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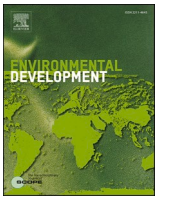

Digging in the shadows: A grounded theory study on the drivers of illegal well drilling in southern Iran

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ABSTRACT

The agricultural sector is the largest consumer of water resources in Iran. Due to the country's physical and geographical constraints, groundwater overexploitation has intensified, making illegal well drilling an increasingly critical and uncontrolled national issue. This study investigates the underlying causes of illegal well drilling in Bushehr province using a qualitative grounded theory approach. Data was collected through in-depth, open-ended interviews, document analysis, and observations. The study's statistical population comprised farmers with water wells and experts from relevant organizations. Using snowball sampling, data collection continued until theoretical saturation was reached, resulting in a total of 53 interviews (23 farmers and 30 experts). The grounded theory analysis followed three coding stages: open, axial, and selective coding. Open coding yielded 322 concepts, which were refined into 21 categories during axial coding. Ultimately, a paradigm model of the drivers of illegal well drilling in southern Iran was presented including the main phenomenon, contextual conditions, causal conditions, intervening conditions, strategies, and consequences. Providing a comprehensive conception of the subject, the findings can pave the route for mitigating illegal well drilling and promoting sustainable groundwater management.

1. Introduction

Groundwater is a vital water resource with a hidden yet highly vulnerable nature, widely utilized across domestic, industrial, and agricultural sectors in both rural and urban communities. In other words, it plays a crucial role in daily life (Rahimi-Feyzabad et al.,

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2021, 2022a, 2022b; Conti et al., 2016). Beyond its essential function, groundwater also provides significant economic benefits, including fostering economic growth, supporting rural development, and generating employment opportunities. Moreover, it contributes to income stabilization and sustains the livelihoods of poor farmers, reducing migration during droughts by enhancing income security. Additionally, it mitigates agricultural risks and enables small-scale farmers to invest in modern technologies, leading to higher yields and improved productivity. It is estimated that approximately 70 % of the global extracted groundwater is applied for agricultural purposes. This dependence is even more pronounced in arid and semi-arid regions of the world (Hora, 2022). However, the rapid and largely unregulated expansion of groundwater use in agriculture has led to substantial social and economic consequences (Rahimi-Feyzabad et al., 2021; Pietersen, 2005). As it predominantly impacted societies and economies without attracting much public attention, the widespread extraction is also referred to as a "silent revolution" (Llamas & Martínez-Santos, 2005a, 2005b).

A striking example of this phenomenon is Iran, located in an arid and semiarid region (Ataei et al., 2018). Despite Iran's heavy investment in the water sector in order to mitigate water paucity and prevent crises (Izadi et al., 2019; Boazar et al., 2019), it ranks fifth globally in annual groundwater extraction for irrigation. Since the 1960s, the proliferation of water pumps and irrigation wells has contributed to a continuous decline in groundwater levels across the country (Rahimi-Feyzabad et al., 2021; Tatar et al., 2019; Nabavi, 2018). In Iran, approximately 75 % of the irrigation required for agriculture, particularly in the central and southern regions, is supplied by groundwater (Yazdanpanah et al., 2013a, 2014, 2013b). The overexploitation of groundwater resources has been driven by several factors, including limited water availability, uneven water distribution across the country, population concentration in arid and semi-arid regions, increasing water demands, and low water-use efficiency in the agricultural sector (Moghaddasi et al., 2008; Mohammadjani and Yazdanian, 2014).

The rising extraction of groundwater in Iran involves both legal and illegal withdrawals. Official reports indicate that nearly 50 % of groundwater extractions occur without proper authorization, as many farmers resort to digging wells and using unauthorized methods to expand their agricultural activities (Novo et al., 2015). Current statistics reveal that there are approximately 770,000 wells in Iran (Economy of Iran, 2016), collectively withdrawing 58 billion cubic meters of water annually (Kalantari, 2015). Of these, only 440,000 wells are legally authorized, while the remainders operate illegally (Chavoshi, 2014).

