Exploring farmers' perceptions about their depleting groundwater resources using path analysis: implications for groundwater overdraft and income diversification

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PAPER

Exploring farmers' perceptions about their depleting groundwater resources using path analysis: implications for groundwater overdraft and income diversification

Seyyed Mahmoud Hashemi[1] · Ann Kinzig[1] · Joshua K. Abbott[2] · Hallie Eakin[2] · Reza Sedaghat[3]

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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. 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 paper 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.

Keywords Groundwater management · Common-pool resources · Income diversification · Iran · Socio-economic aspects

Introduction

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 withdrawals 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). Therefore, in many regions worldwide, groundwater resources are being abstracted faster than they are being recharged, resulting in water scarcity and quality-related issues (Megdal 2018; Gleeson et al. 2020). 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 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 Fig. 1, Iran was among the top five groundwater exploiters in the world; it was also among the top three countries in the world

✉ Seyyed Mahmoud Hashemi
shashem9@asu.edu

[1] School of Life Sciences, Arizona State University, 427 East Tyler Mall, Tempe, AZ 85287, USA

[2] School of Sustainability, Arizona State University, Tempe, USA

[3] Horticultural Sciences Research Institute, Pistachio Research Center, Agricultural Research, Education and Extension Organization (AREEO), Rafsanjan, Iran

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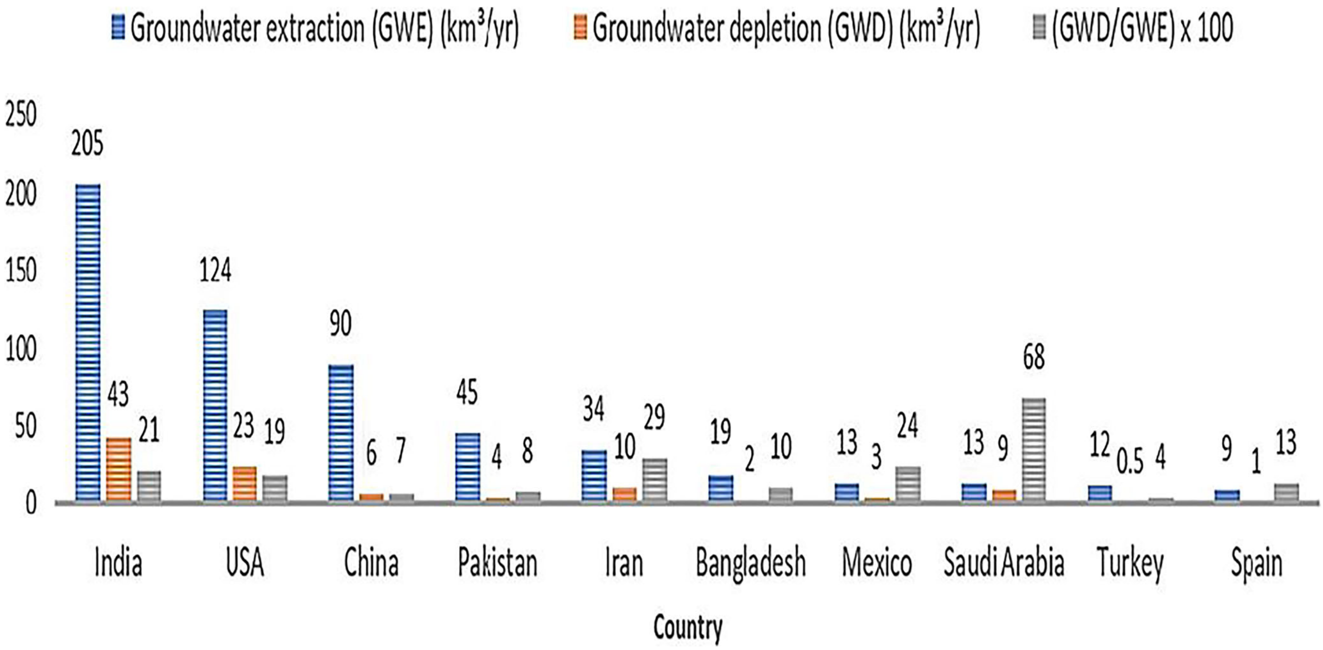

Fig. 1 The average annual groundwater extraction, depletion, and fraction of groundwater depletion over the groundwater abstractions, over the years 2000–2009, by the top 10 countries in the world (source of data: Doll et al. (2014))

in terms of groundwater depletion rates (with an annual average of 10 km^3 groundwater depletion rate). Figure 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 (Scott and Shah 2004; Madani 2014; Hashemi et al. 2017; Nabavi 2017; Valizadeh et al. 2019).

