure 2.2).

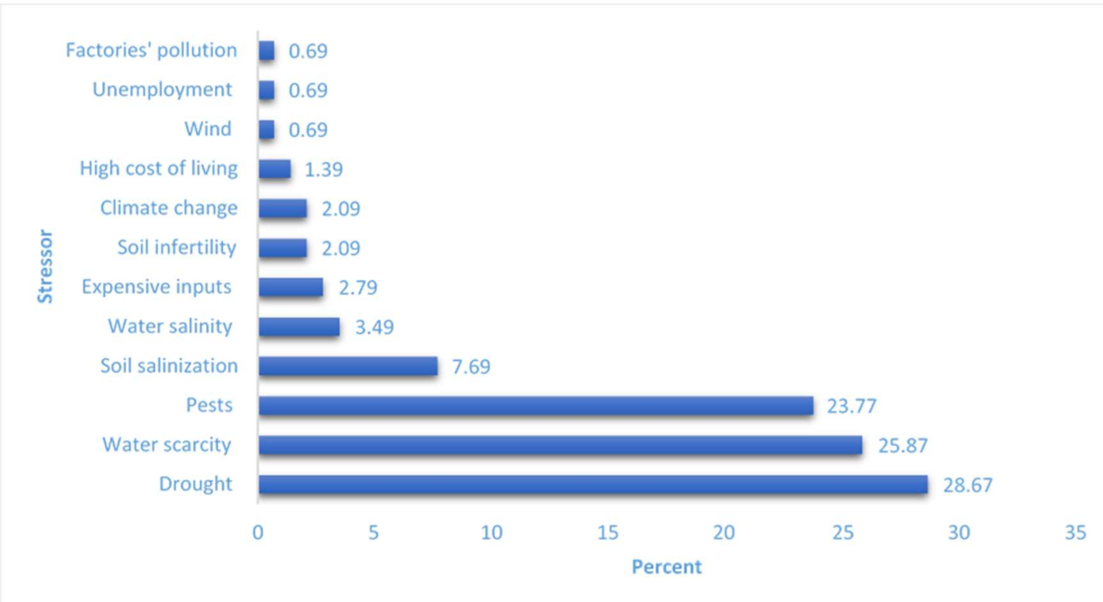

Figure 2.2. **Percentages of Rafsanjani pistachio growers' responses to the open-ended question 'What is the most important stressor threatening your livelihood?'**

A few observations follow from these findings. First, socio-economic factors were found to be secondary stressors (compared to 'ecological' stressors, such as 'drought' or 'water scarcity'; see Figure 2.2) affecting Rafsanjani pistachio growers' livelihoods. However, this finding does not mean that economic factors are not important livelihood stressors. In fact, there is often not a very clear boundary between livelihoods' ecological

[15] - Pistachio trees in Iran are attacked by numerous pests (phytophagous insects and mites). The common pistachio psylla, the pistachio twig borer, and the pistachio bugs are three major pests that can cause serious damage to pistachio trees/yields by attacking pistachio leaves, fruits, and/or twigs (Mehrnejad, 2001).

and economic stressors, and often they are closely linked (Mertz et al., 2009). Second, these findings do not mean that my study's households were necessarily under an influence of only a single threatening stressor. In fact, just like many farmers in the world, pistachio growers in the Rafsanjan Plain are being challenged by a multi-stressor environment, composed of both ecological and social stressors (Eakin, 2005; Karamouz et al., 2011; O'Brien & Leichenko, 2000; Oraei et al., 2014; Sedaghat, 2002). Third, pistachio growers seemed to not consider the many factors that have contributed to the unsustainability of groundwater use in Rafsanjan, such as illegal wells, heavy subsidies for water and energy, and ineffective groundwater regulation as stressors or threats to their livelihoods.

The Causes of Changes in Precipitation and Temperature in Rafsanjan As Perceived by Rafsanjani Pistachio Growers

Farmers' perceptions of the causes of changes in precipitation and temperature in Rafsanjan can influence their adaptive capacities to groundwater scarcity. When farmers attribute the cause of changes in precipitation and temperature to non-anthropogenic factors, they are less likely to limit their groundwater use (Hashemi et al., 2020a). To put it simply, the question is: do pistachio growers ascribe the causes of changes in precipitation and temperature in Rafsanjan to human-related or non-human-related factors? For instance, Park et al. (2012) found that Australian farmers who thought that human activities have not been contributing to climate change tended to consider only minor changes to adapt to future climatic changes. On the other hand, those farmers who were taking major changes (e.g., land use or location changes) in response to climate change were considering climate change as a human-induced phenomenon (Park et al., 2012). Still, there were some farmers in the study who did not believe in anthropogenic climate change, but they were willing to adopt major changes (Park et al., 2012).

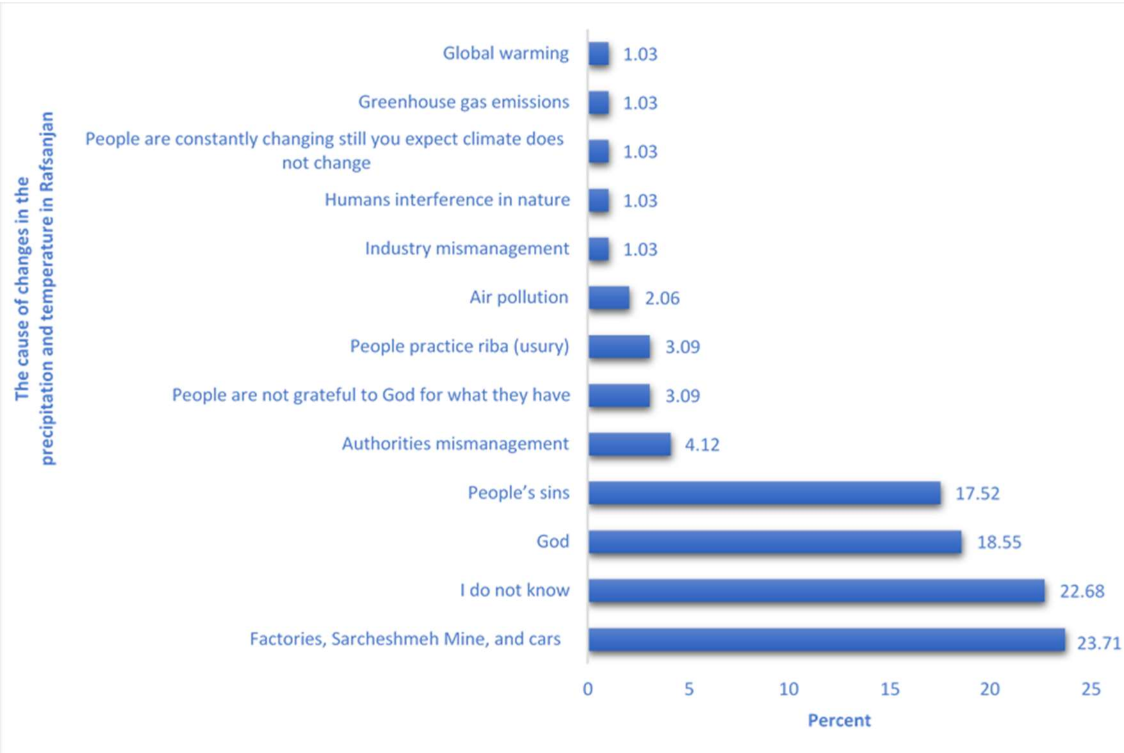

***Figure 2.3.* Percentages of Rafsanjani pistachio growers' responses to the open-ended question 'What is the cause of the changes in precipitation and temperature in Rafsanjan?'**

As presented in Figure 2.3, Rafsanjani pistachio growers' views on the cause of changes in precipitation and temperature in Rafsanjan varied greatly (they were asked 'What is the cause of changes in precipitation and temperature in Rafsanjan?', as an open-ended question). Their responses can be categorized into four groups. The majority of respondents believed that either God-related factors (42%) or human activities, such as factories, Sarchesmeh Copper Complex[16], and cars (29%) have caused changes in

[16] - Sarcheshmeh Copper Complex is a copper mine in the Rafsanjan County.

precipitation and temperature in Rafsanjan (Figure 2.3). Group 3 (about 23% of respondents) had no idea about the causes of changes in precipitation and temperature in Rafsanjan (they responded 'I do not know'; Figure 2.3). Lastly, a few respondents (4%; Group 4) believed that 'authorities' mismanagement' has led to the changes in precipitation and temperature in Rafsanjan (Figure 2.3). These perceptions about the causes of changes in precipitation and temperature are not unique to Rafsanjani pistachio growers. For example, in a study of Australian farmers, it was revealed that most of the farmers believed that nature was to be blamed for changes in climate (Kuehne, 2014). As mentioned earlier in this chapter, Ethiopian farmers also thought that deforestation, God's wrath, human activities, or weakened indigenous practices and values were responsible for climate change (Hameso, 2018).

Perceptions of 'Groundwater-Dependent Livelihood System'

The State of The Groundwater Resources in Rafsanjan As Perceived by Rafsanjani Pistachio Growers

Perceptions of aquifer dynamics (i.e., aquifer's current and future water availability) can influence irrigators' adaptive behaviors (Mendham & Curtis, 2014). Seventy-six percent of Rafsanjani pistachio growers sampled in this study described the current state of groundwater resources in Rafsanjan as 'poor'. Eighty-seven percent of them also evaluated the probable future state of the groundwater resources as 'poor'. Despite these perceptions, in many areas of Rafsanjan, the owners do not turn their pumps off even though excessive amounts of water can damage the orchards (this is both because they do not believe that 'excess' water will damage the trees, and there is a commons-problem impulse to pumping among Rafsanjani pistachio growers (Jamali Jaghdani, 2011). In addition, about 10% of pistachio growers reported the low quality of groundwater resources in Rafsanjan as the most important stressor that was negatively affecting their livelihoods (Figure 2.2). However, in some parts of Rafsanjan, which have good groundwater quality (e.g., Kabutar Khan), pistachio growers add salt to their pistachios orchards because they believe that some salt will actually improve the quality of the pistachio production, even though such practice is not approved by agricultural experts (Jamali Jaghdani, 2011). Lastly, when respondents were asked 'Which of the following resource(s) in Rafsanjan needs more attention with respect to its conservation/future state? (1) groundwater resources; or (2) agricultural soils', 89% of growers responded that they worried about the future state of groundwater resources (2% of growers were concerned about the future state of agricultural soils, and the remaining 9% were concerned about the future state of both agricultural soils and groundwater resources in Rafsanjan).

Rafsanjani pistachio growers' views on the state of groundwater resources in Rafsanjan are more pessimistic than those of scientists. For example, in a gathering named 'The ways out of the water crisis in Rafsanjan', which was held in Rafsanjan in 2013 with the participation of Rafsanjani pistachio growers, authorities of Rafsanjan County's Water and Agriculture Departments, and academicians, Rafsanjani pistachio growers unanimously disagreed with the hydrologists over at least two of their findings: the average amount of decline in the water table over time in the Rafsanjan Plain and the proportion of the flood irrigation returning to the Rafsanjan aquifer. While the hydrologists believed that the Rafsanjan's groundwater table has been falling on average

20 meters over a 40-year timespan, pistachio growers insisted that the water table has been falling on average much more than 20 meters during the same interval (Torabi, 2013). In addition, pistachio growers disagreed with the hydrologists that 35% of the flood irrigation returns to the aquifer. They thought that this number is too much considering the Rafsanjan Plain's properties, such as high temperatures (Torabi, 2013). This does not necessarily mean that the hydrologists were correct, as there is lots of uncertainty around the issue of hydrology of groundwater resources (Moench, 2007).
In summary, Rafsanjani pistachio growers hold very pessimistic, and, at the same time, rather uncertain views of the current and future states of their groundwater resources. For example, while the first author of this chapter was carrying out interviews and conducting a focus group with pistachio growers in Rafsanjan, some (mostly old) Rafsanjani pistachio growers stated that '*You never know about the future! We may get thousands and thousands of millimeters of rainwater just in the coming year, which may be big enough to completely recharge the aquifer.*' and '*There is a sea deep down in Rafsanjan. Why won't the Water Department people allow us to dig new wells and/or go deeper and use that?*' The issue of uncertainty about the future state of groundwater resources and its impacts on Rafsanjani pistachio growers' decision-making process remains to be addressed in future research.

Factors Affecting Rafsanjani Pistachio Growers' Perceptions of The State of The Groundwater Resources in Rafsanjan

According to a study (Hashemi et al., 2020a) conducted in Rafsanjan, pistachio growers who perceived a worse state for groundwater resources in Rafsanjan were more likely to increase groundwater extraction. In my study, three variables have found to show statistically significant relationships with pistachio growers' perceptions of the current state of the groundwater resources in Rafsanjan (Eq. 2.1). That is, older pistachio growers, pistachio growers who were the owners of their orchards, and pistachio growers who had access to extension services were more likely to perceive a better state for the groundwater resources in Rafsanjan.

$$Y = -80.46 + 0.77 (X_1)^{**} + 0.34 (X_2)^{*} + 16.07 (X3)^{**} \qquad \text{(Eq. 2.1)}$$

Note. **Significant at $p < 0.05$; *Significant at $p < 0.10$; Nagelkerke R Square statistics = 0.44; Cox & Snell R Square = 0.32

Where

X_1: Pistachio grower's age

X_2: Pistachio grower's orchard ownership (value 0 if the pistachio grower was not an owner of his/her orchard(s). Value 1 otherwise)

X_3: Pistachio grower's access to extension services (value 0 if the pistachio grower did not have access to agricultural extension services. Value 1 otherwise)

The Most Important Negative Impacts of Stressors on The Livelihoods as Perceived by Rafsanjani Pistachio Growers

When respondents were asked 'What is the most important negative impact of stressors on your livelihood', as an open-ended question, the frequently mentioned answers were declining yields, poverty, and dying pistachios trees (Figure 2.4). All in all, the negative impacts can be categorized into the following groups (Figure 2.4): (1) ecologically-related impacts (e.g., 'Pistachio trees are dying' and 'Soil infertility') (about 69%); (2) socioeconomic-related impacts (e.g., 'Poverty', 'Growers' difficult life', ‘Migration’, and ‘Pseudo-jobs[17]‘ (about 28 %); and (3) psychological impacts (e.g., ‘Stress and sadness’) (about 2 %).

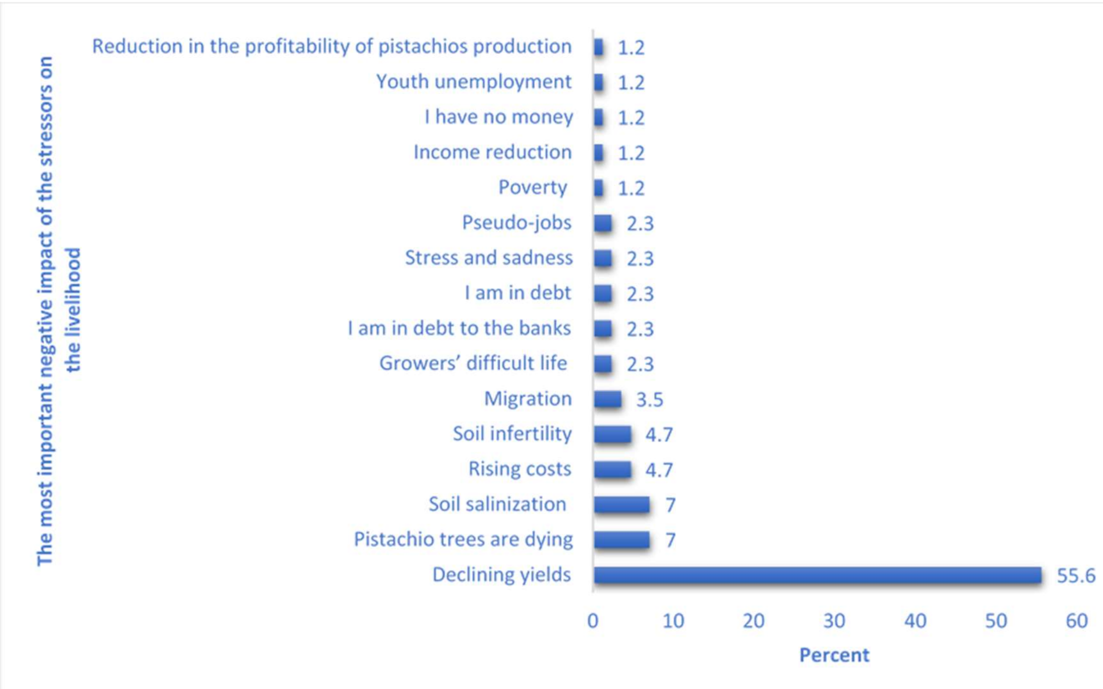

Figure 2.4. **Percentages of Rafsanjani pistachio growers’ responses to the open-ended question ‘What is the most important negative impact of the stressors on your livelihood?’**

Perceptions of The Future Resilience of The Livelihood to Groundwater Scarcity in Rafsanjan

Seventy-six percent of farmers did not believe that their pistachio production businesses would continue to function in the face of water scarcity in future. The remaining 24% were not sure about this (they responded ‘I do not know’). This is in contrast to what was found about Australian rural landholders (Mendham & Curtis, 2014). Mendham and Curtis (2014) reported that although most respondents were

[17] - In Iran, jobs, including selling cigars along the street and fortunetelling that most often do not conform to the social norms, and do not usually provide the individual with adequate financial means are called ‘pseudo-jobs’.

concerned about the negative impacts of aquifer exploitation, they believed, at the same time, the impacts would be avoidable, partly due to farmers' experience of a small decline (1 meter) in the water table, which is completely different from farmers' experience in Rafsanjan, where they have been observing a 20-meter decline in the groundwater table in a 40-year timespan (Torabi, 2013).