The rapid increase in well drilling in recent years has escalated into a nationwide and largely uncontrolled issue (Ansari, 2013). To safeguard groundwater resources and address growing water demands, it is imperative for responsible institutions and organizations to prioritize the promotion of sustainable and just water consumption and the conservation of existing resources. Additionally, the enactment of new regulations should enhance monitoring efforts (Molden et al., 2001) and help prevent unauthorized well drilling and excessive groundwater extraction.

A straightforward approach to mitigating this issue is the closure and restriction of illegal wells. However, such measure could have detrimental effects on some users and areas with limited water access. Also, many researchers (Giordano et al., 2013; World Wildlife Fund, 2006; Foster and Loucks, 2006; Bakhshi Jahormi et al., 2014; Khair et al., 2015; Velayati, 2014) highlighted the failure of policies designed to achieve sustainable groundwater management and curb over-extraction. The persistence of illegal groundwater use presents a significant challenge for policymakers and decision-makers due to complex social, economic, and political considerations.

Thus, before implementing any measures, it is crucial to obtain a comprehensive understanding of the factors driving farmers to engage in such practices. In order to acquire a profound and comprehensive insights into this issue, this study aims to investigate the causes of illegal well drilling in Bushehr Province, located in southern Iran applying a qualitative grounded theory approach. Despite the importance of examining the factors influencing unauthorized well drilling, to the best of the authors' knowledge, neither deep nor comprehensive study has addressed this issue in previous research specifically in this region. Providing a paradigm model in this research not only could fill the noted gap, but also may make theoretical contributions in this issue.

2. Background

Groundwater, the world's second-largest source of freshwater, is stored within the water-saturated layers beneath the Earth's surface. Global water resource assessments indicate that groundwater accounts for approximately 0.6 % of total water reserves and 60 % of renewable accessible resources. Around one-third of the world's population relies on groundwater, with over 70 % of it being used for agricultural purposes. In Iran and other countries with similar climatic conditions, groundwater is one of the most critical sources for both agriculture and drinking water (Jokar and Masoudi, 2017).

Numerous studies have documented the unauthorized use of groundwater resources. Khair et al. (2015) found that prolonged droughts, particularly in arid regions, have led to an increase in well drilling. Bakhshi Jahromi et al. (2014) noted that during droughts, agricultural production is constrained by water scarcity, particularly in regions with inadequate rainfall and limited water accessibility. Consequently, groundwater withdrawals in such areas have intensified, often exceeding natural recharge rates. Similarly, research conducted by Novo et al. (2015) in Spain revealed that following the droughts of the 1950s–1990s, the failure to close newly constructed illegal wells served as an incentive for farmers to compensate for income losses incurred during dry periods.

De Stefano and Lopez-Gunn (2012) emphasized that unauthorized water use is a multifaceted issue deeply embedded in cultural and ethical norms, shaping both individual and collective behavior among groundwater users. However, the primary motivation for unauthorized withdrawals is economic gain as several studies have shown (Holtz and Pahl-Wostl, 2012; Sharzeie and Amirtaimoori, 2012). The financial incentives associated with groundwater use encourage widespread illegal extraction, particularly in regions with scarce water resources (World Wildlife Fund, 2006).

Several factors contribute to the unauthorized use of groundwater. First, in agricultural contexts, the economic benefits of illegally sourced water are evident. High-value crops such as fruits and vegetables generate significant profits (Novo et al., 2015) and remain

highly competitive in the market. Second, these crops tend to have higher yields per hectare, further incentivizing groundwater withdrawals. Third, access to water directly increases land value. For example, in Spain, the price of agricultural land has risen by 1.5 times for vineyards and doubled for olive groves due to water availability (De Stefano and Lopez-Gunn, 2012). Fourth, in certain countries, particularly in Europe, government subsidies indirectly encourage higher production levels for specific crops (Novo et al., 2015; Ross and Martinez-Santos, 2010).