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 and 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; Moridi 2017; Tasnim 2016; Mirzaei et al. 2019).

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 paper, 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 2012; Zeraatkar and Golkar 2016; Mirnezami et al. 2018; Nabavi 2018). 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 paper). 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 (Gardner et al. 1990; Anderson et al. 2002). 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 and 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 (O'Connor et al. 1999; Bluemling et al. 2010). When a common-pool resource (e.g., groundwater resources) becomes scarce, people tend to take a conservative approach toward the use of the resource (Samuelson et al. 1984; Rutte et al. 1987; Zaikin et al. 2018; Liu and Hao 2020). 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; Wolf 1999; Cuadrado-Quesada 2014)—for instance, groundwater overuse and salinity (along with community leadership and government involvement) in Angas Bremer, in Australia, lead to the participation of the 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 (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 and 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 (Grossman and Mendoza 2003; Maldonado et al. 2009; Blanco et al. 2015; Cerutti and Schlüter 2019; 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 noncooperative 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. (1999) 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; additionally, uncertainty can also justify a noncooperative 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 and 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 aforementioned 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 knowledge of authors of this paper, 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 and 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 and Shah 2005).

There are five policy options that are commonly used globally 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 in the preceding (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 and Samuelson 1999).

In this paper, 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 are examined. Although the focus of this paper is on the Rafsanjani farmers' groundwater overdraft strategy ("increasing groundwater extraction"), the link between the same aforementioned 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. 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 (Fig. 2) is in Kerman Province, in the southeast of Iran. It is the center of pistachio cultivation in the world (Hassanshahi and 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 and 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).

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 and 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 and Ramazani Sarbandi 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 and 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