Subjective Norms About Groundwater Conservation in Rafsanjan

Subjective norm pertains to an individual's perception of social pressure he/she receives from significant others to adopt (or not to adopt) a behavior (Chang et al., 2016). Ajzen and Fishbein's subjective norm construct closely resembles the social norm concept (Mackie et al., 2012). A typical groundwater irrigator in Rafsanjan gave a 3.9 (on a 5-point scale) to the statement 'most people who are important to me think that increasing the amount of water I pump from my well(s) is a good action' (about 81% of respondents had 'high' or 'very high' agreements with this statement and about 11% of Rafsanjani growers had 'low or 'very low agreements with this statement).

Perceptions of 'Response Options'

Barriers to Respond to Groundwater Scarcity as Perceived by Rafsanjani Pistachio Growers

There is a strong relationship between perceptions of constraints and responses (Iglesias & Garrote, 2017). Barriers to adaptation to groundwater scarcity are generally classified into three types: biophysical, economic, and social barriers (De Jalón et al., 2015). While economic and biophysical barriers concern how financial-related issues and the quantity and quality of groundwater resources hinder farmers in responding to groundwater scarcity, social barriers consist of cognitive, as well as institutional, barriers (De Jalón et al., 2015). As shown in Figure 2.5, most Rafsanjani pistachio growers cited lack of credit or information as the constraints that prevent them from responding to groundwater scarcity.

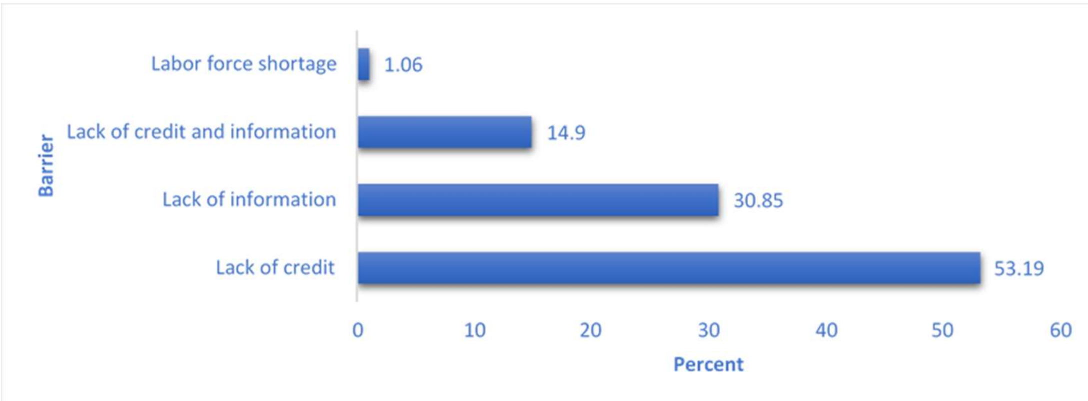

***Figure 2.5.* Percentages of Rafsanjani pistachio growers' responses to the open-ended question 'What barrier(s) has prevented you from responding to groundwater scarcity?'**

Information Sources for Responding to Groundwater Scarcity as Perceived by Rafsanjani Pistachio Growers

Previous studies have shown that access to information, especially through extension services, increases the likelihood of adapting to environmental changes by farmers (Deressa et al., 2009; Habtemariam et al., 2016). As shown in Figure 2.6, most Rafsanjani pistachio growers have relied on their personal experience or relatives as their information sources to respond to groundwater scarcity.

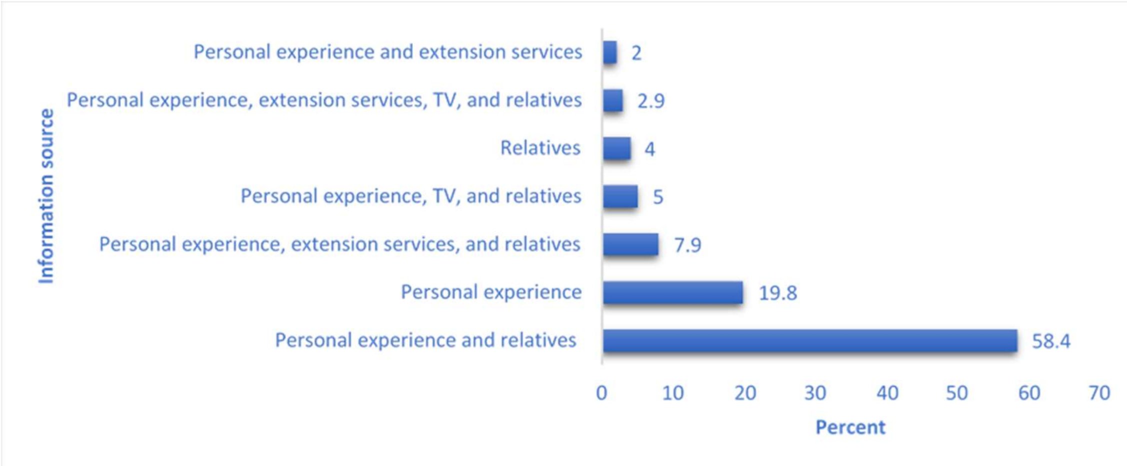

Figure 2.6. **Percentages of Rafsanjani pistachio growers' responses to the open-ended question 'What information source(s) have you used to respond to groundwater scarcity?'**

Perceptions of the Effectiveness of Responses Adopted by Rafsanjani Pistachio Growers

Farmers' perception of effectiveness of responses/solutions is a very important determinant of the actual use of responses (Iglesias & Garrote, 2017; Running et al., 2019). Table 2.2 illustrates the rankings of five responses were commonly taken by Rafsanjani pistachio growers in order to respond to groundwater scarcity (they were asked 'How do you rank the effectiveness of following five coping strategies for responding to groundwater scarcity?').

Table 2.2.

Rafsanjani pistachio growers' rankings of the effectiveness of five strategies for responding to groundwater scarcity.

Responses \ Ranking	1	2	3	4	5	Total rank
Earning revenue outside the Plain	3 (2.97)	0 (0.00)	3 (2.97)	11(10.89)	84(83)	130
Earning non-agricultural revenue inside of the Plain	0(0.00)	3(2.97)	0(0.00)	45(44.55)	53(52)	155
Reducing pistachio planting area	3(2.97)	3(2.97)	27(26.73)	32(31.68)	36(35)	208
Increasing groundwater extraction	59(58.42)	31(30.69)	0(0.00)	0(0.00)	11(10)	430
Improving irrigation water efficiency (i.e. improving water transport's efficiency in canals and/or the field application efficiency)	31(30.69)	62(61.39)	8(7.92)	0(0.00)	0(0.00)	427

Note. 1 is the most effective and 5 is the least one for responding to groundwater scarcity. In addition, numbers and numbers given in parentheses show growers' frequencies and percentages for each strategy, respectively (e.g., about 31%, 61%, and 7% of the growers considered "Improving irrigation water efficiency" as their first, second, and the third most effective strategy). The numbers given in 'Total rank' column were calculated based on the percentages given in this table. The larger the number the more effective response growers thought it was in order to respond to groundwater scarcity.

As illustrated in Table 2.2, respondents believed that the 'increasing groundwater extraction' and 'improving irrigation water efficiency' (e.g., by deepening wells) were the most effective strategies in order to cope with groundwater scarcity, among the five strategies. It should be mentioned that the 'improving irrigation water efficiency' strategy does not necessarily result in the groundwater conservation in Rafsanjan (and in many other regions in the world; Grafton et al., 2018). In fact, according to a study conducted by Abdollahi (2008), Rafsanjani pistachio growers were using the water saved through using pressurized irrigation systems (e.g., drip irrigation) to reduce the irrigation intervals, expand the area under irrigation, and/or create new orchards. On the other hand, Rafsanjani pistachio growers thought that strategies involving income diversification ('Earning revenue outside the Plain' and 'Earning non-agricultural revenue inside of the Plain') were the least effective strategies for coping with groundwater scarcity (Table 2.2). Rafsanjani growers' choice of and preference for groundwater overdraft-related responses over those strategies that involve groundwater conservation and income diversification raise serious questions about the long-term sustainability of the groundwater resources and pistachio production in the region.

Table 2.3 gives pistachio growers' views on the solutions to overcome the groundwater resources' problem in Rafsanjan. As shown, about 37% of farmers either did not have any ideas about how to solve the groundwater problem (25%), or they thought that farmers alone are not able to do anything about the groundwater scarcity problem (e.g., '*It is too late. There is no remedy for this anymore*'; '*Nothing can be done about it.'*; *It is the government's responsibility to do something about this problem;* 12%); the remaining farmers (63%) believed that the problem could be solved through implementing demand-reduction measures (e.g., improving irrigation water efficiency). Furthermore, no one among pistachio growers mentioned anything about using economic instruments (e.g., tax, and energy pricing) to conserve the groundwater resources in Rafsanjan (see Table 2.3).

Table 2.3.

Rafsanjani pistachio growers' responses to the open-ended question "What is the solution to the groundwater resources' problem in Rafsanjan?".

Response	Percentage of pistachio growers
I do not know	25
Improving irrigation water efficiency	23.5
Pistachio growers' education	8.8
Cooperation in controlling wells' water overdraft	5.8
Modern irrigation technologies if the government provides us with loans	4.4
It is too late. There is no remedy for this anymore	4.4
It is the government's responsibility to do something about this problem.	4.4
Loans	2.9
Reducing water consumption	2.9
Sealing of the illegal wells	2.9
Sealing of the illegal wells owned by the rich who used bribery to dig them	2.9
Earning non-agricultural revenue inside of the Plain	1.4
Soil desalinization	1.4
Only God can help us	1.4
Groundwater abstraction's regulation through water quotas	1.4
Restoration of the qanats	1.4
Watershed management programs	1.4
Nothing can be done about it. The only solution is to get lots of rain	1.4
Buying water from other pistachio growers	1.4

A comparison of results given in Table 2.2 with those in Table 2.3 shows that while the most effective responses for dealing with groundwater scarcity, based on Rafsanjani pistachio growers' views (given in Table 2.2), result in an increase in the groundwater extraction in Rafsanjan, pistachio growers' proposed-solutions for the groundwater resources' problem (given in Table 2.3) generally lead to a decrease in the groundwater extraction. In other words, when pistachio growers were asked about the effectiveness of the five strategies, they evaluated the effectiveness based on the values of each strategy to the (short-term) production of pistachios (see Table 2.2). However, only if they were explicitly asked about the conservation of groundwater resources, did they suggest demand-reduction solutions. In addition, in both cases (Tables 2.2 and 2.3), respondents generally saw strategies involving income diversification as their least favorable/effective solutions.

SUMMARY AND CONCLUSIONS

Misperceptions, misinformation, and/or lack of knowledge regarding the groundwater-based livelihood system can constrain farmers' adaptation to groundwater scarcity (Eakin et al., 2016; Rodriguez et al., 2017). In this study, I explored how pistachio growers in Rafsanjan Plain, Iran perceive their groundwater-dependent livelihood systems, the stressors that threaten their livelihoods, and their responses to those stressors. In addition, I reported some differences between pistachio growers' perceptions/knowledge of the groundwater system and those of scientists. The results of this study have implications for achieving the Sustainable Development Goals on conserving groundwater resources as well as sustaining rural livelihoods and eradicating poverty. Farmers' priorities (groundwater resource conservation vs. farmer wellbeing), perceptions, and knowledge of the groundwater system are instrumental to both groundwater protection and farmer wellbeing (Sanderson & Curtis, 2016).

I found that the majority of pistachio growers' perceptions and subjective norms on the groundwater system in Rafsanjan disfavor groundwater conservation for future use (and favor short-term profit maximizing from pistachio cultivation). For instance, most pistachio growers generally thought that the ‘increasing groundwater extraction’ strategy and strategies involving income diversification were the most and least effective livelihood strategies, respectively. In addition, it appears that pistachio growers did not consider the factors (groundwater overdraft as a result of illegal wells, heavy subsidies for water and energy, etc.) that have contributed to the unsustainability of groundwater use in Rafsanjan as stressors or threats to their livelihoods. Clearly, these findings call for educational interventions on changing farmers’ perceptions and norms about the sustainability of their groundwater-based livelihood system in Rafsanjan. In addition, the adoption of pro-conservation social norms by a certain fraction of a society (e.g., those with social influence) may facilitate the respected behaviors to get diffused to the whole society (Kinzig et al., 2013).

Income diversification is the key to building resilient groundwater-dependent livelihood systems as one of the Sustainable Development Goals (SDG1 “build the resilience of the poor and those in vulnerable situations to climate-related extreme events and other economic, social and environmental shocks and disasters”). In this study, I found that strategies involving income diversification were the least effective livelihood strategies in pistachio growers’ views. This can be problematic because of the dependence of pistachio growers’ livelihoods on depleting groundwater resources in Rafsanjan. This suggests that groundwater conservation and livelihood adaptation policies should change pistachio growers’ attitudes of income diversification strategies as a first step toward diversifying pistachio growers’ livelihood portfolios by an attitude change intervention (e.g., persuasion) (Hashemi et al., 2020b).

This study found that Rafsanjani farmers hold heterogenous perceptions regarding their groundwater system (e.g., stressors, responses) because of their different socio-economic backgrounds and experiences. For instance, I found that older pistachio growers or pistachio growers with access to extension services were more likely to assess the state of the groundwater resources in Rafsanjan more positively. Therefore, this heterogeneity should be acknowledged as a basis for developing targeted policies that aim at groundwater resources conservation and building the resilience of pistachio growers' livelihoods.

Finally, this chapter documented several subjects ranging from the hydrology of groundwater resources in Rafsanjan to the relationship between groundwater quantity (and quality) and pistachio yields where pistachio growers in Rafsanjan and scientists possessed different knowledge systems. These knowledge differences between pistachio growers and scientists point to where the two knowledge systems need to be integrated. While these two knowledge systems can be integrated more smoothly for 'visible' concepts (e.g., determinants of pistachio yields), this integration may face some barriers for less 'visible' concepts (e.g., the proportion of the irrigation returning to the aquifer) given that both sides (pistachio growers and scientists) usually have confidence in their own knowledge systems. In order to build trust between the two knowledge systems, participatory communication and research involving both scientists and pistachio farmers in Rafsanjan should be conducted (Wilkins, 2001 cited in Valdivia et al., 2010). The first step for bridging the gap between different perceptions seems to be developing attitudes and norms that value collaboration with and learning from other stakeholders;

organizations, such as Iran Water Prudence Research Institute, with the mission of connecting different water stakeholders can be used for facilitating this process.

ACKNOWLEDGMENTS

Part of the questionnaire used in this study was developed in collaboration with Mohammad Reza Farzaneh and Ali Bagheri; they, along with the Iran Water Policy Research Institute, were also very helpful with the data collection.

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CHAPTER 3

EXPLORING FARMERS' PERCEPTIONS ABOUT THEIR DEPLETING GROUNDWATER RESOURCES: IMPLICATIONS FOR GROUNDWATER OVERDRAFT AND INCOME DIVERSIFICATION[18]

ABSTRACT

Iran is among the world's top five groundwater exploiters and, similar to many countries in the world, aquifers in Iran have been rapidly depleted over the past decades primarily as a result of groundwater use by farmers. This research was conducted to explore whether the perceptions of pistachio growers in Rafsanjan Plain, Iran (a global center for pistachio production), on the depleting groundwater resources have led to the conservation of the resources and/or income diversification. In addition, the association between these perceptions and factors representing knowledge of growers was examined. To this end, two path models were developed and tested using path analysis and logistic regression. The results indicate that growers who had more pessimistic perceptions of the groundwater resources in Rafsanjan were more likely to increase groundwater extraction; however, these growers were also more likely to seek external employment (income diversification). The final path models suggest attitudes toward groundwater conservation were the most important determinants of pumping behavior, while perceptions of the state of the groundwater were the most important determinants of income diversification.

[18] - A version of this chapter has appeared as Hashemi, S. M., Kinzig, A., Abbott, J. K., Eakin, H., & Sedaghat, R. (2020). Exploring farmers' perceptions about their depleting groundwater resources using path analysis: implications for groundwater overdraft and income diversification. *Hydrogeology Journal*, *28*(6), 1975-1991.

Whether Iranian policies to increase awareness of falling water tables could succeed in securing water conservation would depend on the 'balance' of these two forces—an increase in pumping with increased pessimism or a potential decrease in pumping through income diversification. The chapter concludes with a discussion on the implications of the results for interventions aimed at changing not only the groundwater users' decisions about groundwater use, but also their decisions about income diversification.

INTRODUCTION

To cope with the water-scarcity-related problems, many farmers in Iran reliant on groundwater have intensified their exploitation of the remaining groundwater resources, which are already fast depleting. As water tables fall and wells dry, farmers respond with digging even deeper wells and installing more powerful pumps (Madani et al., 2016). Deep wells (with an average depth of 90 m) are used in Iran in over 70% of all groundwater extractions (Karimi et al., 2012). For instance, Rafsanjan Plain, Iran, the study area of this chapter, was declared as a prohibited area for digging new wells in 1974 by the government, at which point there were 585 wells. However, this could not stop an increase in the number of wells being dug in Rafsanjan. In fact, due to several conditions, including subsequent changes/repeals in the law that prohibited drilling new wells in Rafsanjan (and in Iran as a whole) as well as the lack of law enforcement, farmers in Rafsanjan have continued to drill new wells since 1974 (the number of wells reached 1,445 in 2014) (Jamali Jaghdani, 2011; Mirnezami et al., 2018; Nabavi, 2018; Zeraatkar & Golkar, 2016). To respond to groundwater scarcity, in addition to increasing groundwater extraction (e.g., by deepening wells), in recent years, some Rafsanjani pistachio growers have diversified their livelihoods (as will be discussed later in this chapter). Factors that influence how farmers make decisions about their exploitation of groundwater resources and livelihood diversification should inform policies for changing farmers' unsustainable behavior toward groundwater resources (Elsawah et al., 2015; Sanderson et al., 2017).