Holtz and Pahl-Wostl (2012) simulated groundwater withdrawal scenarios in Spain's Guadiana Basin and found that the potential profits from horticultural crop cultivation serve as a powerful incentive for farmers, while crop diversification reduces financial risk. Similarly, studies by Novo et al. (2015) and Aldaya and Llamas (2013) on the western La Mancha aquifer demonstrate that illegal water use is most prevalent in grape and vegetable production (including horticultural and greenhouse crops). Even in cases where agricultural policy prohibits the granting of new water rights, economic incentives have driven continued illegal groundwater extraction due to higher productivity and efficiency per cubic meter of water used.

In summary, the factors driving unauthorized groundwater use can be categorized as follows.

2.1. The inherent nature of groundwater

Groundwater, a reliable and less vulnerable water source amid climate change, requires significantly lower investment than surface water systems, which involve costly infrastructure such as canals and dams (Garrido et al., 2006). This accessibility allows farmers and agricultural workers to extract groundwater without relying on public investments (De Stefano and Lopez-Gunn, 2012).

Unlike rainfed or surface-irrigated lands, where farmers have little control over water availability, groundwater provides a more stable supply. Unreliable rainfall increases the risks associated with investing in crop production, potentially leading to significant financial losses. Many small-scale farmers take out high-interest loans to expand their operations, and in cases of crop failure, they may face permanent debt, loss of land, and forced labor under contract farming (Burke and Moench, 2000).

Groundwater access mitigates these risks by ensuring a stable water supply, supporting high-value crop production (Llamas and Custodio, 2003), and contributing to economic growth while reducing poverty (Hoogesteger and Wester, 2015). However, because groundwater extraction and its negative effects are not immediately visible (Hammani et al., 2009), this has facilitated overuse and unauthorized exploitation of scarce resources (Bakhshi Jahormi et al., 2015).

2.2. Lack of transparency and ineffectiveness of laws and policies

Basic regulations are generally established to manage access to resources and maintain a balance between supply and demand among different users sharing common resources (Yaghobi et al., 2014). However, legal tools often fall short in achieving the protection and long-term sustainability goals of resource management (De Stefano and Lopez-Gunn, 2012). The lack of written legislation and policy for groundwater management could culminate in harvesting illegal groundwater and consequently over-exploiting (Yong et al., 2018). Water laws are designed as tools for government management of common resources, aiming to identify illegal water users who undermine planning efforts and official oversight (De Stefano and Lopez-Gunn, 2012).

These laws and regulations must be transparent, comprehensive, fair, and non-interpretable. Ideally, well-implemented, region-specific water laws would minimize issues (Velayati, 2014). However, it remains debatable whether simply passing the necessary laws is enough to safeguard public interests or demonstrate governmental authority (Ansari, 2013). Moreover, laws that are complex and ambiguous do not guarantee success in balancing supply and demand or in protecting water resources (De Stefano and Lopez-Gunn, 2012), particularly when they are insufficient or unsuitable for managing groundwater effectively (EASAC, 2010). The complexity of water laws often hinders the sustainable management of groundwater (Bakhshi Jahormi et al., quoted by Madani and Dinar, 2014).

Furthermore, in many cases, existing laws apply mainly to surface water and are ineffective in addressing the rapid increase in groundwater exploitation (EASAC, 2010). In fact, many countries lack coherent groundwater management policies or comprehensive water laws that focus specifically on groundwater (Nanni et al., 2006). Even where laws have been enacted, inadequate infrastructure and lack of appropriate conditions have led to poor implementation, resulting in numerous challenges (Ansari, 2013).