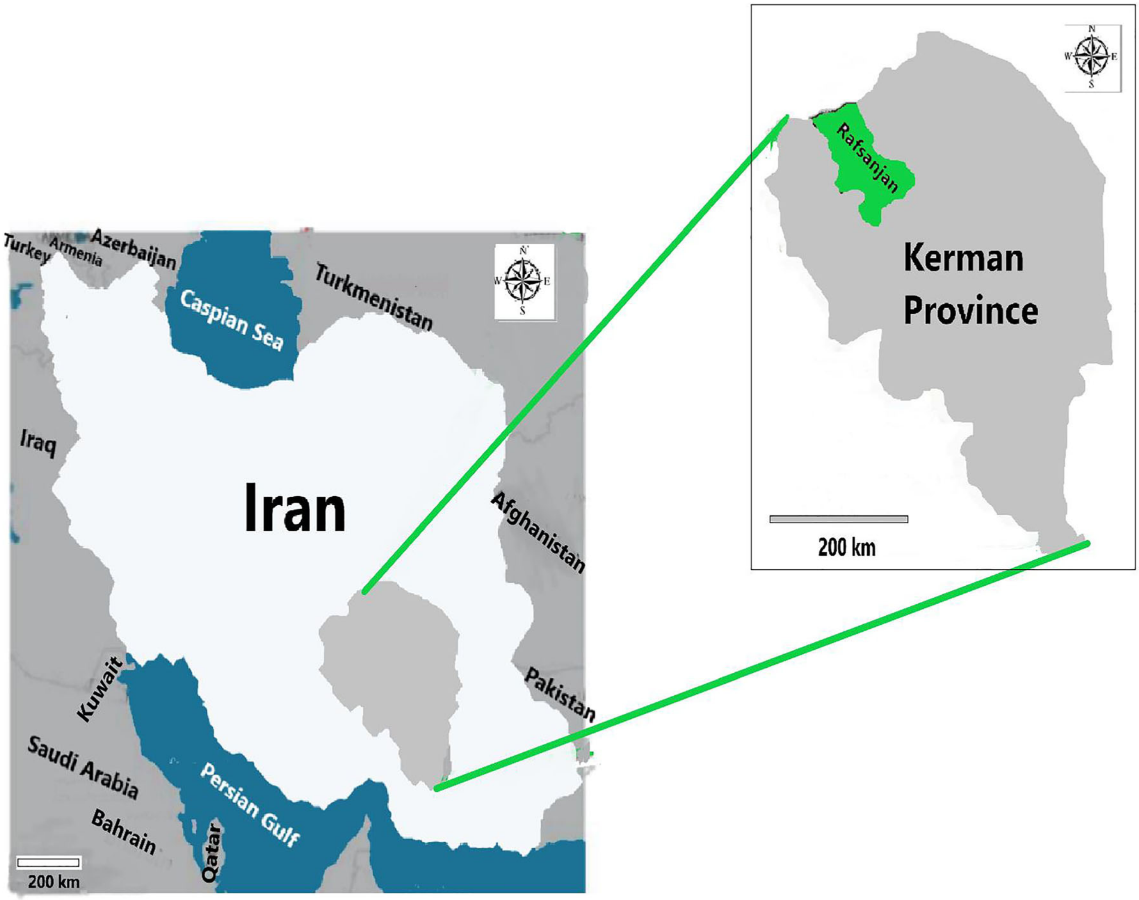

Fig. 2 The location of the study area: Rafsanjan Plain in Kerman Province, in southeastern Iran (adapted from Mirshekar et al. 2020)

million m^3/year could be sustainably extracted (extraction = recharge). In 2015, water extraction was above 737 million m^3/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 (Sedaghat 2002; Parsapour-Moghaddam et al. 2015). 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. Also, in Rafsanjan cultivation of low-water crops (e.g., saffron, barberry, jujube, medicinal plants, and borage) have been expanding. For example, currently, 2 ha of barberry, more than 30 ha of saffron, and 5 ha of borage have been planted in Rafsanjan (IRNA 2019). In addition, some Rafsanjani farmers (in Rafsanjan County, out of about 65,000 ha of pistachio cultivation area, about 12,000 ha) have switched from the flood irrigation method, which has the irrigation efficiency of 40–45%, to the pressurized irrigation system (e.g., drip irrigation), which has an irrigation efficiency of 85% (ISNA 2019).

Path model

Figure 3 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 paper's knowledge of the study area, the scholarly literature (as discussed here and previously), and this study's main purpose (the impact of perceptions about groundwater resources on the uptakes of groundwater