The attributes of common-pool resources (along with resource users and governance systems) affect overuse or destruction of resources and therefore sustainability of social-ecological systems (Ostrom 2007; 2009). Common-pool resources are natural or man-made resources that are described by high exclusion costs and high subtractability (Anderson et al., 2002; Gardner et al., 1990). According to Osés-Eraso and Viladrich-Grau (2007) and Nhim et al. (2019), there is mixed evidence in the scholarly literature as to whether or not common-pool resource scarcity leads to the conservation of the resource. While some research has found that scarcity can lead to conservation of the common-pool resource, other researchers have shown that it may result in overdraft (or overuse) of the resource (Long & Pijanowski, 2017).

A common assumption in the environmental psychology literature is that individuals are more likely to adopt a behavior consistent with environmental conservation if they perceive a poor condition for the state of the resource (Bluemling et al., 2010; O'Connor et al., 1999). When a common-pool resource (e.g., groundwater resources) becomes scarce, people tend to take a conservative approach toward the use of the resource (Li & Hao, 2020; Rutte et al., 1987; Samuelson et al., 1984; Zaikin et al., 2018). In addition, a resource crisis (e.g., groundwater scarcity) can lead resource users to cooperate with each other and therefore increase the sustainability of resource use (Arnold, 1998; Cuadrado-Quesada, 2014; Wolf, 1999). For instance, groundwater overuse and salinity (along with community leadership and government involvement) in Angas Bremer, in Australia, lead to the participation of community to address the problems. Farmers in Angas Bremer also voluntarily adopted measures to reduce groundwater use, including replacing their crops with more water-efficient ones (Cuadrado-Quesada, 2014). As another example, using an experimental approach, Osés-Eraso and Viladrich-Grau (2007) showed that those subjects who were concerned about resource scarcity were more likely to reduce their appropriation levels. Osés-Eraso and Viladrich-Grau (2007) further concluded that concern for resource scarcity among the resource users can also protect resources against the "tragedy of the commons" (Hardin, 1968).

On the other hand, some other bodies of literature advocate the idea that (perceived) scarcity leads to the resource overuse. The conservation psychology suggests that when people hold pessimistic views of the state of the environment, they are less likely to participate in conserving it (McAfee et al., 2019). According to traditional economic theory (the profit maximization), common-pool resources are vulnerable to overexploitation and ultimately the tragedy of the commons because rational behaviors of individual resource users result in an irrational outcome from the community/resource conservation standpoint (Budescu et al., 1995; Osés-Eraso & Viladrich-Grau, 2007). This perspective suggests that under resource scarcity, the users of a common-pool resource extract the resource more, and resource scarcity worsens the tragedy of the commons (Blanco et al., 2015; Cerutti & Schlüter, 2019; Grossman & Mendoza, 2003; Maldonado et al., 2009; Nhim et al., 2019). For instance, Nhim et al. (2019) showed that resource scarcity may hinder cooperation among resource users and erode social norms managing resource exploitation (norms that punish non-cooperative behavior and restrain individual resource use) especially when the resource users deal with inequality and heterogeneity. Moreover, given uncertainty about the future, scarcity may cause resource users to act egoistically (selfishly) and shortsightedly with respect to the resource, because the uncertainty fosters attitudes that favor short-term benefits (Varghese et al., 2013). Jager et al. (2002) and Gustafsson et al. (2009) showed that participants overharvested the resource when resource uncertainty increased. In addition, by using a field study conducted in India, Varghese et al. (2013) revealed that resource scarcity intensifies competitive appropriation behavior. Uncertainty can also justify a non-cooperative behavior (Van Lange et al., 2013). This particularly applies to groundwater users who may be uncertain about the amount of groundwater that will be available for pumping in the future for the following reasons: the groundwater resource is largely invisible and heterogeneous (Molle & Closas, 2019), and there is often a lack of scientific data on water availability within aquifer systems (Moench, 2007); the groundwater resource can be a renewable resource (which means there is uncertainty also about the amount of future recharge rates); and it is shared with many users whose pumping behaviors may be unpredictable. In addition to uncertainty about the future water availability, groundwater users may be faced with uncertainty about the economy, as is the case for farmers in Iran, where there has been economic insecurity and high inflation rates over the past decades.

In the light of the above literature, of particular interest in this research was an examination of whether or not groundwater users' perceptions of their depleting groundwater resources lead to the conservation of the resource and/or income diversification. Previous research has mainly focused on farmers' perception of groundwater exploitation and income diversification strategies as a determinant of the uptake of these strategies (e.g., Yazdanpanah et al., 2014). However, to the best of the authors' knowledge, only a few studies, if any, have concentrated on exploring the impact of perceptions of the state of (depleting) groundwater resources on farmers' use of groundwater exploitation and income diversification strategies in response to groundwater scarcity using behavioral research. While many studies have explained farmers' adaptation to surface water scarcity using behavioral research, few have done so in relation to groundwater use (Mitchell et al., 2012; Sanderson & Curtis, 2016). Compared to most scholarly literature that has focused on the relationship between 'external' factors (policies, institutions, and markets) and agricultural groundwater use, little is known about the link between farmers' well-drilling (or well deepening, in the face of declining water tables) behaviors and their perceptions about depleting groundwater resources (Suhardiman et al., 2018; Watto et al., 2018). This might be in part due to the fact that groundwater exploitation at the level that is occurring today in the world has a relatively recent origin (Mukherji & Shah, 2005).

There are five policy options that are commonly used to control groundwater abstraction (Jakeman et al., 2016): (1) command and control (e.g., direct control); (2) economic instruments (e.g., water and energy pricing); (3) self-governance (e.g., cooperation between groundwater users); (4) information and persuasion instruments (e.g., changing groundwater users' knowledge, attitudes and/or motivations through providing users with information on the state of groundwater resources); and (5) infrastructure instruments (e.g., water saving technologies such as drip irrigation). This study attempts to briefly discuss the implications of the results for the effectiveness of some of the policies mentioned above (groundwater regulation and drip irrigation). In addition, particular attention is given to the discussion of what the results of this study mean for the effectiveness of awareness/information raising programs (e.g., on the current state of aquifer and future climate trends) on the use of groundwater exploitation and income diversification strategies among farmers. The effectiveness of educational programs for the conservation of common-pool resources during resource scarcity has been mixed, according to the previous research (Van Vugt & Samuelson, 1999).

In this chapter, it is explored how a strategy of "increasing groundwater extraction" (e.g., by deepening wells) by Rafsanjani farmers is affected by groundwater resource-related perceptions, including perceptions of: (1) the state of the groundwater resources; (2) the cause of changes in precipitation and temperature in Rafsanjan; and (3) the future resilience of livelihoods to water scarcity. In addition, it is also considered how the farmers' strategy of "increasing groundwater extraction" relates to attitudes toward groundwater conservation. The effects of the farmers' education and experience on their perceptions of the groundwater resource is examined. Although the focus of this chapter is on the Rafsanjani farmers' groundwater overdraft strategy ("increasing groundwater extraction"), the link between the same above-mentioned variables and Rafsanjani farmers' income diversification strategy ("earning revenue outside the Rafsanjan Plain") is also briefly explored. Analyzing the determinants of the Rafsanjani pistachio growers' income diversification strategy is also important, given that they are entirely dependent on a rapidly depleting aquifer, and many already seek greater security by working outside of pistachio farming (Hashemi et al., 2020a). Lastly, the relationship between the adoption of strategies “increasing groundwater extraction” and “earning revenue outside the Rafsanjan Plain” is examined.

METHODS

Study Area

Rafsanjan Plain (Figure 3.1) is in Kerman Province, in the southeast of Iran. It is the center of pistachio cultivation in the world (Hassanshahi & Sarkargar Ardakani, 2019). In Rafsanjan, agriculture is the most important economic activity and 97% of the total growing area is allocated to pistachio cultivation (Mirzaei Khallilabadi & Chizari, 2004; Karamouz et al., 2011). Groundwater resources provide almost all the water (99 %) needed for irrigation, drinking water, and industry purposes in the Rafsanjan Plain (Karamouz et al., 2011). Agriculture, domestic, and industry sectors use 96.4%, 3.5%, and 0.1% of the groundwater resources, respectively (Jamab, 2011 cited in Mehryar et al., 2015).

Figure 3.1. **The location of the study area: Rafsanjan Plain in Kerman Province, in southeastern Iran (adapted from Mirshekar et al., 2020).**

In Rafsanjan, pistachio growers operate their water pumps almost throughout the entire year; the only times that water pumps are not in use are when there is a power outage in the region or when it rains (Jamali Jaghdani & Brümmer, 2016). The Rafsanjan Plain is generally considered as one of the most critical plains in Iran in terms of the magnitude of groundwater depletion (Ghazavi & Ramazani, 2017). In 2017, the Iranian Ministry of Energy declared the Rafsanjan Plain as the most critical plain in the country (IRNA, 2017). The Rafsanjan Plain is currently dealing with four types of drought—

meteorological (precipitation deficit), hydrological (surface and subsurface water resources deficit), agricultural (soil moisture shortages), and socio-economic droughts (water demand exceeds that of water supply) (Mishra & Singh, 2010). It is projected that groundwater recharge will decline in Rafsanjan due to climate change (Abbaspour et al., 2009). The increasing number of pumped wells in the Plain has led to the depletion of the Rafsanjan aquifer (Mehryar et al., 2015). In this region, it is estimated that around 500 million cubic meters/year could be sustainably extracted (extraction = recharge). In 2015, water extraction was above 737 million cubic meters/year (Parsapour-Moghaddam et al., 2015). As a result, the water table has declined on average 80 cm/year, salinity of agricultural water has increased, land subsidence up to 30 cm/year has occurred, and the profitability of pistachio production has declined (Parsapour-Moghaddam et al., 2015; Sedaghat, 2002). In recent years, Water Department officials in Rafsanjan have attempted to strengthen groundwater regulation in Rafsanjan. They have tried to enforce two regulatory plans in Rafsanjan: (1) turning off agricultural wells in the Rafsanjan Plain in fall seasons when pistachio growers do not normally need irrigation and (2) sealing of illegal wells. However, both plans for conserving groundwater resources have failed primarily due to a lack of participation of farmers, especially those owning large orchards.

To cope with groundwater scarcity, some pistachio growers in Rafsanjan have diversified their income sources by buying water and land outside of the Rafsanjan Plain to cultivate pistachios. Other potentially attractive occupations to Rafsanjani pistachio growers are greenhouse farming, calf farming, fish farming, production and distribution of livestock feeds, and building and managing gas stations and small supermarkets with the rates of return of 22.54%, 19%, 17.5%, 15.8%, and 9%, respectively (Sedaghat, 2019 cited in Hashemi et al., 2020a). Also, in Rafsanjan cultivation of low-water crops (e.g., saffron, barberry, jujube, medicinal plants and borage) have been expanding. For example, currently, 2 hectares of barberry, more than 30 hectares of saffron, and 5 hectares of borage have been planted in Rafsanjan (IRNA, 2019). In addition, some Rafsanjani farmers (in Rafsanjan County, out of about 65,000 hectares of pistachio cultivation area, about 12,000 hectares) have switched from the flood irrigation method, which has the irrigation efficiency of 40 to 45%, to the pressurized irrigation system (e.g., drip irrigation), which has an irrigation efficiency of 85% (ISNA, 2019).

Path Model

Figure 3.2 illustrates a path diagram of the research that was tested; the diagram does not include all the possible paths between the variables. The selection of paths was based on the authors of this chapter's knowledge of the study area, the scholarly literature (as discussed here and above), and this study's main purpose (the impact of perceptions about groundwater resources on the uptakes of groundwater overdraft and income diversification strategies). In particular, in this study, it is assumed that each of the Rafsanjani farmers' strategies of groundwater extraction and involvement in earning revenue outside the Rafsanjan Plain is directly and indirectly affected by four variables: (1) perceptions of the state of the groundwater resources in Rafsanjan (STA); (2) perceptions of the cause of changes in precipitation and temperature in Rafsanjan (CAU); (3) perceptions of the future resilience of the livelihood to water scarcity (RES); and (4) attitudes toward groundwater conservation (ATT) (Figure 3.2). It is hypothesized that education and farming experience may influence each of these four variables (Figure 3.2). Various other influences were hypothesized as well (e.g., that CAU influence STA). Table 3.1 describes the measurement of variables in this study.

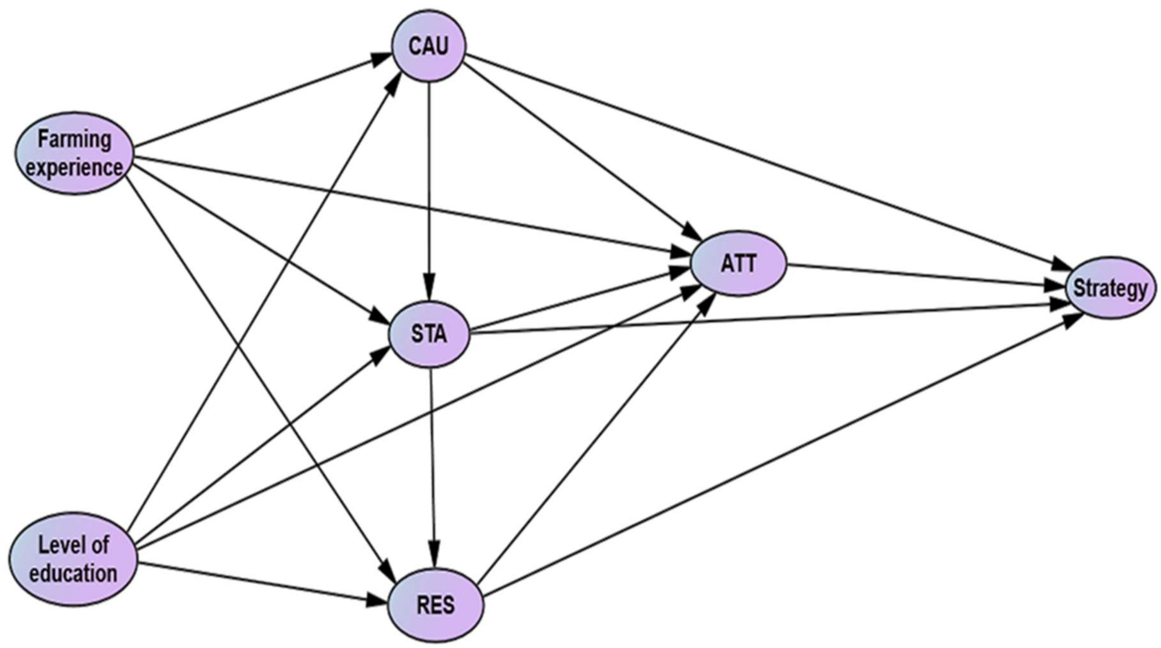

Figure 3.2. **Hypothesized path model of the relations among variables that affect Rafsanjani farmers' uptakes of two (separate) strategies of "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain" (Strategy).** Note. CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources in Rafsanjan; ATT = attitude toward groundwater conservation; and RES = perceptions of the future resilience of the livelihood to water scarcity. See Table 3.1 for details on the measurement of variables.

Table 3.1.

Description of how variables that are represented in the path model, depicted in Figure 3.2, were measured in this study. SD= standard deviation

Variable	Variable measurement	Source/descriptive statistics
Perceptions of the cause of changes in precipitation and temperature in Rafsanjan	Nominal variable. Value 0 if the farmer has not blamed changes in precipitation and temperature in Rafsanjan on anthropogenic causes. Value 1 otherwise.	62.9% Value 0 37.1% Value 1
Perceptions of the state of the groundwater resources in Rafsanjan	Nominal variable. Value 0 if the farmer has described the groundwater resources in Rafsanjan as bad. Value 1 otherwise.	76.5% Value 0 23.5% Value 1
Perceptions of the future resilience of the livelihood to water scarcity	Nominal variable. Value 0 if the farmer was pessimistic about the future of their pistachio production businesses in the face of water scarcity. Value 1 otherwise.	76% Value 0 24% Value 1
Attitude toward groundwater conservation	Nominal variable. Value 0 if the farmer believed that the production of pistachios is more important than the conservation of the groundwater resources. Value 1 otherwise.	Yazdanpanah et al. 2014; Farzaneh 2016. 79.2% Value 0 20.8% Value 1
Strategy ("increasing groundwater extraction")	Nominal variable. Value 0 if the farmer has not increased the groundwater extraction of his/her wells. Value 1 otherwise.	Farzaneh 2016
Strategy ("earning revenue outside the Rafsanjan Plain")	Nominal variable. Value 0 if the farmer has not been involved in earning revenue outside the Rafsanjan Plain. Value 1 otherwise.	Farzaneh 2016
Level of education	Ratio variable. In years.	Mean = 7.77; SD = 4.81
Farming experience	Ratio variable. In years.	Mean = 31.60; SD = 11.97

According to Sanderson et al. (2017), to explain farmers' support for environmental policies, previous research has built on the insights from economics (e.g., utility theory) and psychology (e.g., theory of planned behavior and values-beliefs-norms theory) and has found context specific results. The path model (Figure 3.2) developed in this study is partly based on the Values–Beliefs–Norms (VBN) theory (Stern et al. 1993). The VBN links beliefs, attitudes, and norms to environmental behaviors (Stern et al. 1993). Consistent with the VBN, in the path model depicted in Figure 3.2 there is a causal chain between CAU ("Beliefs"), STA and RES ("Risk Perceptions"), ATT ("Norms"), and Strategy ("Behaviors") (Sanderson & Curtis, 2016).