In Iran, a major issue lies in illegal well drilling, particularly in water-scarce areas. Although authorities have attempted to address this with laws and executive directives, these policies have instead facilitated further abuse of groundwater resources (Velayati, 2014). One example is the "Status Determination of Wells Without Exploitation License" law, which was criticized for being non-comprehensive and lacking expert input. This law inadvertently encouraged the drilling of illegal wells (Bakhshi Jahormi et al., 2015; Ansari, 2013). According to expert assessments, this law has had little impact on protecting groundwater resources, with its implementation deemed weak. It led to around 103,000 unauthorized wells being retroactively legalized without considering the ecological capacity of the region (Khatoonabadi and Ziaee, 2015).

The lack of coordination between agricultural and water policies has further exacerbated the ineffectiveness of laws. For instance, the Spanish government's irrigation incentive programs for profitable crops, such as grapes and vegetables, ran counter to the 1990 ban on new water rights allocation. This policy contradiction encouraged illegal groundwater use for irrigation (Novo et al., 2015).

In Balochistan, Pakistan, while efforts have been made to regulate groundwater, challenges have arisen due to the availability of subsidies, which incentivize well drilling (Khair et al., 2015). These subsidies have undermined monitoring laws and policies designed to manage groundwater sustainably.

Breaking the law, even when justified by complex circumstances, erodes government credibility and authority, further complicating the management of common resources. When governments lose their credibility, they struggle to protect public interests and the environment, reducing their effectiveness in managing vital resources (De Stefano and Lopez-Gunn, 2012).

2.3. Implementation of incentive policies of subsidies

Unfortunately, the implementation of agricultural policies has had limited impact on curbing the illegal increase in resource usage. In fact, it has failed to reduce the practice. Currently, agricultural subsidies are provided for deep wells without any monitoring or investigation into whether these wells are licensed (World Wildlife Fund, 2006). These subsidy policies have, in fact, played a role in promoting the expansion of groundwater use. While successful in boosting agricultural production, they have also led to the increased cultivation of high-water-demand crops such as fruits and vegetables, which are of significant economic value. For instance, apple farming in India saw rapid growth, resulting in the rise of the "apple economy," with returns 4 to 5 times higher than conventional grain crops. The implementation of these policies, along with the improvement of communication networks, created strong incentives for farmers to increase the number of wells and extract more water to meet their demands (Khair et al., 2015). Essentially, these policies have employed financial mechanisms and incentives that encourage farmers to dig illegal wells, deepen existing ones, and exploit groundwater as much as possible (Khatoonabadi and Ziaee, 2015; Mohammadjani and Yazdanian, 2014).

2.4. Inefficiency of structures and institutions

One of the primary roles of water institutions and authorities worldwide is to implement necessary measures for the sustainable use of existing resources and to ensure their long-term viability (De Stefano and Lopez-Gunn, 2012). These institutions are responsible for eliminating incentives for illegal water use (World Wildlife Fund, 2006) and for providing appropriate solutions through cooperation with legal water users (De Stefano and Lopez-Gunn, 2012). However, the absence of suitable legal and administrative structures remains one of the most significant institutional challenges, leading to the ineffectiveness of water management bodies (Lopez-Gunn et al., 2011). Many existing plans and frameworks were established during periods of surplus supply (Bayat et al., 2014), and in times of crisis, water-related institutions have been slow to adapt, often making decisions based on outdated routines (DARDENBusiness PUBLISHING, 2006). As a result, these institutions lack the capacity to address crisis conditions (Economy of Iran, 2016), especially when authorities have limited experience and expertise in groundwater management (Lopez-Gunn et al., 2011).