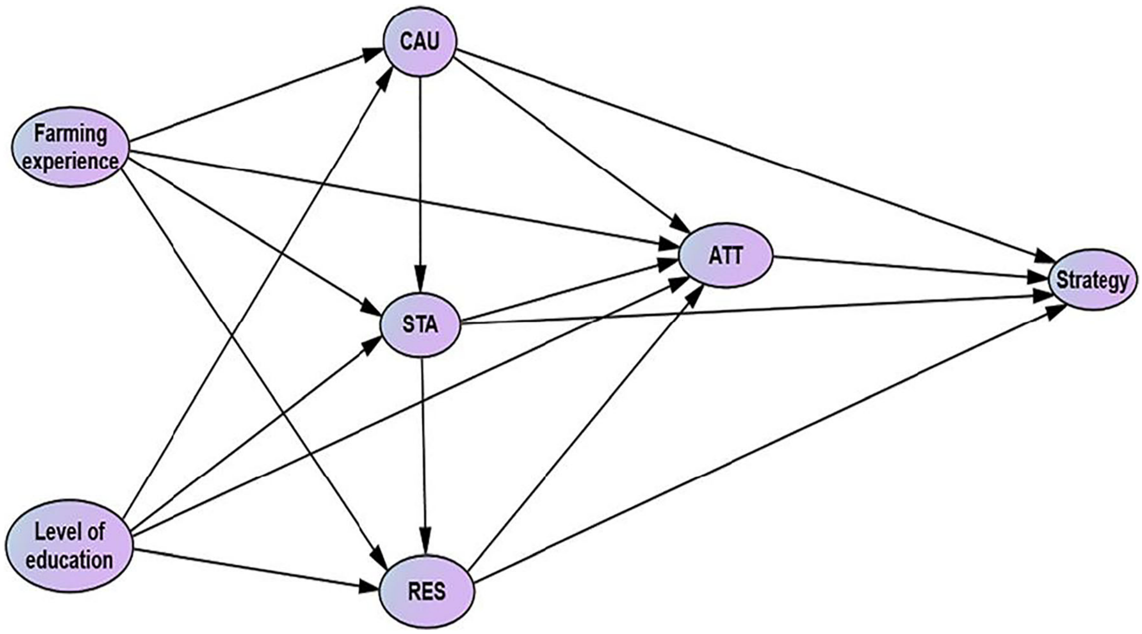

Fig. 3 Hypothesized path model of the relations among variables that affect Rafsanjani farmers' uptakes of two (separate) strategies of "increasing groundwater extraction" and "earning revenue outside the Rafsanjan Plain" (strategy). Note: CAU = perceptions of the cause of changes in precipitation and 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 1 for details on the measurement of variables

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) (Fig. 3). It is hypothesized that education and farming experience may influence each of these four variables (Fig. 3). Various other influences were hypothesized as well (e.g., CAU influence STA). Table 1 describes the measurement of variables in this study.

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 (Fig. 3) 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 Fig. 3 there is a causal chain between CAU ("beliefs"), STA and RES ("risk Perceptions"), ATT ("norms"), and strategy ("behaviors") (Sanderson and Curtis 2016).

The variable STA, CAU, and RES were selected to represent perceptions of the groundwater resources in this study (Fig. 3; Table 1). As thoroughly discussed in the preceding, 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 nonanthropogenic causes), farmers may differently perceive the state of the groundwater resources (Fig. 3; Table 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 nonanthropogenic factors, they are less likely to limit their groundwater use (Grothmann and Patt 2005; Le Dang et al. 2014; Eakin et al. 2016; 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 and Curtis 2016). For example, in a study that explored farm-level groundwater management in Australia by using the VBN theory (Sanderson and 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) found that

Table 1 Description of how variables that are represented in the path model, depicted in Fig. 3, 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

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 Fig. 3 as well as Table 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 and Samuelson 1997; Van Dijk and 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 and 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 of level of education and farming experience were selected to represent farmer knowledge (Fig. 3). 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 proenvironmental 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 and 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 (Fig. 3), a questionnaire was used. Table 1 provides a summary of the questionnaire used in this paper and it also contains a descriptive characteristic/statistics of the variables measured by the questionnaire. The items/questionnaire that are drawn upon in this paper 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. Prior to administering the survey, a brief overview of the research’s purpose was communicated to each farmer; moreover, 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 30–70% ratio, consistent with the actual ratio in the Rafsanjan Plain (Sedaghat 2002; Abdollahi 2007). To further ensure that this paper’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., Javanshah et al. 2003; Jamali Jaghdani 2012; Jafari Mahdi Abad et al. 2016). 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., Sedaghat 2002; Jafari Mahdi Abad et al. 2013), 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 paper 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 and 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 Fig. 3, 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 illustrated in Fig. 3; Sanderson and 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 Fig. 3) on a dependent variable (e.g., ‘strategy’ in Fig. 3). Each indirect effect in the model characterizes the contribution of the independent variable (e.g., STA in Fig. 3) to the dependent variable (e.g., ‘strategy’ in Fig. 3) through another independent variable(s) (e.g., ATT in Fig. 3; 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 paper, the term 'path analysis' refers 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 and 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 (Anderson et al. 1995; Alemu and Shea 2019). 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., Polymeros et al. 2010; Hashimoto et al. 2012), 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 the following). 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), semistandardized path coefficients (beta weights) were computed based on the mean of the predicted probability and the standard deviation of $X_1, ..., X_n$ (Eq. 1).

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 Fig. 3 and described in Table 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. (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.

$$\text{Logit}\ (Y) = \ln\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n \qquad (1)$$

More specifically, to specify the model, six separate binary logistic regression analyses were performed to test the hypothesized path diagram (shown in Fig. 3). Table 2 describes in detail the dependent and independent variables used in each of the six logistic regression models. The Nagelkerke R Square statistics were used, ranging 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.