STA, CAU, and RES were selected as the variables to represent perceptions of the groundwater resources in this study (Figure 3.2 and Table 3.1). As thoroughly discussed above, there is a mix of literature regarding the relationship between the perceived state of groundwater resources and groundwater conservation. It was hypothesized that depending on CAU (i.e., blaming changes in precipitation and temperature on anthropogenic or non-anthropogenic causes), farmers may differently perceive the state of the groundwater resources (Figure 3.2 and Table 3.1). In addition, the behavioral research has shown that CAU can influence farmers' adaptive capacities to groundwater scarcity; when farmers attribute the cause of changes in precipitation and temperature to the non-anthropogenic factors, they are less likely to limit their groundwater use (Eakin et al., 2016; Grothmann & Patt, 2005; Le Dang et al., 2014; Sanderson et al., 2018). More specifically, previous research has found either a positive or an insignificant relationship between farmers' climate change belief and adaptation (Sanderson & Curtis 2016,). For example, in a study that explored farm-level groundwater management in Australia by using the VBN theory (Sanderson & Curtis, 2016), climate change belief was found to be a significant positive determinant of risk perceptions. However, the study of Below et al. (2012) on farmers in Tanzania found no significant correlation between farmers' perceptions of weather-related problems and adaptation. Lastly, Park et al. (2012; cited in Hashemi et al., 2020b) found that Australian farmers who thought that human activities have not been contributing to climate change tended to consider only minor changes to adapt to future climatic changes (see Sanderson et al. (2018) for more information on the values that influence climate change beliefs).

As shown in Figure 3.2 (and Table 3.1), in addition to STA, CAU, and RES, this study's path model includes one more variable of ATT. The hypothesis was that STA, CAU, and RES influence the likelihood of increasing groundwater extraction and earning revenue outside the Rafsanjan Plain strategies by pistachio growers in Rafsanjan (Strategy) via ATT. Under conditions of high uncertainty, "social value orientations" — an individual's value with respect to allocation of outputs to himself/herself compared to others (i.e., "prosocials" and "proselfs") —mediate decisions about the exploitation of the resource (Roch & Samuelson, 1997; Van Dijk & De Cremer, 2006). Social value orientations (ATT) are critical to understanding behavior in a "social dilemma" between the short-term benefits of a groundwater user (pistachio production) and the long-term collective interest of the groundwater user community (groundwater conservation) (Van Lange et al., 2013). Social dilemmas particularly become more pronounced during resource scarcity as uncontrolled harvest of the common-pool resource by some users can have serious costs for all users (Van Vugt & Samuelson, 1999). In other words, wherever the tragedy of the commons (as a type of social dilemma) occurs and resources become increasingly scarcer, there is a dire need for conservation of the resource. However, at the same time users are increasingly motivated to use the resource even more (Dirks, 2019). It was also hypothesized that STA exert influence on Strategy through RES, meaning farmers who perceive a poor condition for the state of the groundwater resources in Rafsanjan are more likely to be more pessimistic about the future of their pistachio production businesses in the face of water scarcity, which in turn could encourage (or discourage) them to engage in two strategies of "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain". The RES variable predicts whether or not farmers invest in conservation measures.

Since this study's main interest was to understand the effects of perceptions and knowledge on the uptakes of Strategy, the background variables (level of education and farming experience) were selected to represent knowledge of farmers (Figure 3.2). There are conflicts in the literature on the relationships between level of education and environmental behaviors and perceptions of risk. While some studies have found that highly educated individuals tend to search for more pro-environmental alternatives, others have underscored that level of formal education is not a determinant of more sustainable practices (Bluemling et al., 2010). In addition, the previous research has shown that knowledge and information may enhance or decrease perceptions of risk, and they are crucial for correct attributions of blame (O'Connor et al., 1999). Also, the literature suggests that farming experience particularly influences perceptions of the state of the groundwater resources (Ishaya & Abaje, 2008).

Lastly, this study examined the relationship between the adoption of strategies "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain";

while some studies found that there is a negative relationship between off-farm employment and water use (e.g., Wachong Castro et al., 2010), other studies suggest that off-farm employment does not lead to water savings (e.g., Yin et al., 2018).

Data Collection Methods

To collect data on the variables represented in the study's path model (Figure 3.2), a questionnaire was used. Table 3.1 provides a summary of the questionnaire used in this chapter and it also contains a descriptive statistics of the variables measured by the questionnaire. The items/questionnaire that are drawn upon in this chapter cover one section of a bigger questionnaire/research project that aimed at examining factors that predict the intention to and use of seven strategies (e.g., increasing groundwater extraction, reducing pistachio planting area, earning revenue outside the Rafsanjan Plain) to adapt to groundwater scarcity among pistachio growers in Rafsanjan (more details on the other sections of the questionnaire are given in Hashemi et al., 2020a,b). Prior to administering the questionnaire, a brief overview of the research's purpose was communicated to each farmer. Before administering the survey, the questionnaire was initially checked for the face and content validity and revised accordingly.

One hundred and ten pistachio growers (households) from the Rafsanjan Plain were selected using a random sampling method. The cross-sectional household survey of farmers covered three major areas of the pistachio production in the Rafsanjan Plain, namely Rafsanjan, Noogh, and Anar. Both large and small pistachio growers were included in this study with a 30 to 70% ratio, consistent with the actual ratio in the Rafsanjan Plain (Sedaghat, 2002; Abdollahi, 2008). To further ensure that this chapter's sample is representative of the population, socio-economic variables of respondents (e.g., hectare in pistachios, years of education, farming experience) were checked against prior research in Rafsanjan (e.g., Jafari Mahdi Abad et al., 2016; Jamali Jaghdani, 2011; Javanshah et al., 2003). All the variables' averages were confirmed by at least two or three previous studies except for "hectare in pistachios", which was confirmed by one study. The pistachio growers' inclusion in the study was based on their willingness to participate in the study. If a farmer was not willing to participate in the study, another farmer was selected. Farmers were informed about the survey which was solely conducted for research purposes, and their answers were anonymous. Respondents did not get paid for participating in the research. Based on the Cochran formula and sample size used in the previous research in Rafsanjan (e.g., Jafari Mahdi Abad et al., 2013; Sedaghat, 2002), the sample size of this research was estimated. Two people from Kerman Province who were familiar with Rafsanjan and with a background in agricultural extension education were recruited to administer the survey. Data were collected through interviews with each one of the pistachio growers using questionnaires in 2015. The survey was in Persian, and the data in this chapter represent translations.

Data Analysis

Of 110 completed questionnaires, 101 questionnaires comprised the analytic sample after checking the responses for accuracy and completeness. Phi and point-biserial correlation coefficients were used to measure the relationships among the variables in this research. Phi is used to calculate the relationship between two dichotomous variables (Sun et al., 2007). In this study, Phi was used to explore the relationships among variables of CAU, STA, ATT, RES, "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain" strategies. Phi was also used to explore the relationship between the adoptions of "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain" strategies. The point-biserial correlation coefficient is used to measure the relationship between a dichotomous variable and an interval (or ratio) variable (Corder & Foreman, 2011). In this study, the point-biserial correlation coefficient was used to explore the relationships between each of the variables of CAU, STA, ATT, and RES and variables of level of education and farming experience.

To explore factors affecting Rafsanjani farmers' increasing groundwater extraction and earning revenue outside the Rafsanjan Plain, the theoretical relationships represented in the path model, depicted in Figure 3.2, were tested by using path analysis (Anderson et al., 1995; Hashimoto et al., 2012). Path analysis is a multivariate statistical technique, which is used to examine relationships between two or more variables (Odongo et al., 2014). It can provide insights into the magnitude, significance, and direction of relationships between variables (Hashimoto et al., 2012; Khairnar et al., 2019). Path analysis is an appropriate procedure for testing hypotheses/relationships involving only observed variables, each measured by one indicator, as it is in the current study (the variables given in the path model; Figure 3.2) (Sanderson & Hughes, 2019). Moreover, through using this technique one is able to partition the effects of one variable in the model on another into direct and indirect effects (Olobatuyi, 2006). Each direct effect in the model characterizes the direct influence of an independent variable (e.g., ATT in Figure 3.2) on a dependent variable (e.g., Strategy in Figure 3.2). Each indirect effect in the model characterizes the contribution of the independent variable (e.g., STA in Figure 3.2) to the dependent variable (e.g., Strategy in Figure 3.2) through another independent variable(s) (e.g., ATT in Figure 3.2) (Olobatuyi, 2006). In the path model, unidirectional arrows that link two variables together signify causal associations. Moreover, two-headed arrows indicate a correlational association between two variables of interest (Anderson et al., 1995).

To avoid confusion in the use of terminology in this chapter, the term *path analysis* is referred to a path analysis using (separate) serial regression equations, and it is different from structural equation modeling, which estimates model equations simultaneously (Grapentine, 2000). In other words, one way of performing path analysis is through a series of regression analyses (Alemu & Shea, 2019). Regression coefficients (beta weights), which indicate the extent to which independent variables(s) influence the dependents variable(s), are identical to path coefficients (Alemu & Shea, 2019; Anderson et al., 1995). Path analysis through a series of regression analyses has been used in a wide variety of fields including educational studies (e.g., Armijo, 2014; Hornung et al., 2017), soil and environmental studies (e.g., Hashimoto et al., 2012; Polymeros et al., 2010), and health studies (Jacobowitz, 2018; Racine et al., 2018), among others. To perform the path analysis (Sherven, 2016), first, path coefficients were computed using a series of logistic regression analyses (see below). In the next step, paths with the path coefficients that were not significant at the 0.10 level were eliminated from the path model. Lastly, to calculate the direct, indirect, and total (direct + indirect) effects in the reduced (final) path model, following King (2007), semi-standardized path coefficients (beta weights) were computed based on the mean of the predicted probability and the standard deviation of $X_1, \ldots, X_n$.

To compute the path coefficients, binary logistic regression analyses were conducted because variables in the path model (Strategy, CAU, STA, ATT, and RES), shown in Figure 3.2 and described in Table 3.1, were all measured as binary nominal variables (each one with two categories). Logistic analysis provides parameter estimates without requiring most of the assumptions of linear probability models (e.g., normal distributions of residuals) (Lieberman et al., 2002). In Eq. 3.1, P is the probability that the dependent variable Y is 1 (e.g., adoption of the "increasing groundwater extraction" strategy, adoption of the "earning revenue outside the Rafsanjan Plain" strategy); $X_1, \ldots, X_n$ are independent variables; β_0 is the intercept; and $\beta_1, \ldots, \beta_n$ are regression coefficients to be estimated.

$$\text{Logit}\,(Y) = \ln[\frac{P}{1-P}] = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n \qquad \text{(Eq. 3.1)}$$

More specifically, to specify the model, for each strategy ("increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain") six separate binary logistic regression analyses were performed to test the hypothesized path diagram, shown in Figure 3.2. Table 3.2 describes in detail the dependent and independent variables used in each of the six logistic regression models. The Nagelkerke R Square statistics was used, which ranges from 0 to 1, to estimate the amount of variance explained by the models (Prunier et al., 2015). All data were analyzed using the IBM SPSS Statistics 24, PROCESS version 3.4 (Hayes, 2018), and Microsoft Excel 2016.

Table 3.2.

Descriptions of six binary logistic regression analyses performed in this study to test the path model given in Figure 3.2. Note. CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources in Rafsanjan; ATT = attitudes toward groundwater conservation; and RES = perceptions of the future resilience of the livelihood to water scarcity.

Model	Dependent variable	Independent variables
1	"increasing groundwater extraction"	CAU, STA, RES, and ATT
2	"earning revenue outside the Rafsanjan Plain"	CAU, STA, RES, and ATT
3	ATT	CAU, STA, RES, level of education, and farming experience
4	RES	STA, level of education, and farming experience
5	STA	CAU, level of education, and farming experience
6	CAU	Level of education and farming experience

RESULTS AND DISCUSSION

Factors Affecting Rafsanjani Pistachio Growers' Decisions to Increase Groundwater Extractions from Their Existing Wells

Table 3.3 shows a summary of the correlation matrix among all variables represented in the hypothesized path model, shown in Figure 3.2, that influence the adoption of "increasing groundwater extraction" strategy by Rafsanjani farmers. Based on the correlation coefficients, in particular, no significant relationships were found between RES and the other variables in the model. This may be because farmers were very homogenous as far as the RES variable is concerned (76% of farmers did not believe that their pistachio production businesses would continue to function in the future, and the remaining 24% were not certain about this). In other words, if farmers were (more) heterogeneous with respect to this variable, it may have had significant impact(s) on the other variables. In addition, as shown in Table 3.3, there was found a negative relationship between adoptions of "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain" strategies by pistachio growers. That is, farmers involved in the "increasing groundwater extraction" strategy were less likely to be involved in "earning revenue outside the Rafsanjan Plain" strategy and vice versa.

Table 3.3.

Phi/point-biserial correlation coefficients among the variables in the path model (Figure 3.2). Note. CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources in Rafsanjan; ATT = attitudes toward groundwater conservation; and RES = perceptions of the future resilience of the livelihood to water scarcity.

Variable	CAU	STA	ATT	RES	Earning revenue outside the Rafsanjan Plain
CAU	-	-	-	-	-
STA	0.19*	-	-	-	-
ATT	0.08	0.19*	-	-	-
RES	0.03	0.09	0.05	-	-
Level of education	0.50***	0.12	0.3***	.04	-
Farming experience	0.10	0.19*	0.03	0.02	-
Increasing groundwater extraction	-0.16	-0.09	-0.22**	-0.09	-0.17*

* Significant at $p < 0.10$; **Significant at $p < 0.05$; *** Significant at $p < 0.01$

Of the paths/path coefficients depicted in the path model (Figure 3.2 shows the paths), as illustrated in Figure 3.3, six paths/path coefficients were significant: the paths from (1) ATT to Strategy; (2) Level of education to ATT; (3) STA to ATT; (4) CAU to STA; (5) Level of education to CAU; and (6) Farming experience to STA.

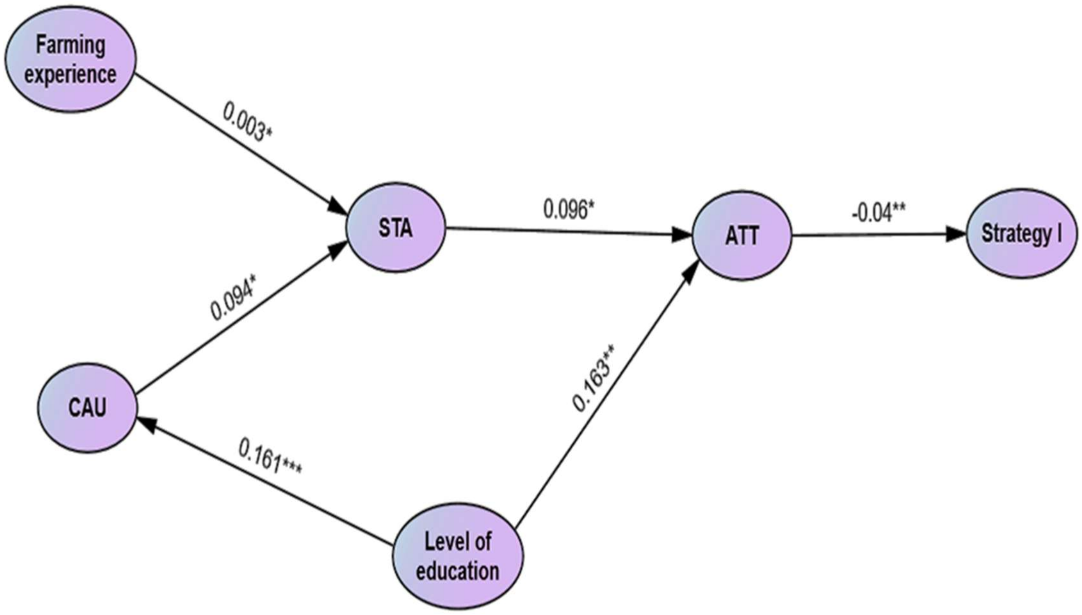

***Figure 3.3.* A reduced (final) path model of factors affecting Rafsanjani pistachio growers' uptake of strategy I (increasing groundwater extraction).** Note: CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources; and ATT = attitudes toward groundwater conservation. Numbers adjacent to the lines are semi-standardized path coefficients; * Significant at $p < 0.10$; **Significant at $p < 0.05$; *** Significant at $p < 0.01$.

As shown in Figure 3.3, one variable (out of four considered variables) is directly associated with the likelihood of increasing groundwater extraction by Rafsanjani pistachio growers: ATT. In particular, farmers who had negative attitudes toward groundwater conservation (farmers who believed that the production of pistachios is more important than the conservation of groundwater resources) were more likely to increase groundwater extraction (Figure 3.3 and Table 3.4). Variables of STA and years of education are directly associated with ATT (Figure 3.3 and Table 3.4). That is, farmers who evaluated the water resources in Rafsanjan as better and farmers with more years of formal education were more likely to possess more positive attitudes toward groundwater conservation.

STA indirectly through ATT related to the likelihood of increasing groundwater extraction by pistachio growers in Rafsanjan (Figure 3.3 and Table 3.4). That is, farmers who perceived a worse condition for the state of the groundwater resources in Rafsanjan were more likely to increase groundwater extraction. This finding is in accordance with an interview with a pistachio grower conducted in Rafsanjan Plain in 2016 (Moghimi Benhangi et al., 2017, p.25) as given below.

"*When I see someone who is [right] next to me pumps water, I say [to myself] why should not I do so? … Why should I give up my right …This [water] is my right … This [water] is farmers' share. This [share] works in a way that if I do not pump it today, my share may not be available tomorrow … if you are saying [to me] 10 years from now we have a water crisis, we [should] get prepared for it by getting the most, in any possible way, out of our orchards in a way we will be in a good shape by the end of 10 years.*"

Compared to scientists (e.g., hydrologists), it seems that farmers' views on the state of groundwater resources in Rafsanjan are more pessimistic (Hashemi et al., 2020b). Therefore, creating a sense of urgency by disseminating information on how negative/serious the current/future state of groundwater resources in Rafsanjan are could backfire and encourage farmers to increase groundwater abstraction. Instead, there is a need to correct farmers' views on the state of groundwater resources in Rafsanjan by hydrogeologists and other professionals working in groundwater trusted by Rafsanjani farmers.