The inability of water authorities, organizations, and policymakers to control the negative effects of groundwater exploitation and make informed decisions about the future (Mukherji and Shah, 2005) stems from a lack of necessary knowledge (Llamas and Custodio, 2003), improper allocation of roles, and unclear responsibilities among water governing bodies (Mukherji and Shah, 2005). Additionally, complex and bureaucratic laws, along with the lack of technical and human resources to enforce them, hinder effective decision-making (Lopez-Gunn et al., 2011). This ultimately results in a lack of political motivation to implement stringent laws and policies, allowing illegal water use to persist (World Wildlife Fund, 2006; Khair et al., 2015).

In essence, complex legal frameworks burden responsible authorities (De Stefano and Lopez-Gunn, 2012; World Wildlife Fund, 2006), affecting their decision-making capabilities (Giordano et al., 2013) and reducing their ability to respond to user needs in a timely manner (De Stefano and Lopez-Gunn, 2012). Consequently, institutional performance declines. Furthermore, the enforcement of laws is delayed due to a lack of knowledge, appropriate technical tools (Llamas and Custodio, 2003), and insufficient organizational capacity (Foster and Loucks, 2006), as well as a shortage of qualified personnel (Jung et al., 2012). The dispersed nature of groundwater resources, coupled with ineffective policies for identifying and addressing violations, contributes to the negligence in law enforcement (De Stefano and Lopez-Gunn, 2012).

For example, the process of allocating water rights is slow and overly complicated, discouraging individuals from pursuing the necessary licenses (De Stefano and Lopez-Gunn, 2012; Mukherji and Shah, 2005). Additionally, global experiences show that groundwater permit systems are highly susceptible to corruption, and establishing groundwater rights is difficult (Hoogesteger and Wester, 2015). This leads to indiscriminate well drilling (Kordavani, 2011) and exacerbates water crises, underscoring the failure of water policies, institutions, and management tools (Saleth, 1994).

2.5. Lack of proper and sufficient monitoring

Many of the problems resulting from the decline in groundwater resources stem from the lack of effective monitoring of groundwater development (Lopez-Gunn et al., 2011), which has led to significant environmental costs (Llamas and Custodio, 2003). The absence of a precise control and monitoring system for the optimal use of water resources (Bakhshi Jahormi et al., 2015), combined with the authorities' lack of expertise in groundwater management and their focus on monitoring surface water, has reduced the deterrents against illegal groundwater extraction by unauthorized users (De Stefano and Lopez-Gunn, 2012). This has allowed individuals to dig wells and exploit groundwater, even in restricted areas, without proper rights (Velayati, 2014; Reis, 2014), and without facing adequate monitoring or legal consequences (Velayati, 2014). This situation has fostered exploitative and competitive behaviors in the use of scarce resources (Bakhshi Jahormi et al., 2015), encouraging even authorized users to seek illegal means to acquire new water resources (World Wildlife Fund, 2006).

Khair et al. (2015) report that in Baluchistan province in southeastern Iran, there is no organized body for monitoring and controlling groundwater. Water committees at the district and provincial levels are only responsible for regulating the distance between wells, and monitoring only occurs if a formal complaint is lodged against a specific well, in accordance with the groundwater management guidelines of 1978.

Given the characteristics of groundwater and the ease of illegal access, effective management requires strict control and monitoring by government organizations. Although groundwater control and monitoring are challenging (Hoogesteger and Wester, 2015) due to individual and scattered access to wells (Hammani et al., 2009), high implementation costs (Novo et al., 2015), and a lack of sufficient

human resources (Mukherji and Shah, 2005), these tasks are not impossible (De Stefano and Lopez-Gunn, 2012).

2.6. Weak representation and bargaining power of farmers and well-owners in decision-making

User participation in groundwater management processes is essential for the success of organizations and executive systems (Lopez-Gunn et al., 2011; Nanni et al., 2006). It fosters cooperation in addressing common resource problems and dilemmas (Heikkila and Gerlak, 2005) and ensures access to accurate, reliable information (Lopez-Gunn et al., 2011). However, many authorized users are unwilling to engage in groundwater management efforts (World Wildlife Fund, 2006), resulting in the exclusion of farmers and well owners from consultation and decision-making processes. Additionally, the conflicting roles and interests of stakeholders in water management councils often lead to a lack of meaningful participation (Lopez-Gunn et al., 2011), with individual perspectives rarely being considered (De Stefano and Lopez-Gunn, 2012). This lack of involvement has caused tension and disconnection between officials, groundwater management organizations, and farmers, who are the primary users of water resources (Santos et al., 2008).