Results and discussion

Factors affecting Rafsanjani pistachio growers' decisions to increase groundwater extractions from their existing wells

Table 3 shows a summary of the correlation matrix among all variables represented in the hypothesized path model, shown in Fig. 3, 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, 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 the "earning revenue outside the Rafsanjan Plain" strategy and vice versa.

Of the paths/path coefficients depicted in the path model (Fig. 3 shows the paths), as illustrated in Fig. 4, six paths/path coefficients were significant: the paths from (1) ATT to strategy I; (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.

As shown in Fig. 4, 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 (Fig. 4; Table 4). Variables of STA and years of education are directly associated with ATT (Fig. 4; Table 4). That is, farmers who evaluated the water resources in Rafsanjan as better and farmers with more years of formal

Table 2 Descriptions of six binary logistic regression analyses performed in this study to test the path model given in Fig. 3. 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

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 (Fig. 4; Table 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 in the following.

> "When I see someone who is [right] next to me pumping 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, unpublished data, 2020). Therefore, creating a sense of urgency by disseminating information on how negative/serious the current/future state of groundwater resources in Rafsanjan is 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 (Fig. 4; Table 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 (Fig. 4; Table 4). That is,

Table 3 Phi/point-biserial correlation coefficients among the variables in the path model (Fig. 3). 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***	0.04	–
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 $p < 0.01$

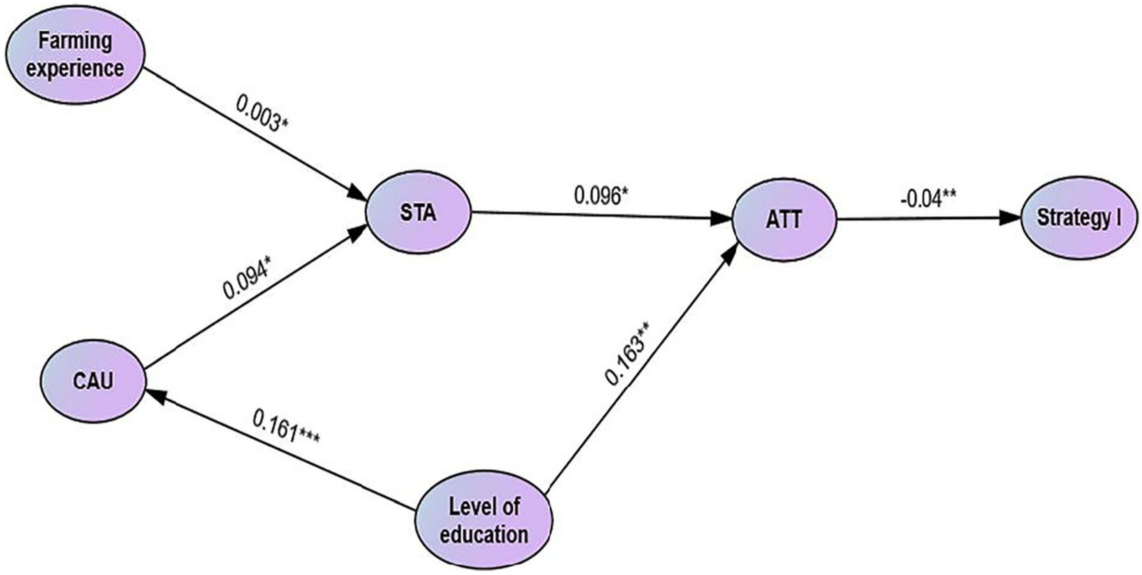

Fig. 4 A reduced (final) path model of factors affecting Rafsanjani pistachio growers' uptake of strategy I (increasing groundwater extraction). Note: CAU = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; STA = perceptions of the state of the groundwater resources in Rafsanjan; and ATT = attitudes toward groundwater conservation. Numbers adjacent to the lines are semistandardized path coefficients; * Significant at $p < 0.10$; ** Significant at $p < 0.05$; *** Significant at $p < 0.01$

farmers with fewer years of formal education were more likely to blame changes in precipitation and temperature in Rafsanjan on nonanthropogenic causes.

Table 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 I). As shown in Table 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 4). However, the variables in the path model explained little of the variance in STA and CAU (see Nagelkerke R Square statistics in Table 4), clearly indicating that some other variables not considered in the model were responsible for the substantial remaining unexplained variance.