In addition, the level of education influences the likelihood of increasing groundwater extraction by pistachio growers in Rafsanjan indirectly via ATT. In particular, farmers with fewer years of formal education were more likely to increase groundwater extraction. STA in turn was influenced by CAU and farming experience (Figure 3.3 and Table 3.4). Namely, farmers who blamed changes in precipitation and temperature in Rafsanjan on anthropogenic causes and farmers with more years of farming were more likely to perceive a better condition for the state of the groundwater resources in Rafsanjan. Lastly, level of education affected CAU (Figure 3.3 and Table 3.4). That is, farmers with fewer years of formal education were more likely to blame changes in precipitation and temperature in Rafsanjan on non-anthropogenic causes.

Table 3.4 presents total effects (as well as direct and indirect effects) of CAU, STA, ATT, level of education, and farming experience on the Rafsanjani farmers' CAU, STA, ATT, and increasing groundwater extraction (Strategy). As shown in Table 3.4, based on the total effects, the most important predictor of increasing groundwater extraction was found to be ATT; in addition, the strongest predictors of ATT, STA, and CAU were level of education, CAU, and level of education, respectively. Lastly, the variables in the path model explained somewhat high amounts of variance in Rafsanjani pistachio growers' uptake of increasing groundwater extraction strategy and ATT (see Nagelkerke R Square statistics in Table 3.4). However, the variables in the path model explained little of the variance in STA and CAU (see Nagelkerke R Square statistics in Table 3.4), clearly indicating that some other variables not considered in the model were responsible for the substantial remaining unexplained variance.

Table 3.4.

Semi-standardized direct, indirect, and total effects of CAU, STA, ATT, level of education, and farming experience on the Rafsanjani farmers' CAU, STA, ATT, and Strategy I. Note. Strategy I = increasing groundwater extraction; CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources; and ATT = attitudes toward groundwater conservation. The direct effects indicate the effects (or the semi-standardized path coefficients) of the independent variables on the dependent variables within each of four prediction equations (CAU, STA, ATT, and Strategy). Indirect effects can be quantified as the product of all semi-standardized path coefficients from one variable to another. Total effects can be calculated as the sum of the direct and indirect effects (or the semi-standardized path coefficients); the Nagelkerke R Square statistic represents the total variance explained by the models; the path model is shown in Figure 3.3.

Variable	**Indirect effect on**				**Direct effect on**				**Total effect on**			
	CAU	**STA**	**ATT**	**Strategy I**	**CAU**	**STA**	**ATT**	**Strategy I**	**CAU**	**STA**	**ATT**	**Strategy I**
CAU	0	0	0.008	-0.0004	0	0.09	0	0	0	0.09	0.008	-0.0004
STA	0	0	0	-0.004	0	0	0.09	0	0	0	0.09	-0.004
ATT	0	0	0	0	0	0	0	-0.047	0	0	0	-0.047
Level of education	0	0.01	0.001	-0.008	0.16	0	0.16	0	0.16	0.01	0.161	-0.008
Farming experience	0	0	0.0002	-0.00001	0	0.003	0	0	0	0.003	0.0002	-0.00001
Nagelkerke R Square statistic	-	-	-	-	-	-	-	-	0.16	0.11	0.22	0.43

Factors affecting Rafsanjani pistachio growers' earning revenue outside the Rafsanjan Plain

Table 3.5 presents the correlation coefficients between CAU, STA, ATT, and RES and the adoption of "earning revenue outside the Rafsanjan Plain" strategy by Rafsanjani farmers. Based on the correlation coefficients, no significant relationships were found between CAU, RES, and ATT and the adoption of "earning revenue outside the Rafsanjan Plain" strategy.

Table 3.5.

Phi correlation coefficients between CAU, STA, ATT, and RES and the adoption of the "earning revenue outside the Rafsanjan Plain" strategy by Rafsanjani pistachio growers. Note. CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources in Rafsanjan; ATT = attitudes toward groundwater conservation; and RES = perceptions of the future resilience of the livelihood to water scarcity.

Variable	**CAU**	**STA**	**ATT**	**RES**
Earning revenue outside the Rafsanjan Plain	-0.03	-0.18*	-0.01	-0.006

* Significant at p < .10

As shown in Figure 3.4, in contrast to the "increasing groundwater extraction" strategy (Figure 3.3), STA both indirectly and directly affects Rafsanjani farmers' uptake of "earning revenue outside the Rafsanjan Plain" strategy. Moreover, STA exerts the strongest influence on the likelihood of "earning revenue outside the Rafsanjan Plain" by Rafsanjani farmers (by contrast, ATT is the most important predictor of adoption of "increasing groundwater extraction" strategy by Rafsanjani farmers).

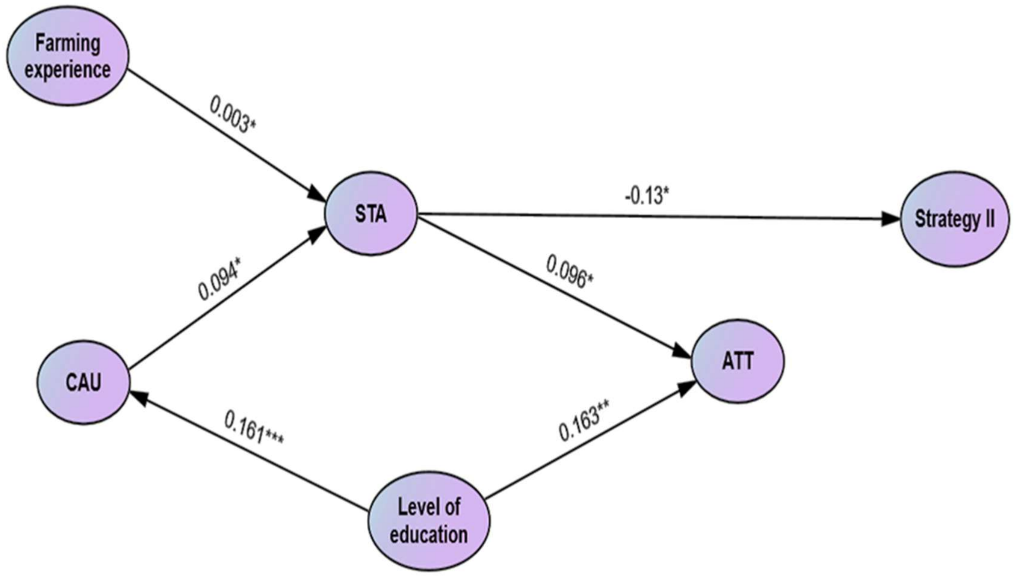

***Figure 3.4.* A reduced (final) path model of factors affecting Rafsanjani pistachio growers' uptake of strategy II ("earning revenue outside the Rafsanjan Plain").**
Note: CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources in Rafsanjan; and ATT = attitudes toward groundwater conservation. * Significant at $p < 0.10$; **Significant at $p < 0.05$; *** Significant at $p < 0.01$.

One variable is directly associated with the likelihood of Rafsanjani pistachio growers' earning revenue outside the Rafsanjan Plain: STA (Figure 3.4). In particular, farmers who perceived that the water resources were in a better condition were less likely to be involved in earning revenue outside the Rafsanjan Plain (Figure 3.4).

Lastly, based on the total effects, the three most important predictors of "earning revenue outside the Rafsanjan Plain" by pistachio growers were found to be STA, CAU, and level of education (in order of importance; Table 3.6). Namely, farmers who perceived that the water resources were in a poorer condition, farmers who blamed changes in precipitation and temperature in Rafsanjan on non-anthropogenic causes, and farmers with less years of formal education were more likely to be involved in earning revenue outside the Rafsanjan Plain.

Table 3.6.

Semi-standardized total (direct + indirect) effects of perceptions of the cause of changes in precipitation and temperature in Rafsanjan, perceptions of the state of the groundwater resources in Rafsanjan, attitudes toward groundwater conservation, level of education, and farming experience on Rafsanjani farmers' earning revenue outside the Rafsanjan Plain. Note. the Nagelkerke R Square statistic represents the total variance explained by the model; the path model is shown in Figure 3.4.

Variable	Total effect on strategy
Perceptions of the cause of changes in precipitation and temperature in Rafsanjan	-0.01
Perceptions of the state of the groundwater resources in Rafsanjan	-0.13
Attitudes toward groundwater conservation	0
Level of education	-0.001
Farming experience	-0.0005
Nagelkerke R Square statistic	0.11

SUMMARY AND CONCLUSIONS

This chapter has shown the impact of perceptions about groundwater resources in Rafsanjan among Rafsanjani pistachio growers, Iran on the uptake of two (separate) strategies of "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain". In addition, the association between these perceptions and two variables, i.e. level of education and farming experience, was examined.

The most important predictor of the adoption of "increasing groundwater extraction" strategy by Rafsanjani farmers was attitudes toward groundwater conservation. In particular, farmers who had negative attitudes toward groundwater conservation (farmers who believed that the production of pistachios is more important than the conservation of groundwater resources) were more likely to increase groundwater extraction. Also, this study showed that formal education does not have the capability to significantly change attitudes toward groundwater conservation; in addition to calling for developing educational programs on changing attitudes toward groundwater conservation in Rafsanjan, this finding might call for considering non-educational interventions (e.g., economic instruments). Previous research has found that financial incentives can motivate farmers to reduce water consumption (Ding & Peterson, 2012 cited in Sanderson et al., 2017).

The Rafsanjani farmers' negative subjective norms (Hashemi et al., 2020b) and attitudes about groundwater conservation also might have implications for the farmers' reactions to other policies recently implemented or currently under consideration in Rafsanjan, as environmental values are especially important predictors of policy support (Sanderson et al., 2017). As long as farmers value (short-term) pistachio production over groundwater conservation, getting farmers to use drip irrigation would not result in a reduction in the amount of water use by farmers as they would likely use the saved water to expand the area under cultivation and/or reduce the irrigation intervals (Scott et al., 2014). Likewise, with the current subjective norms and attitudes toward groundwater conservation in Rafsanjan, the use of command and control instruments currently planned for the implementation (in Iran in general) and in Rafsanjan (e.g., installing smart-metering systems on wells, turning off wells, etc. (Nabavi, 2018)) could face some resistance in Rafsanjan (Molle et al., 2018). When state-initiated policies do not align with local norms there is likely to be less adherence to laws and regulations (Shalsi et al., 2019).

The strongest determinant of the uptake of "earning revenue outside the Rafsanjan Plain" strategy by Rafsanjani farmers was the perception of the state of the groundwater resources. That is, farmers who perceived the water resources in Rafsanjan as worse were more likely to seek jobs outside the Rafsanjan Plain. On the other hand, farmers who perceived a worse condition for the state of the groundwater resources in Rafsanjan were also more likely to increase groundwater extraction. This may suggest that interventions involving only information campaigns on falling water tables (i.e., informing farmers that the aquifer is running dry) and on future climate trends (i.e., spreading information among farmers on decreasing precipitation and increasing temperature in the future) may actually encourage farmers to increase groundwater extraction. Therefore, communicating an 'optimal' amount of risk about the state of groundwater resources might be a more effective policy.

This study found some evidence supporting that growers involved in seeking external employment were less likely to be involved in increasing pumping rates and vice versa. Therefore, it seems that income diversification among farmers can be considered as a policy option for controlling groundwater depletion in Rafsanjan. This policy can also help with building resilience to groundwater scarcity among farmers. However, it should be stated that this result is solely based on a correlation analysis and correlation does not imply causation. Follow up studies with a focus on the relationship between these two strategies among farmers in Rafsanjan are needed to test whether this result actually can be translated to causality. Furthermore, given that perceptions of the cause of changes in precipitation and temperature affect perceptions of the state of the groundwater resources, the cause of changes in precipitation and temperature, as a topic, should be a particular part of any informal or formal education program aimed at the conservation of groundwater resources; however, it seems that educational instruments alone would not be sufficient to change perceptions of the cause of changes in precipitation and temperature, as these perceptions are affected by community culture as well.

Finally, this study focused on the perceptions about groundwater resources to predict the adoption of the two strategies among Rafsanjani farmers; it is suggested that in future studies Rafsanjani pistachio growers' perception of the strategies — as another influential determinant (Ajzen, 2011) — is also used. For the purposes of this study, only the variables level of education and farming experience were used in order to predict the perceptions about groundwater resources; similar studies in the future could consider more factors, including pistachio growers' income and social capital. Lastly, this study showed that the effect of perceptions about groundwater resources on the uptake of strategies differs from strategy to strategy; therefore, conducting similar studies for other strategies to cope with the water scarcity in Rafsanjan (e.g., drip irrigation) seems to be necessary.

ACKNOWLEDGMENTS

Helpful comments on this chapter were received by Christopher Scott, and the journal editor and reviewers. Part of the questionnaire used in this study was developed in collaboration with Mohammad Reza Farzaneh and Ali Bagheri; they, along with the Iran Water Policy Research Institute, were also very helpful with the data collection.

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CHAPTER 4

UNDERSTANDING INCOME DIVERSIFICATION IN RESPONSE TO WATER SCARCITY AMONG FARMERS USING SOCIO-PSYCHOLOGICAL FACTORS[19]

ABSTRACT

Income diversification is an essential livelihood strategy for farmers facing unsustainable groundwater withdrawals. In this chapter, I develop a general structural equation model that analyzes socio-psychological factors that affect intentions to adopt and actual adoption of income diversification in response to groundwater scarcity. The developed model includes affective attitudes, instrumental attitudes, and self-efficacy. This model explains 55 and 36% of the variance in intentions to pursue and actual pursuit of income diversification among farmers in the Rafsanjan Plain, Iran, respectively. These results can inform policies for promoting income diversification and have implications for sustaining farmers' livelihoods and groundwater resources.

INTRODUCTION

Many farmers living in arid and semi-arid regions of the world are currently experiencing declining groundwater tables, water scarcity, growing pumping costs, and deteriorating groundwater quality (Bekkar et al., 2009; Famiglietti, 2014; Konikow &

[19]- A version of this chapter has appeared as Hashemi, S. M., Kinzig, A., Eakin, H., Abbott, J. K., & Sedaghat, R. (2020). Developing a socio-psychological model explaining farmers' income diversification in response to groundwater scarcity in Iran. *International Journal of Water Resources Development,* DOI: 10.1080/07900627.2021.1879029.

Kendy, 2005). These farmers may need to diversify their income streams—taking on, for instance, jobs outside the agricultural sector—if they are to remain resilient to social-ecological stressors (Alonso & Krajsic, 2015; Eakin et al., 2016; Hashemi et al., 2017; Marshall et al., 2012).

In this chapter, I study the income-diversification strategies of the community of pistachio growers in the Rafsanjan Plain, Iran. These farmers are heavily dependent on a fast-depleting aquifer for irrigation purposes; the groundwater extraction rate in the Rafsanjan Plain has exceeded the recharge rate for over four decades. Incremental adaptation (e.g., improving irrigation water efficiency) alone is not sufficient to solve the problem (Marshall et al., 2012; Rickards, 2013). There is an urgent need for transformative changes, such as income diversification, that re-orient people toward livelihood strategies that do not rely exclusively on groundwater resources (Moench, 2007; Senger et al., 2017a).

Cognitive factors (e.g., attitudes toward change, place attachment), however, may limit a farmer's transformative capacity (Burnham & Ma, 2017; Eakin et al., 2016; Grothmann & Patt, 2005; Marshall et al., 2012). For instance, many farmers often possess a strong attachment to their farms, their lifestyle, their agricultural community, or their region. This can make income diversification (or farm exit) difficult (Wheeler et al., 2018). Therefore, in this chapter, the psychological factors that determine Rafsanjani pistachio growers' decision to pursue income diversification as a strategy to deal with groundwater scarcity are analyzed.

The literature describes farmers' responses to cope with groundwater scarcity in different ways. For example, according to Frija et al. (2016), farmers' strategies can be divided into two broad groups: "positive" or "negative." "Positive" strategies include using alternative sources of groundwater and improving irrigation water efficiency. "Negative" strategies include reducing cultivated areas under irrigation and turning to off-farm activities as an income source (Frija et al., 2016). By contrast, Bekkar et al. (2009) categorize farmers' strategies in response to falling groundwater levels as "offensive" or "defensive." "Offensive" strategies include increasing the availability of water (e.g., digging wells). "Defensive" strategies include conserving water (e.g., adopting water conservation technologies). Bekkar et al. (2009) do not consider off-farm strategies in their study.

Rather than defensive/offensive or negative/positive, I conceptualize pistachio growers' responses to groundwater scarcity as either maladaptive or adaptive. The maladaptive category consists of continuing groundwater overdraft by, for instance, deepening wells to sustain groundwater extraction. In contrast, the adaptive category includes groundwater conservation (e.g., reducing planted acreage) and income diversification strategies. This chapter focuses on the results of farmers' pursuit of income diversification, as an adaptive strategy. Hashemi et al. (2020a) reports on pistachio growers' pursuit of maladaptive strategies (e.g., deepening wells) in Rafsanjani.