Knüppe and Pahl-Wostl (2011) analyze that the tensions and conflicts between various levels of groundwater management stem from one-way communication from authorities, which leaves local stakeholders (i.e., water users) out of the decision-making and planning processes. The unwillingness of experts to involve users in these discussions (Mukherji and Shah, 2005) has resulted in a growing distrust of authorities among water users (De Stefano and Lopez-Gunn, 2012). This lack of trust has led to misunderstandings, with farmers perceiving experts as the sole owners of water rights who prevent them from accessing groundwater by digging wells. Consequently, these misconceptions often result in farmers ignoring expert authority and engaging in unauthorized well drilling and excessive exploitation of water resources. To address these challenges, it is critical for officials and experts to consider the views and concerns of farmers and well owners when making decisions about water use (Velayati, 2014).

2.7. The pressure of powerful political actors

Reducing well drilling and the associated exploitation of groundwater is a challenging task due to the economic incentives and growth objectives from a political perspective, especially for political forces. This is because actions that limit economic interests in current uses, some of which are politically influential, typically encounter political resistance and a loss of political support (Hoogesteger and Wester, 2015). Powerful political groups often exert pressure on water officials and authorities to avoid confrontation with social and economic groups that profit from illegal water use (World Wildlife Fund, 2006). This pressure has led authorities to secretly grant new privileges to such individuals (De Stefano and Lopez-Gunn, 2012).

In general, influential political and economic figures can circumvent regulations by negotiating with authorities and using financial resources to drill wells and exploit groundwater (Burke and Moench, 2000). Even if new laws and regulations are enacted, they may still face opposition from these powerful stakeholders (Randolph Bruns et al., 2005). As a result, corruption becomes prevalent in groundwater management, with private interests being prioritized over social welfare and public concerns, causing significant harm. Examples of this corruption include bribing officials and supervisors to obtain drilling licenses, falsifying well locations, or covering up excessive water exploitation, particularly by individuals with strong political and economic influence (Lopez-Gunn et al., 2011).

2.8. The lack of valuing groundwater

Groundwater plays a critical role in domestic water use, particularly in agricultural activities (Jokar and Masoudi, 2017). However, it has received limited attention.

The low price of groundwater (Yazdanpanah et al., 2015), coupled with the desire for profit and economic benefits (Konikow and Kendy, 2005; World Wildlife Fund, 2006) from increased agricultural yields through groundwater irrigation (Holtz and Pahl-Wostl, 2012), has fueled the illegal use of this resource (Gavin et al., 2010). In other words, the lack of effective pricing mechanisms for groundwater poses a risk of resource abuse and threatens its sustainability. The true value of water is often only recognized when users are required to pay for their excessive consumption or face economic losses, prompting them to reduce their water usage (EASAC, 2010).

2.9. Accepting illegal practices as social norms

Sometimes, the carrying out and concealment of illegal activities, coupled with the silence of the surrounding social environment (Van De Bunt, 2010), become social norms that are accepted by illegal users, with little social stigma attached to the unauthorized and unlicensed use of groundwater. This tolerance of illegal practices within the community (De Stefano and Lopez-Gunn, 2012) has negatively impacted legal users (World Wildlife Fund, 2006), and any efforts to address this issue often result in conflict between legal and illegal water users (Novo et al., 2015). The community's silence and acceptance of unauthorized activities have allowed illegal users to publicly seek negotiations for the legalization of their unauthorized groundwater usage (De Stefano and Lopez-Gunn, 2012). A notable example occurred in the Loma de Ubeda aquifer in Andalucia, Spain, where the uncontrolled expansion of olive irrigation led to 90 % of the wells lacking official exploitation licenses (World Wildlife Fund, 2006; De Stefano and Lopez-Gunn, 2012). Farmers in this region requested the legalization of their wells. In such contexts, community tolerance can sometimes reverse motivation, as widespread law-breaking may make violations appear to be more rational or acceptable behavior (De Stefano and Lopez-Gunn, 2012).