Table 4 Semistandardized 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 in Rafsanjan; and *ATT* = attitudes toward groundwater conservation. The direct effects indicate the effects (or the semistandardized 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 semistandardized path coefficients from one variable to another. Total effects can be calculated as the sum of the direct and indirect effects (or the semistandardized path coefficients); the *Nagelkerke R Square statistic* represents the total variance explained by the models; the path model is shown in Fig. 4

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

Table 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 $p < .10$

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

Table 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.

As shown in Fig. 5, in contrast to the "increasing groundwater extraction" strategy (Fig. 4), 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).

One variable is directly associated with the likelihood of Rafsanjani pistachio growers' earning revenue outside the Rafsanjan Plain: STA (Fig. 5). 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 (Fig. 5).

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 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 nonanthropogenic causes, and farmers with less years of formal education were more likely to be involved in earning revenue outside the Rafsanjan Plain.

Summary and conclusions

This paper has shown the impact of perceptions about groundwater resources in Rafsanjan among Rafsanjani pistachio growers, Iran on the uptake of two (separate) strategies of

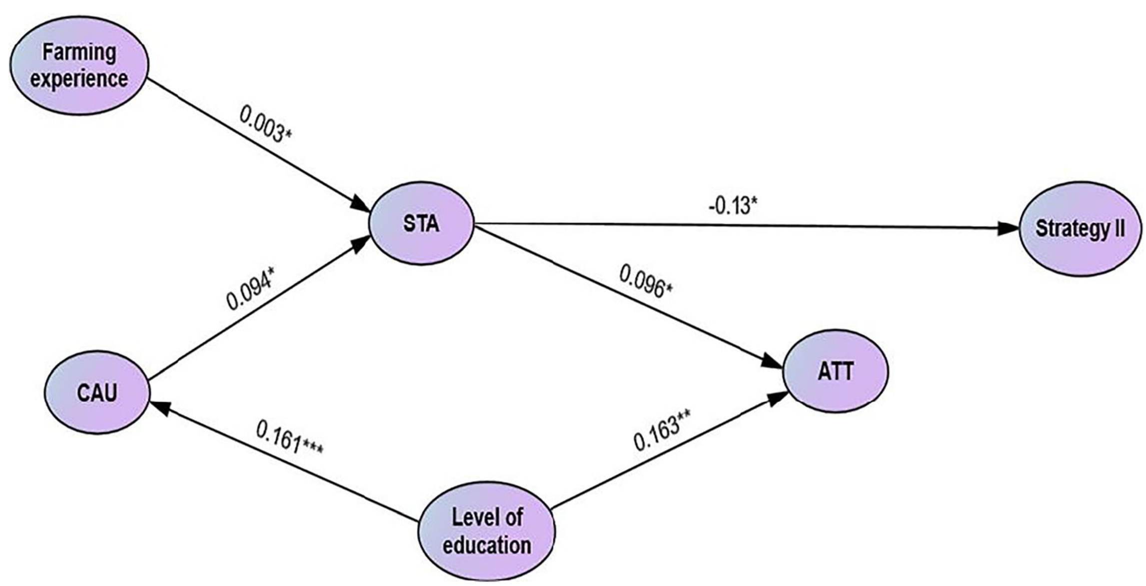

Fig. 5 A reduced (final) path model of factors affecting Rafsanjani pistachio growers' uptake of strategy II ("earning revenue outside the Rafsanjan Plain"). Note: *CAU* = perceptions of the cause of changes in precipitation and temperature in Rafsanjan; *STA* = perceptions of the state of the groundwater resources in Rafsanjan; and *ATT* = attitudes toward groundwater conservation. * Significant at $p < 0.10$; ** Significant at $p < 0.05$; *** Significant at $p < 0.01$

Table 6 Semistandardized 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 Fig. 5

Variable	Total effect on strategy II
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

"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 noneducational interventions (e.g., economic instruments). Previous research has found that financial incentives can motivate farmers to reduce water consumption (Ding and Peterson 2012 cited in Sanderson et al. 2017).

The Rafsanjani farmers' negative subjective norms (Hashemi, unpublished data, 2020) 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 following 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.

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