Income diversification, which is pursued by many farmers as a means of obtaining an important fraction of their total income, is a rational strategy adopted by a household to improve its wellbeing (Barrett et al., 2001; Ellis, 2010). Diversification is a key to building resilient livelihood systems for farmers who live in arid and semiarid areas and rely on depleting groundwater resources (de Sousa et al., 2017; Gong et al., 2020; Moench, 2007; Smith, 2004; Sok & Yu, 2015; Wan et al., 2016). The "livelihood resilience" of a farming household is defined as the capacity of the household to withstand, recover, or transform its livelihood structures in order to adapt to stressors (Gong et al., 2020). Income diversification can increase a farmer's total income and reduce household poverty, as long as the farmer has access to employment opportunities with high economic returns (Barbieri and Mahoney, 2009; Barrett et al., 2001; Danso-Abbeam et al., 2020; de Sousa et al., 2017; Smith, 2004; Vote et al., 2015). Diversification also can enhance production productivity through an increase in the adoption of agricultural technologies (Danso-Abbeam et al., 2020; Yin et al., 2016), and lead to the conservation of groundwater resources (Moench, 2007). Nevertheless, there is mixed evidence in the scientific literature about the relationship between income diversification and the amount of irrigation water used; while some studies have found that there is a positive relationship between income diversification and groundwater conservation, other researchers have not found any positive impacts (Hashemi et al., 2020a; Yin et al., 2016). In the case of Rafsanjan, previous research has found some evidence supporting the idea that income diversification may result in the reduction of groundwater overdraft (Hashemi et al., 2020a). However, the reduction of groundwater overdraft among pistachio growers in Rafsanjan as a result of income diversification may not reduce the overall extraction of groundwater in Rafsanjan, as more groundwater would likely be used in the drinking and industry sectors

Objective farmer and farm characteristics, economic business structure, and ownership or local labor market conditions have been the focus of previous research on the determinants of income diversification among farmers (Berhanu et al., 2007; de Sousa et al., 2017; Hansson et al., 2012; Weltin et al., 2017). For instance, de Sousa et al. (2017) have showed that crop and income diversification was primarily determined by farmers' resource constraints. Wan et al. (2016) found that income diversification by rural households in China results in a reduction of drought impacts and an enhancement of household resilience. Their study shows that the spatial location of rural households plays an important role in explaining farmers' degree of income diversification (Wan et al., 2016). Other research has demonstrated that income diversification is an essential survival strategy of the very poor, whereas it is a strategy for wealth accumulation and welfare improvement for the rich (Berhanu et al., 2007). Small-scale and family farms tend to be involved in income diversification in the form of off-farm employment (Weltin et al., 2017). There is little research on the influence of psychological factors on income diversification despite the importance of cognitive factors in determining farmer behavior (Eakin et al., 2016; Hansson et al., 2012; He et al., 2020; Marshall et al., 2012). In particular, to the best of my knowledge, there are very few studies, if any, that have analyzed income diversification in response to groundwater scarcity among farmers using socio-psychological factors (in my case by drawing on the Theory of Planned Behavior; see the Methods section). Thus, my research can be used as a basis for understanding what cognitive factors might promote or limit income diversification, and inform the development of interventions that promote income diversification with implications for sustaining both farmers' livelihoods and groundwater resources in Rafsanjan and other regions in the world that experience groundwater scarcity.

The main purpose of my study was to identify psychological antecedents that may be associated with intentions to and use of income diversification strategies in response to groundwater scarcity by pistachio growers in the Rafsanjan Plain, Iran.

METHODS

Study area

The Rafsanjan Plain (also known as Rafsanjan Study Area) is a part of the Kavir Daranjir Basin, in Iran. Rafsanjan is one of the major sources of pistachios in the world (Rahnama & Zamzam, 2013). Eighty percent of Rafsanjan's economy depends on pistachio production (Bazarekar, 2019). In this region, 99% of all water used in agriculture, drinking, and industry sectors come from the groundwater resources, making Rafsanjan very dependent on its groundwater resources (Bagheri and Babaeian, 2020; Karamouz et al., 2011). Rafsanjan has an arid subtropical climate; it annually receives less than 100 mm rainfall; and has hot summers and dry winters (Sayyaf et al., 2014).

In Rafsanjan, a dramatic increase in the number of agricultural wells (from about 70 wells in the 1960s to 1,300 wells in the 2000s) has caused the water table to decline significantly (about 17 m over the past 3 decades). This in turn has resulted in a reduction in well discharge rates and severe deterioration of agricultural and drinking water quality, among other impacts (Motagh et al., 2017). In Rafsanjan, the presence of double-digit inflation rates for pistachio production inputs as well as a decrease in pistachio production harvests have seriously threatened the viability of pistachio production, especially for smallholders (Sedaghat, 2019).

In response to groundwater scarcity, some Rafsanjani pistachio growers have, in recent years, diversified their livelihoods by developing pistachio orchards in other regions of the country. Other jobs that have been pursued by pistachio growers in Rafsanjan and Kerman Province are greenhouse farming, calf farming, fish farming, production and distribution of livestock feeds, and building and managing gas stations and small supermarkets with rates of return of 22%, 19%, 17%, 16%, and 9%, respectively (Hashemi et al., 2020a).

The Theory of Planned Behavior

In this study, I selected the TPB as a basis for identifying psychological factors that influence farmers' income diversification in response to groundwater scarcity, because income diversification in response to groundwater scarcity normally faces constraints, such as costs, skills, etc.

According to the TPB, an individual's intention has a key role in explaining his/her behaviors. In Ajzen's words (Ajzen, 1991; p. 181) "… a central factor in the theory of planned behavior is the individual's intention to perform a given behavior. … As a general rule, the stronger the intention to engage in a behavior, the more likely should be its performance." Intention, in turn, can be predicted by three constructs of "perceived behavioral controls over the behavior" (PBC), "attitudes toward the behavior" (ATT), and "subjective norms about the behavior" (SN) (Ajzen, 1991).

The PBC construct represents an individual's perceived control over both external control variables (e.g., barriers, opportunities) and internal control variables (e.g., information, skills) in performing a behavior (Conner & Armitage, 1998). The ATT construct can be seen as a subject's psychological evaluation of how much he/she likes (or dislikes) a behavior of interest (Essenfelder et al., 2018). The SN construct measures the social pressures on a person to adopt (or not to adopt) a particular behavior based on approval (or disapproval) of the behavior from people who are important to the person (Conner & Armitage, 1998). Lastly, the TPB predicts that two constructs of Intention and PBC *directly* determine a behavior of interest.

Instruments and Data Collection Methods

The TPB was used to develop a questionnaire distributed to 110 pistachio growers (households) in the Rafsanjan Plain, Iran. A summary of the questionnaire is given in Table 4.2. The items given in the questionnaire were assembled and adjusted from my experience with previous research projects, published literature on related topics, especially the work of Yazdanpanah et al. (2014) on farmers' intention and behavior regarding water conservation using the TPB in Iran, and Ajzen's (2015) recommendations on how to construct a TPB questionnaire.

As shown in Table 4.2, this study's questionnaire included 16 items measuring SN (2 items), PBC (5 items), ATT (7 items), and Intention (2 items) regarding income diversification in response to groundwater scarcity. In the questions, farmers were asked to indicate their agreement with a statement using a five-point Likert-type scale from 1 to 5 as follows: 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high. One variable–

–behavior (earning revenue outside the Rafsanjan Plain)—was indicated by a simple "yes or no" answer. The data collection methods used in this chapter are further described in Hashemi et al. (2020a).

Data Analysis

One hundred and one questionnaires (of 110 initially completed questionnaires) were used in the data analysis after checking the questionnaires for completeness. To analyze the data, I developed a methodology that was partly based on an approach for scale construction proposed by Hinkin et al. (1997). The methodology includes three steps: (i) developing a scale for determinants of income diversification intentions using exploratory factor analysis; (ii) evaluating the income diversification scale's construct validity and reliability; and (iii) exploring factors affecting income diversification intentions and behavior among pistachio growers using structural equation modeling and logistic regression analysis, based on the scale developed in the previous step.

Step (i): Developing A Scale for Determinants of Income Diversification Intentions by Conducting Exploratory Factor Analysis

Prior to conducting structural equation modeling, exploratory factor analysis (EFA) was used (Huijts et al., 2014). In my study, the use of EFA serves several purposes. First, given that there are no standardized TPB scales for measuring farmers' decisions to diversify their income sources (Hansson et al., 2012), I used EFA to develop a scale for determinants of income diversification intentions and to construct distinct latent variables (Hansson et al., 2012; Holland et al., 2020). Second, in some contexts, TPB constructs (ATT, SN, and PBC) may consist of two subcomponents (Rhodes and

Courneya, 2003). Therefore, the use of EFA enabled us to test whether or not, for instance, the attitude construct consists of two subcomponents of affective and instrumental attitude or a singular attitude (Rhodes & Courneya, 2003). Third, the use of EFA before the application of structural equation modeling more often results in a model with satisfactory fit indices (Pinto et al., 2019).

To develop a scale for determinants of income diversification intentions, I began analyzing the data collected on items measuring SN, PBC, and ATT (Table 4.2) by performing EFA. Specifically, using EFA, I analyzed 14 initial questions that I used to measure SN (n = 2 questions), PBC (n = 5 questions), and ATT (n = 7 questions). The use of EFA allowed us to check if each of the questions belonged to a pre-assigned variable of either SN, PBC, or ATT. Questions with factor loadings less than 0.5, as suggested by Hair et al. (2010), or with cross-loadings were eliminated from the analysis one at a time until only questions without cross-loadings and with factor loadings equal to or above 0.5 remained. For more information on how the EFA was performed in this study, readers are referred to the Appendix A.

Step (ii): Evaluating the Construct Validity and Reliability of Income Diversification Scale

In the next step, I tested the construct validity and reliability of the final factor solution/scale provided by the EFA. To do so, I proceeded by calculating the convergent validity, discriminant validity, and construct reliability of the final factor solution. To compute these, average variance extracted (AVE), the squared correlations between the extracted factors, and the composite reliability (CR) were calculated, respectively. The

Appendix A provides more information on the evaluation of construct validity and reliability of income diversification scale in this chapter.

Step (iii): Exploring Factors Affecting Income Diversification Intentions and Behavior Among Pistachio Growers Through Conducting Structural Equation Modeling and Logistic Regression Analysis

In the next step of the analysis, I used structural equation modeling (SEM) to evaluate the structure of relationships between the factors provided by the EFA (see the Appendix A for an introduction to SEM). Following Schumacker and Lomax (2004), I went through the following steps for conducting SEM analysis: specification, estimation, evaluation, and modification. In the first step of SEM analysis, confirmatory factor analysis was used to develop a measurement model based on results from the EFA conducted in the previous stage. For the parameter estimation, the maximum likelihood method was used. To test the measurement model, I used the CMIN/DF (Chi-square/df), CFI (Comparative Fit Index), RMSEA (Root Mean Square Estimate Approximation), and PCLOSE (p of Close Fit) fit indices. In case that the measurement model did not show an acceptable fit to the data, model modification (e.g., elimination of a variable/s) was done. After an acceptable measurement model was developed, a general structural equation model was estimated by going through the same procedure used for the measurement model.

Since SEM is not an appropriate statistical technique for analyzing relationships involving dichotomous variables (the variable for the behavior of “earning revenue outside the Rafsanjan Plain”), a binary logistic regression analysis was used. More specifically, to assess the associations between Rafsanjani farmers' use of the behavior "earning revenue outside the Rafsanjan Plain" as a dependent variable and the constructs Intention and PBC as independent variables, a binary logistic regression analysis was performed. To accomplish this, the factor scores associated with the independent variables in the exploratory factor model were calculated and then used in the binary logistic regression model.

RESULTS AND DISCUSSION

Rafsanjani Pistachio Growers' Socio-Economic Characteristics

Some socio-economic variables of pistachio growers are illustrated in Table 4.1. The average age of growers was 55 years and they had an average of 31 years of pistachio cultivation experience (Table 4.1). A large share of Rafsanjani growers had low levels of formal education, with an average of eight years. The vast majority of pistachio growers (95%) had orchards with less than 10 hectares in pistachios and with no livestock (82%) or membership in agricultural organizations (81%) (Table 4.1). Finally, 90% of the households stated that pistachio cultivation was their main job (Table 4.1). Chapter 3 gives results regarding the relationship between Rafsanjani pistachio growers' socio-economic characteristics (e.g. level of education, farming experience) and their engagements in income diversification activities.

Table 4.1.

A summary of some socio-economic variables of Rafsanjani pistachio growers.

Variable	Frequency (N=101)	Percent	(Mean)/(SD)
Age			(55.33)/ (9.02) (years)
Younger than 30	1	1	
30-45	12	11.8	
45-60	65	64.4	
60-75	22	21.8	
Older than 75	1	1	
Formal years of education			(7.77)/ (4.81)
Less than 5	36	35.6	
5-8	28	27.7	
8-12	25	24.8	
12-16	11	10.9	
More than 16	1	1.0	
Pistachio growing experience (years)			(31.60)/ (11.97)
Less than 10	6	5.9	
10-20	10	9.9	
20-30	31	30.7	
More than 30	54	53.5	
Hectare in pistachios			(5.53)/(7.59)
Less than 2	22	21.8	
2-5	43	42.6	
5-10	31	30.6	
More than 10	5	5.0	
Livestock ownership			
No	83	82.2	
Yes	18	17.8	
Organization membership			
No	82	81.2	
Yes	19	18.8	
Main job			
Farming (pistachio cultivation)	91	90	
Mine worker	3	3.0	
Shopkeeper	2	2.0	
Teacher	2	2.0	

Hospital staff	1	1.0	
Pistachios dealer	1	1.0	
Bank staff	1	1.0	

Rafsanjani Pistachio Growers' Descriptive Scores on The Theory of Planned Behavior's Variables

Table 4.2 contains the respondents' average (and standard deviation) scores on the TPB's items that measured the four variables of ATT, PBC, SN, and Intention. On average, respondents received a score of 2.81 out of 5 on the items (or between "low" and "moderate" on a five-point scale from "very low" to "very high"). Pistachio growers reported the highest agreement with the statement "I think earning revenue outside the Plain is costly for me" (mean value = 4.18). Meanwhile, they showed the lowest agreement with the statement "earning revenue outside the Plain is easy to do for me" (mean value = 2.35). In addition, pistachio growers clearly thought "earning revenue outside the Rafsanjan Plain" was useful, assigning it a value somewhere between "high" and "very high" (mean value = 4.10). This may be because 87% of Rafsanjani pistachio growers evaluated the future state of groundwater resources as "bad" or "very bad" (Hashemi et al., 2020a,b) and 76 % of them thought that their pistachio production businesses would not be able to withstand future groundwater scarcity (Hashemi et al., 2020a,b).

Nevertheless, even though farmers felt that earning revenue outside the Rafsanjan Plain was useful (mean value = 4.10), it was not necessarily their preferred strategy (mean value = 2.92) in the face of declining groundwater tables. Farmers in general are known to have a deep attachment to their profession and to where they live and are rather risk-averse, which may contribute to forming the negative attitudes toward external employment (Eakin et al., 2016; Marshall et al., 2012; Weltin et al., 2017; Wheeler et al., 2018). One of the general models for describing how people form and change their attitudes is the “Past Attitudes are Still There” model (Petty et al., 2006 cited in Bohner & Dickel, 2011). According to this model, attitude change is a combination of two processes of forming new attitudes and “marking” the old attitudes as valid or invalid in reference to the newly-formed attitudes (Bohner & Dickel, 2011). For instance, consider a pistachio grower in Rafsanjan who holds positive attitudes toward earning revenue inside of the Rafsanjan Plain and, at the same time, holds negative attitudes toward earning revenue outside the Rafsanjan Plain. After being targeted by an attitude change intervention (e.g., persuasion; Steinmetz et al., 2016) that aims at forming positive attitudes toward seeking external employment, this pistachio grower may not only like the “earning revenue outside the Rafsanjan Plain” behavior but also like or dislike the “earning revenue inside of the Rafsanjan Plain” strategy. Therefore, this might suggest that an attitude change intervention in Rafsanjan should consider both types of aforementioned attitudes (older and newer attitudes) toward seeking external employment.

Table 4.2.

Descriptive statistics of the Theory of Planed Behavior's items among Rafsanjani pistachio growers.

Variable	Mean	SD	Source	Comment
Perceived Behavioral Control			Yazdanpanah et al. (2014); Ajzen (2015); Farzaneh (2016).	The level of agreement with each item was measured using a five-point Likert-type scale from 1 to 5 as follows: 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high.
I think I lack the time and skills needed to earn revenue outside the Rafsanjan Plain. ×	3.61	1.27		
Do you think how feasible earning revenue outside the Rafsanjan Plain is?	3.37	1.37		
Earning revenue outside the Plain is easy to do for me.	2.35	1.34		
To what extent do you think you have authority over earning your revenue outside the Plain?	3.78	1.24		
I think earning revenue outside the Plain is costly for me. ×	4.18	0.79		
Attitude			Yazdanpanah et al. (2014); Ajzen (2015); Farzaneh (2016).	The level of agreement with each item was measured using a five-point Likert-type scale from 1 to 5 as follows: 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high.
I believe that earning revenue outside the	3.25	1.41		

Rafsanjan Plain in order to adapt to groundwater scarcity is wise.				
I believe that earning revenue outside the Rafsanjan Plain in order to adapt to groundwater scarcity is useful.	4.10	1.01		
Earning revenue outside the Rafsanjan Plain becomes necessary only in drought conditions. ×	3.58	1.29		
In order to increase my income, I need to earn revenue outside the Rafsanjan Plain.	2.92	1.46		
Farmers should think about how to earn revenue outside the Rafsanjan Plain rather than thinking about how to earn their revenues inside of the Rafsanjan Plain.	3.47	1.16		
I believe that earning revenue outside the Rafsanjan Plain in order to adapt to groundwater scarcity is my preferred strategy.	2.92	1.49		
I believe that earning revenue outside the Rafsanjan Plain in response to groundwater scarcity is unnecessary ×	2.26	1.25		
Subjective norm			Yazdanpanah et al. (2014); Ajzen (2015);	The level of agreement with each item was measured using a five-point Likert-type scale

			Farzaneh (2016).	from 1 to 5 as follows: 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high.
If I do not earn revenue outside the Rafsanjan Plain, people who are important to me will approve of my action. ×	3.26	1.37		
Most people who are important to me think that earning revenue outside the Rafsanjan Plain is a good action.	3.75	1.21		
Intention			Yazdanpanah et al. (2014); Ajzen (2015); Farzaneh (2016).	The level of agreement with each item was measured using a five-point Likert-type scale from 1 to 5 as follows: 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high.
Are you planning on earning revenue outside the Rafsanjan Plain?	3.35	1.39		
I am going to encourage other farmers to earn revenues from outside the Plain.	3.59	1.26		
Behavior			Farzaneh (2016)	It was measured as a dichotomous variable with two categories of yes or no
The earning revenue outside the Rafsanjan Plain	49.5% Yes 50.5% No			

[×] Reverse coding

Exploring Underlying Determinants of Subjective Norm, Perceived Behavioral Control, and Attitude with Respect to the Earning Revenue outside the Rafsanjan Plain Behavior

To develop a scale for the determinants of intentions among pistachio growers in Rafsanjan to diversify income sources, I first used exploratory factor analysis (EFA) on the items in Table 4.2 measuring SN, PBC, and ATT. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated at 0.53, which is greater than 0.5, indicating that the data were appropriate for EFA (Hutcheson & Sofroniou, 1999). The Bartlett test of sphericity was also found to be significant ($\chi^2 = 137.813$, $p < 0.001$), accepting the alternative hypothesis that the correlation matrix is not an identity matrix (Lian & Weisfeld-Spolter, 2015). Moreover, five items with low factor loadings or with cross-loadings were dropped. In the final solution, three factors (comprising 9 items in total) were extracted and named PBC-ATT7, ATT_i (instrumental attitude), and ATT_{ii} (affective attitude). These factors accounted together for 57.33% of the total variance in SN, PBC, and ATT (Table 4.3).

Table 4.3.

Performing exploratory factor analysis (principal components analysis) on items measuring Rafsanjani pistachio growers' SN, PBC, and ATT with respect to the "earning revenue outside the Rafsanjan Plain" behavior. This table shows that three items were loaded on each factor (e.g., "PBC1", "PBC2", and "ATT7" were loaded on the factor "PBC-ATT7").

Measurement items extracted from principal components analysis	**Item code**	**Factor loading[a]**	**Percentage of the total variance explained[b]**	**Eigenvalue**	**Average variance extracted**	**Composite reliability**
PBC-ATT7			24.40	2.19	0.56	0.79
I think I lack the time and skills needed to earn revenue outside the Rafsanjan Plain. ×	PBC1	(0.776)				
Do you think how feasible earning revenue outside the Rafsanjan Plain is?	PBC2	(0.770)				
I believe that earning revenue outside the Rafsanjan Plain in order to adapt to groundwater scarcity is wise.	ATT7	(0.703)				
ATT$_i$			18.39	1.65	0.49	0.74
I believe that earning revenue outside the Rafsanjan Plain in order to adapt to groundwater scarcity is useful.	ATT4	(0.829)				
Earning revenue outside the Rafsanjan Plain becomes necessary only in drought conditions. ×	ATT5	(0.742)				

In order to increase my income, I need to earn revenue outside the Rafsanjan Plain.	ATT6	(0.500)				
ATT_{ii}			14.53	1.30	0.49	0.74
Farmers should think about how to earn revenue outside the Rafsanjan Plain rather than thinking about how to earn their revenues inside of the Rafsanjan Plain.	ATT1	(0.870)				
I believe that earning revenue outside the Rafsanjan Plain in order to adapt to groundwater scarcity is my preferred strategy.	ATT2	(0.694)				
I believe that earning revenue outside the Rafsanjan Plain in response to groundwater scarcity is unnecessary. [×]	ATT3	(0.500)				

Note. PBC-ATT7 = perceived behavioral control-ATT7; ATT_{i} = Instrumental attitude; and ATT_{ii} = Affective attitude

[a] Only factor loadings with absolute values greater than 0.5 are given in this table.

[b] "The percentage of the total variance explained" (associated with a component/factor) indicates a percentage of variability accounted for by each factor to the total variance in all the original items. The percentage of the total variance explained by a factor can be calculated by multiplying the factor's eigenvalue by 100 and then dividing by the number of total items (Lorenzo-Seva, 2013).

[×] Reverse coding

As shown in Table 4.3, factors PBC-ATT7, ATT_i (instrumental attitude), and ATT_{ii} (affective attitude) contributed to 24.4, 18.3, and 14.5 % of the total variance explained, respectively. The results of EFA show that some of my initially-designated items for measuring ATT were divided and loaded on the PBC-ATT7, ATT_i (instrumental attitude), and ATT_{ii} (affective attitude) factors, instead (see Table 4.3). This is consistent with previous research that each TPB's constructs (ATT, SN, and PBC) may consist of two subcomponents (Ajzen, 2000 cited in Rhodes and Courneya, 2003). For the attitude construct of the TPB, previous research has found that this construct may consist of two separate subcomponents of "affective" (ATT2 in Table 4.3) and "instrumental" (ATT4 in Table 4.3) attitude (Rhodes and Courneya, 2003). Affective attitudes are often measured by items that can be characterized as "unpleasant-pleasant," while instrumental attitudes are measured by items characterized as "worthless-valuable" (Conner et al., 2011). Previous research has also shown that, in some cases, perceived behavioral control acts as a complementary construct for measuring attitude (Sreen et al., 2018).

Likewise, previous studies have reported that there are two separate subcomponents of perceived behavioral control—namely "self-efficacy" (beliefs in one's competence in order to perform a behavior of interest) and "controllability" (beliefs about one's control over performing a behavior of interest) (Ajzen, 2002). Self-efficacy usually has higher predictive power than does controllability for both intentions and behaviors (Rhodes & Courneya, 2003). In my study, the PBC items retained in the final factor solution measure the self-efficacy component (PBC1 and PBC2; see factor PBC-ATT7 in Table 4.3).

Moreover, both of my subjective norm-designated items ("if I do not earn revenue outside the Rafsanjan Plain, people who are important to me will approve of my action."

and “most people who are important to me think that earning revenue outside the Rafsanjan Plain is a good action.”) were dropped from the EFA (Table 4.3). In fact, the subjective norm construct has often been found to exert no direct effect on intention if the effects of attitude and PBC are controlled for (Bamberg & Moser, 2007). For instance, in a study of determinants of farm diversification among Australian olive growers, the authors did not find a clear relationship between subjective norms and decisions to diversify (Duarte Alonso & Krajsic, 2015). Lastly, the lack of a significant effect of SN on intention does not necessarily signify this latent variable’s weak predictability power; in fact, Armitage and Conner (2001; p. 471), after conducting a meta-analysis, concluded “the subjective norm construct is generally found to be a weak predictor of intentions. This is partly attributable to a combination of poor measurement and the need for expansion of the normative component.”

Assessing the Validity and Reliability of The Scale for The Determinants of Income Diversification Intentions Among Rafsanjani Pistachio Growers

The results of examining the convergent validity, discriminant validity, and construct reliability of the three-factor solution provided by the EFA are presented in Table 4.3. As shown, the AVE value calculated for the factor PBC-ATT7 is more than 0.5, meeting the criterion for an acceptable convergent validity, whereas AVE values calculated for the factors ATT_i (instrumental attitude) and ATT_{ii} (affective attitude) are at marginal levels (Table 4.3). All AVE values are greater than the squared correlations between constructs, fulfilling the condition for establishing the discriminant validity (Fornell & Larcker, 1981; Table 4.3). Lastly, all CR values calculated for the three factors are more than 0.6 (Table 4.3), indicating acceptable levels of construct reliability (Bagozzi & Yi, 1988).

Measurement Model

In the first step of SEM analysis, I used confirmatory factor analysis with maximum likelihood estimation to confirm the structure (how, and the extent to which, the extracted items are linked to their factors) that was found in the EFA. CMIN/DF, CFI, RMSEA, and PCLOSE were calculated at 1.434, 0.957, 0.066, and 0.026, respectively, indicating an acceptable fit of the measurement model to the data. After validating the measurement model, I proceeded to estimate the structural model.

General Structural Equation Model

In the last step of the SEM process, the measurement model was used for creating a general structural equation model. The structural model's fit to the data was confirmed (the calculated CFI and RMSEA values were at marginal levels; CMIN/DF = 1.86; CFI = 0.89; RMSEA = 0.09; and PCLOSE = 0.03). Figure 4.1 illustrates the structural model along with the standardized path coefficients and the significance levels. For clarity, the statistically significant structural relationships (paths) are highlighted in Figure 4.1.

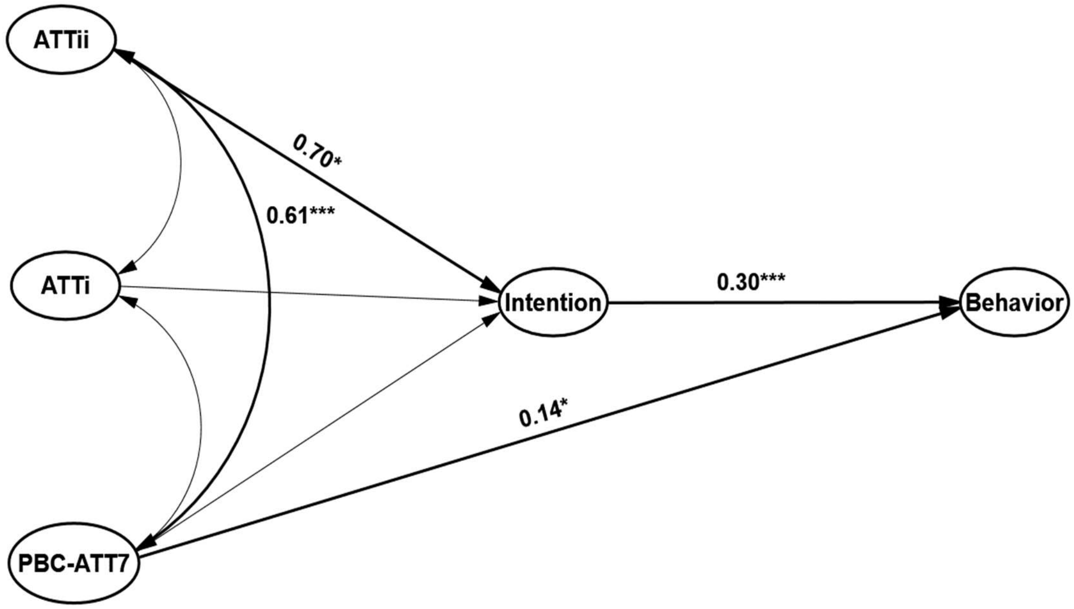

Figure 4.1. **A general structural equation model of income diversification among pistachio growers in Rafsanjan ("earning revenue outside the Rafsanjan Plain").** Note. for examining the association between two variables of "Intention" and "PBC-ATT7" and Rafsanjani farmers' uptake of the "earning revenue outside the Rafsanjan Plain" behavior, a binary logistic regression model was estimated; ATTi = Instrumental attitude; ATTii = Affective attitude; PBC-ATT7 = Perceived behavioral control-ATT7; *Significant at $p < 0.05$; *** Significant at $p < 0.001$; see Table 4.3 for the descriptions of items (ATT1, ATT2, ATT3, etc.) in this model.

Table 4.4.

Standardized direct, indirect, and total effects between variables that affect Rafsanjani pistachio growers' income diversification behavior.

	Squared multiple correlation (R2)/Nagelkerke R Square					
	Intention			**Behavior**		
	0.55			0.36a		
Construct	**Direct effect on**		**Indirect effect on**		**Total effect on**	
	Intention	Behavior	Intention	Behavior	Intention	Behavior
PBC-ATT7	0.04	0.14^{*}	0	0.01	0.04	0.15*
ATTi	0.21	0	0	0.06	0.21	0.06
ATTii	0.70^{*}	0	0	0.21^{*}	0.70^{*}	0.2^{*}
Intention	0	0.30^{***}	0	0	0	0.30^{***}

Note. for examining the association between two variables of "Intention" and "PBC" and Rafsanjani farmers' uptake of the "earning revenue outside the Rafsanjan Plain" behavior, a binary logistic regression model was estimated; ATT_{i} = instrumental attitude; ATT_{ii} = Affective attitude; PBC-ATT7= Perceived behavioral control-ATT7; the path model is shown in Figure 4.1.

[a]Nagelkerke R Square; *Significant at p < 0.05; *** Significant at p < 0.001; the direct effects indicate the effects of the independent variables on the dependent variables; indirect effects are the multiplication of all path coefficients from one variable to another; total effects are the sum of the direct and indirect effects; bootstrapping (number of bootstraps samples = 1,000) was used to determine the p-values of indirect and total effects (Hayes, 2018).

Table 4.4 presents direct effects of ATT_{i} (instrumental attitude), ATT_{ii} (affective attitude), and PBC-ATT7 on Intention. In addition, direct, indirect, and total effects of ATT_{i} (instrumental attitude), ATT_{ii} (affective attitude), PBC-ATT7, and Intention on the income diversification behavior are given in Table 4.4. As shown in Table 4.4, the most important determinant (i.e., the independent variable with the largest total effect) of engagement in income diversification was Intention followed by ATT_{ii} (affective attitude). In addition, the independent variable with the largest effect on Intention was ATT_{ii} (affective attitude). There were no significant relationships between ATT_{i} (instrumental attitude) and Intention or between PBC-ATT7 and Intention. I also found no significant relationships between ATT_{i} (instrumental attitude) and ATT_{ii} (affective attitude) or between ATT_{i} (instrumental attitude) and PBC-ATT7. Moreover, both Intention and PBC-ATT7 *directly* and positively affected the use of income diversification behavior by pistachio growers in Rafsanjan (Figure 4.1 and Table 4.4). Lastly, the variables represented in the model (Figure 4.1) explained acceptable amounts of variance in both Intention and Behavior (see squared multiple correlations and Nagelkerke R Square in Table 4.4).

Previous research using the TPB consistently supports the observation that there is a positive association between the attitude construct and intentions (and therefore indirectly behaviors) (Russell & Fielding, 2010). In this study, all three factors that were extracted from the factor analysis consisted of items that measure attitudes (of nine items retained in the final factor solution, seven items are ATT-designated items and the two remaining are PBC items; see Table 4.3). In addition, in my study, attitudes toward income diversification exert a strong influence on both Intention and behavior (see Figure 4.1 and Table 4.4). In particular, I found that ATT_{ii} (affective attitude) was much more influential than ATT_{i} (instrumental attitude) in predicting both the intentions to adopt, and adoption of income diversification behavior among pistachio growers. It has been found that for some behaviors, affective attitudes are a stronger predictor of intentions and actions than instrumental attitudes (Conner et al., 2011). Nevertheless, the focus of this study was not to understand the distinctions between the impacts of affective and instrumental attitudes. Therefore, the associated results should be treated with caution and follow-up studies are warranted.

The literature has frequently shown that the three constructs of subjective norms, attitudes, and perceived behavioral controls do not equally contribute to the prediction of intentions and in many cases only one or two of the three constructs significantly affect intentions (Ajzen, 1991; Fishbein & Ajzen, 2011; Le Dang et al., 2014). In my study, I found a lack of statistically significant relationship between the factor PBC-ATT7, which includes perceived behavioral control-designated items, and intention to pursue “earning revenue outside the Rafsanjan Plain” behavior among pistachio growers in Rafsanjan. This lack of relationship has been reported previously in the literature (Johe & Bhullar, 2016). In particular, Senger et al. (2017b), using structural equation modeling, did not find perceived behavioral control as a statistically significant predictor of farmers’ intentions to diversify agricultural production.

Factors Affecting Rafsanjani Pistachio Growers’ Attitudes Toward Income Diversification

As shown in the previous section, among three factors of ATT_i (instrumental attitude), ATT_{ii} (affective attitude), and PBC-ATT7, ATT_{ii} (affective attitude) was found to be the strongest predictor of both intentions to use and the use of “earning revenue outside the Rafsanjan Plain” behavior among pistachio growers. In this section, determinants of ATT_{ii} (affective attitude) are explored by performing a linear regression analysis (data are not shown). The results showed that two variables of livestock ownership and pistachio orchard area accounted for 30% (Adjusted R Square = 0.30) of the variance in ATT_{ii} (affective attitude). That is, pistachio growers who owned livestock (β = - 0.59) and those who possessed larger pistachio orchards under irrigation (β = -0.39) were more likely to hold negative attitudes toward the "earning revenue outside the Rafsanjan Plain" behavior (i.e., they were more likely to score lower on three items that measure the factor ATT_{ii} (affective attitude)). As a possible explanation, this finding might suggest that Rafsanjani farmers with livestock and larger pistachio orchards have stronger place and/or job attachments, or a lower need for income diversification. These farmers therefore will develop attitudes that disfavor external employment. On the other hand, the remaining farmers in Rafsanjan who do not have many attachments to either place or their farming livelihoods, or have fewer assets generally, may share attitudes that favor diversifying their income sources by traveling outside the Rafsanjan Plain. I want to emphasize this explanation is a hypothesis, and, clearly, this hypothesis remains to be tested in future research on the impact of the variables place and job attachments on the uptake of income diversification strategies in Rafsanjan.

SUMMARY AND CONCLUSIONS

Income diversification is an essential strategy for farmers living in arid and semi-arid countries, like Iran, to build their resilience to groundwater scarcity. However, cognitive barriers can prevent farmers from diversifying their income sources in response to groundwater scarcity, as farmers traditionally do not view income diversification as their preferred livelihood strategy and policy makers tend not to promote diversification as a rural development policy. There are, nevertheless, a few studies in the literature that explore income diversification in response to groundwater scarcity using a behavioral approach, suggesting that psychological variables may be instrumental in determining farmers' choice of strategies.

Considering the challenges associated with conducting behavioral research (e.g., human behavior complexity, difficulties with instrument design), Floress et al. (2018) recommend that this type of research should be theoretically grounded. A review of environmental psychology papers (Moore & Boldero, 2017) showed that while cognitive factors, such as attitudes and moral norms, can predict the adoption of behaviors that face no or few barriers or constraints, a different approach is needed where there are constraints. Ajzen's Theory of Planned Behavior (TPB) (Ajzen, 1991) takes into account both cognitive factors and barriers. It is better suited for explaining behavior in the face of barriers or constraints, such as cost and effort. I selected the TPB as a basis for identifying psychological factors that influence farmers' income diversification in response to groundwater scarcity in this study because income diversification in response to groundwater scarcity by Rafsanjani farmers normally face constraints, such as costs, skills, information, etc.

In many studies, farmers' behaviors are explained and projected based on the rational actor theory (Schlüter et al., 2017). According to this line of research, the rational farmer has the information required to decide on his or her best possible future, which means he/she is totally free from misinformation, misperception, and biases, and has unlimited cognitive capacity. Therefore, the rational farmer is able to calculate and select the optimal possible groundwater-use trajectory that delivers maximum utility to him/her (van Duinen et al., 2016). However, researchers increasingly acknowledge that decisions are determined by both economic and non-economic drivers (Huber et al., 2018). A related decision-making theory is the TPB which shares some of the principles of the rational actor theory but takes into account the importance of subjective norms and the perceived behavioral control that an individual has on his/her behavior (Meyfroidt, 2013). The TPB is one of the most commonly used theories in many research fields, including social psychology and studies of farmer behavior (Russell & Fielding, 2010; Sutherland & Holstead, 2014). Several meta-analyses have supported the TPB's power to predict intentions and behaviors across a range of activities, including water conservation (Russell & Fielding, 2010; Steinmetz et al., 2016). In addition, the TPB based-behavior change interventions have led to change in behaviors (Montano & Kasprzyk, 2015).

I contribute to the knowledge on drivers of farmers' diversification by using the TPB (Ajzen, 1991, 2011), to develop and validate a scale to measure the determinants of income diversification decisions in response to groundwater scarcity. I expect my scale focusing on socio-psychological dimensions of decision-making will have wider applications beyond my case study, particularly as groundwater depletion threatens other farming regions globally. Measuring the cognitive orientation of farmers towards income diversification can provide insight into the potential for transformative livelihood change.

Conceptually, my work provides evidence in support of the use of the Theory of Planned Behavior as a basis for identifying and exploring socio-psychological factors that affect farmers' income diversification intentions and behavior in response to groundwater scarcity, rather than using the Theory of Planned Behavior as a predictive model (Burton, 2004; Colémont & Van den Broucke, 2008; Hall et al., 2019). Among the three the Theory of Planned Behavior's constructs of attitude, subjective norms, and perceived behavioral control, the most important predictor of both pistachio growers' intentions to use and actual use of income diversification behavior was their attitude (especially the affective attitude construct) toward income diversification, followed by perceived behavioral control (especially self-efficacy construct). I did not find that the subjective norm construct was a significant determinant of pistachio growers' intentions. These results underscore the significance of considering psychological constructs for promoting income diversification among pistachio growers and have implications for policies for sustaining farmers' livelihoods and groundwater resources. For example, in addition to economic incentives, there is a need to target attitude and perceived behavioral control by interventions toward income diversification (e.g., by using "persuasion", "information", and/or "increasing skills" interventions; for a complete list and discussion of behavior change methods, see Steinmetz et al. (2016)) that attempt to promote income diversification among pistachio growers in Rafsanjan. Future research should identify effective ways to change these attributes among Rafsanjani pistachio growers.

Another topic of research for future studies is the inclusion of more constructs to the TPB. Indeed, Ajzen (1991) sees the TPB as a model that is open to further constructs that increase its predictive power (Conner & Armitage, 1998). On average, Intention and PBC together predict 25% to 30% of the variance in behavior of interest (Kaiser, 2006). The TPB on average also explains 39% of the variance in Intention (Armitage & Conner, 2001). Therefore, to decrease these unexplained variances in Intention and Behavior, many researchers have added additional variables to the standard TPB model, including past behavior (Smith et al., 2007; Sommer, 2011), self-identity (Smith et al., 2007; van Dijk et al., 2016), belongingness (Pelling & White, 2009), and demographic variables

(Pelling & White, 2009). Finally, my findings also can serve as the basis for developing agent-based (Koutiva et al., 2019) and system dynamics (Ding et al., 2016) models to simulate farmers' income diversification decisions. These integrated water resources models can further be employed to explore the impacts of different social and economic interventions on the dynamics of farmers' income diversification behavior as well as the aquifer storage in Rafsanjan.

ACKNOWLEDGMENTS

The journal's editor, and reviewers provided helpful comments on an earlier version of this chapter/paper. Part of the questionnaire used in this study was developed in collaboration with Mohammad Reza Farzaneh and Ali Bagheri; they, along with the Iran Water Policy Research Institute, also helped with data collection.

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CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

SUMMARY OF MAJOR FINDINGS

This dissertation explored pistachio growers' adaptations to groundwater scarcity in the Rafsanjan Plain, Iran. Through adopting an integrated approach combining vulnerability and resilience frameworks, in Chapter 2, I developed a theoretical framework as a diagnostic tool for conceptualization and measurement of adaptation of a groundwater-dependent farmer to groundwater scarcity. The framework consists of three components: 'Social-ecological stressors', 'Groundwater-dependent livelihood system', and 'Response options' (see Table 5.1). Each component in turn includes some subcomponents/variables (see Table 5.1). In addition to the three components, I explored the impacts of two more components of farmers' background variables and structural factors on the adaptation of pistachio growers to groundwater scarcity (Table 5.1). In the following, first a summary of major conclusions of each chapter are provided, which are organized around the five components mentioned above (Table 5.1). Then, the overall conclusions of the dissertation are given.

Table 5.1

Factors considered in this dissertation to explore the adaptation of pistachio growers to groundwater scarcity

Component	Subcomponent/variable	Chapter	Nature of analysis
Social-ecological stressors	Perception of social-ecological stressors	Chapter 2	Qualitative
	Perceptions of the cause of changes in temperature and precipitation	Chapters 2 and 3	Quantitative
Groundwater-dependent livelihood system	Perceptions of the state of the groundwater resources	Chapters 2 and 3	Quantitative
	Perceptions of the negative impacts of stressors on the livelihoods	Chapter 2	Qualitative
	Perceptions of the future resilience of the livelihood to groundwater scarcity	Chapters 2 and 3	Quantitative
	Subjective norms about groundwater conservation	Chapter 2	Qualitative
Response options	Perceptions of the effectiveness of responses to groundwater scarcity	Chapter 2	Qualitative
	Perceptions of barriers to respond to groundwater scarcity	Chapter 2	Qualitative
	Information sources used by farmers for responding to groundwater scarcity	Chapter 2	Qualitative
	Perception of responses as a determinant of the adoption of these strategies	Chapter 4	Quantitative
Farmers' background variables	Age, Pistachio orchard ownership, Access to extension services	Chapter 2	Quantitative
	Level of education, Farming experience	Chapter 3	Quantitative
	Livestock ownership, Pistachio orchard area	Chapter 4	Quantitative
Structural factors	Knowledge difference between farmers and scientists	Chapter 2	Qualitative

Social-Ecological Stressors

- Most pistachio growers in Rafsanjan thought that their livelihoods were negatively under the influence of drought, water scarcity, or pests. At the same time, it seems that pistachio growers did not perceive the factors that have been established as the (root) causes of groundwater scarcity in Rafsanjan (e.g., excessive area under pistachio cultivation, illegal wells) as stressors to their livelihoods. I also found that most pistachio growers believed that human activities have not been causing changes in precipitation and temperature in Rafsanjan. Moreover, Chapter 3 showed that farmers who blamed changes in precipitation and temperature in Rafsanjan on anthropogenic causes were more likely to perceive a better condition for the state of the groundwater resources in Rafsanjan and therefore were less likely to increase groundwater extraction in Rafsanjan. Evidently, these findings show that misinformation and misperceptions have made pistachio growers fail to identify the root causes of the problems and attribute changes in precipitation and temperature in Rafsanjan to non-anthropogenic factors.

Groundwater-Dependent Livelihood System

- The study found that pistachio growers who perceived a worse state for groundwater resources in Rafsanjan were more likely to increase groundwater extraction. However, these growers were also more likely to seek external employment (income diversification).
- I found that, generally, negative impacts of stressors on the livelihoods can be categorized into the following groups: (1) ecologically-related impacts (e.g.,

‘‘Pistachio trees are dying’’; about 69%); (2) socioeconomic-related impacts (e.g., ‘Poverty’; about 28%); and (3) psychological impacts (e.g., ‘‘Stress and sadness’’; about 2%).

- It was found that seventy-six percent of farmers did not believe that their pistachio production businesses would continue to function in the face of water scarcity in the future (‘‘perception of the future resilience of the livelihood to groundwater scarcity’’). However, this perception was not a statistically significant predictor of groundwater overdraft or income diversification behaviors among farmers in this study.
- I found the majority of pistachio growers’ subjective norms and attitudes on the groundwater-dependent livelihood system in Rafsanjan favor short-term profit maximizing from pistachio production (and disfavor groundwater conservation for future use). This can be problematic given that the study also found that pistachio growers who held negative attitudes toward groundwater conservation were more likely to increase groundwater pumping rates.

Response Options

- I found most pistachio growers generally think that the strategy of “increasing groundwater extraction” and strategies involving income diversification are the most and least effective livelihood strategies to address livelihood stressors, respectively. Rafsanjani pistachio growers’ choice of and preference for groundwater overdraft-related responses over those strategies that involve groundwater conservation and income diversification raise serious questions about the long-term sustainability of the groundwater resources and pistachio production in the region. Furthermore, most Rafsanjani pistachio growers cited a lack of credit or information as the constraints that prevent them from responding to groundwater scarcity. Most of them have also relied on their personal experience or relatives as their information sources to respond to groundwater scarcity.

- In the present study, attitudes toward income diversification found to exert a strong influence on both intentions to pursue and the actual pursuit of income diversification among pistachio growers. In particular, I found that affective attitude was much more influential than instrumental attitude, subjective norm, or perceived behavioral control in predicting both the intentions to adopt and the adoption of income diversification behavior among pistachio growers.

Farmers' Background Variables

- This research (Chapter 2) showed that older pistachio growers, pistachio growers who were the owners of their orchards, and pistachio growers who had access to extension services were more likely to perceive a better state for the groundwater resources in Rafsanjan. This can be important considering I found also that pistachio growers who perceived a worse state for groundwater resources in Rafsanjan were more likely to increase groundwater extraction.
- This research (Chapter 3) found that attitudes toward groundwater conservation can be changed through education as farmers with more years of formal education were more likely to reduce groundwater extraction. However, formal education alone does not have the capability to significantly change attitudes toward groundwater conservation and it needs to be accompanied with noneducational

interventions (e.g., economic instruments). Farmers with more years of farming were also more likely to perceive a better condition for the state of the groundwater resources in Rafsanjan.

- Pistachio growers who owned livestock and those who possessed larger pistachio orchards under irrigation were more likely to hold negative attitudes toward the income diversification behavior. As a possible explanation, this finding might suggest that Rafsanjani farmers with livestock and larger pistachio orchards have stronger place and/or job attachments, or a lower need for income diversification. These farmers therefore will develop attitudes that disfavor external employment. On the other hand, the remaining farmers in Rafsanjan who do not have many attachments to either place or their farming livelihoods, or have fewer assets generally, may share attitudes that favor diversifying their income sources by travelling outside the Rafsanjan Plain.

Structural Factors

- Chapter 2 documented several subjects where pistachio growers in Rafsanjan and scientists possessed different knowledge systems. These knowledge differences between pistachio growers and scientists point to where the two knowledge systems need to be integrated. In order to build trust between the two knowledge systems, participatory communication and research involving both scientists and pistachio growers in Rafsanjan should be conducted.

DISSERTATION OVERALL CONCLUSIONS AND RECOMMENDATIONS

The overall conclusions of the dissertation and major lessons learned from conducting this dissertation research are the following:

Based on insights gained in Chapter 2, one might suggest using the policy option of information campaigns to create a sense of urgency by disseminating information on how negative the current state of groundwater resources in Rafsanjan is. However, as I argued in Chapter 3 this solution may actually encourage farmers to increase groundwater extraction. Instead, there is a need to correct farmers' views on the state of groundwater resources in Rafsanjan by hydrogeologists and other professionals working in groundwater trusted by Rafsanjani farmers. Still, this is not the whole story! I found in Chapter 3 that pistachio growers who perceived a worse state for groundwater resources in Rafsanjan were more likely to seek income diversification. Therefore, whether Iranian policies to increase awareness of falling water tables could succeed in securing water conservation would depend on the 'balance' of these two forces—an increase in pumping with increased pessimism or a potential decrease in pumping through income diversification.

While Chapter 3 linked groundwater resource-related perceptions (e.g., the perceptions of the state of depleting groundwater resources in Rafsanjan) to farmers' income diversification behavior, Chapter 4 concentrated on farmers' perception of income diversification as a determinant of the adoption of these strategies. Although perceptions of the state of the groundwater was found to be a significant determinant of income diversification, affective attitude toward income diversification was much more influential. Therefore, if it is possible to change either of those constructs (perceptions of the state of depleting groundwater resources vs. affective attitude toward income diversification) in order to promote income diversification, the latter perceptions would seem more promising.

This would also save policy makers from the unintended consequences of promoting income diversification among farmers through informing farmers of the serious state of groundwater resources in Rafsanjan. However, this would not be an easy job as farmers traditionally do not view income diversification as their preferred livelihood strategy and policy-makers tend not to promote diversification as a rural development policy. But, this could gradually change as the state of water resources in Rafsanjan is exacerbating over time.

This dissertation documented several instances pointing to pistachio growers' misinformation, misperception, or lack of knowledge with respect to a host of subjects (e.g., hydrology of groundwater resources in Rafsanjan), which can constrain farmers' adaptation to groundwater scarcity (Eakin et al., 2016; Rodriguez et al., 2017). These findings call for considering educational interventions on correcting farmers' perceptions about their groundwater-based livelihood system in Rafsanjan. However, this does not mean, regardless of the subject, providing farmers with information and knowledge comes with no unintended consequences. For example, as shown in Chapter 3, increasing awareness of falling water tables among farmers could result in the overdraft of groundwater resources.

Lastly, throughout this dissertation research, the author of this dissertation found over and over again that without acknowledging the heterogeneity of Rafsanjani pistachio growers with respect to many aspects, the associated modeling and policymaking can be too simplified and even misleading. Therefore, this heterogeneity should be acknowledged as a basis for developing targeted policies that aim at groundwater resource conservation and building the resilience of pistachio growers' livelihoods.

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APPENDIX A

CHAPTER 4 DATA ANALYSIS

Conducting Exploratory Factor Analysis (EFA)

In this study, following Williams et al. (2010), EFA was performed: (1) computing Kaiser-Meyer-Olkin and Bartlett's sphericity tests (the appropriateness of the data for EFA is determined by computing the Kaiser-Meyer-Olkin measure of sampling adequacy); (2) conducting principal components analysis; (3) determining the number of factors to be extracted as three (since I analyzed questions that altogether measured three latent variables of SN, PBC, and ATT, the number of factors to be extracted was three); (4) using the oblique rotation method (Direct Oblimin); and (5) giving the final factor a name/theme (based on questions present in each factor).

Construct Validity and Reliability of The Income Diversification Scale

In this study, to assess the convergent validity, discriminant validity, and construct reliability of the final factor solution, average variance extracted (AVE), the squared correlations between the extracted factors, and the composite reliability (CR) were calculated, respectively. In particular, convergent validity and discriminant validity are two aspects of the construct validity (Nestor & Schutt, 2018). AVE is an indicator of the convergent validity, which can be computed following Eq. 1 (Netemeyer et al., 2003). [20] AVE represents the average amount of variances in the observed variables that were explained by their related factors (Farrell, 2010). AVE values equal to or more than 0.5 indicate an acceptable convergent validity (Hair et al., 2010).

$$AVE = \frac{\sum_{i=1}^{k} \lambda_i^2}{k} \qquad \text{(Eq. 1)}$$

Where

[20] - This is an equation for the calculation of the average squared factor loading, a simpler AVE (Netemeyer et al., 2003).

k is the number of observed variables/questions

λ_i is the factor loading for the *i*th observed variable/question

To establish the discriminant validity of the factors, the squared correlations between the factors should be greater than their corresponding AVE values for the factors (Fornell & Larcker, 1981). Lastly, Eq. 2 was used to compute CR (Hair et al., 1998). CR is the variance shared among the questions that measures a factor (Fornell & Larcker, 1981). CR estimates the reliability of constructs more accurately than Cronbach's alpha— as a traditional test of reliability— since it takes into account observed variables' various loadings (Ravens, 2013).

$$CR = \frac{(\sum_{i=1}^{k} \lambda_i)^2}{(\sum_{i=1}^{k} \lambda_i)^2 + (\sum_{i=1}^{k} \delta_i)} \quad \text{(Eq. 2)}$$

Where

λ_i is the factor loading for the *i*th observed variable (question)

δ_i is the error variance for the *i*th observed variable (question)

$\delta_i = (1- \lambda_i^2)$

<u>Conducting Structural Equation Modeling</u>

I used structural equation modeling (SEM) to evaluate the structure of relationships between the factors provided by the EFA. SEM is a multivariate technique that combines elements from multiple regression, path analysis, factor analysis, and other techniques for testing models for dependency (and in some sense causal) relations between observed and latent variables (Dilalla, 2000; Foster et al., 2006; McDonald and

Ho, 2002). However, SEM is different from other statistical techniques due to several aspects, including its capability to estimate and correct for measurement errors, and its ability to incorporate both observed and latent variables in modeling (Byrne, 2010; Sengupta & Kundu, 2016). A general (full or complete) SEM model is composed of two sub-models: a measurement model and a structural model (Anderson & Gerbing, 1988). A measurement model concerns the relations between latent variables and their observed variables, which is developed using confirmatory factor analysis. The structural model, on the other hand, subsequently defines links among the latent variables (Byrne, 2010; Marsh et al., 2014; McDonald & Ho, 2002; Schumacker & Lomax, 2004).

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