2.10. Lack of education, awareness, and the spread of false beliefs

Most users lack access to adequate knowledge and training regarding the effective use of water resources, which would allow them to use water more efficiently. Additionally, the information available to the public about illegal water usage is incomplete and scattered (World Wildlife Fund, 2006). In fact, regulating and controlling groundwater use is fundamentally an information problem, as people are often unaware of the amount of water they are exploiting (Hammani et al., 2009). The lack of awareness, combined with the motivation to obtain significant benefits from illegal water use (Lopez-Gunn et al., 2011; Novo et al., 2015), has led individuals to extract water regardless of legal restrictions (World Wildlife Fund, 2006). Furthermore, widespread misconceptions among users have hindered the effective use of available resources. Many users believe that groundwater is infinite and connected to underground seas and rivers (Varady et al., 2012). For example, most farmers understand that winter irrigation does not significantly contribute to meeting the water needs of trees, yet they believe that if the well water is not used, nearby wells will take it and other users will exploit it (Ebrahimi Louyeh, 2008). Therefore, it is essential to raise awareness through open information services for farmers, and relevant authorities should inform users about data on aquifers (World Wildlife Fund, 2006; Velayati, 2014).

2.11. Households' livelihood

From the earliest times, groundwater has played a critical role in human life and sustaining and growing livelihoods. A wide variety of case studies from Asia, Africa, and South America revealed that groundwater, often invisibly, improves people's lives and livelihoods and promotes equitable growth (Re et al., 2022). For instance, approximately 60–70 percent of population in Pakistan depends either directly or indirectly on groundwater need to produce more food and promote their livelihood (Zakir-Hassan et al., 2023). Shankar et al. (2011) found that 68 % of families with wells in these regions are small or marginal farmers who increasingly depend on groundwater for their livelihood. As a result, the vital connection between groundwater and people's livelihoods has led to its value being underestimated (Mukherji and Shah, 2005). In addition, efforts to regulate and control groundwater use have faced resistance due to the challenges they pose to this critical resource (Mukherji and Shah, 2005; Chavoshi, 2014).

3. Methodology

This research focuses on illegal well drilling in Bushehr province as a case of study. This province, with an area of 23,167.567 square kilometers and a population of 1,032,949, is located in southwestern Iran, with longitudes from 50°6° to 52°58° E and latitude from 27°14° to 30°16° (Yazdanpanah et al., 2021). Nearly 5500 illegal wells have been identified in the province, 1550 of which were drilled after the enactment of the law on determining the fate of unlicensed wells in 2006. The existence of 5500 illegal and unlicensed wells constitutes a high percentage compared to 8100 licensed wells (Regional Water Company of Bushehr, 2017).

4. Methods

A qualitative approach using grounded theory was employed to identify causes of illegal well drilling. Grounded theory, developed by Barney Glaser and Anselm Strauss in 1967, focuses on building theories based on data from social studies (Egan, 2002). It involves conceptualizing data through evidence collection and analyzing the relationships between the emerging concepts (Giske and Artinian, 2007; Egan, 2002). This study conducted in three stages mentioned in the following.

4.1. First stage: Entering the field of research

The research participants, including experts from the Agricultural Jihad Organization and Water Organization of Bushehr Province, Environmental Research Department, Natural Resources and Watershed Management Department, and the Governor's Department, were included as most were authorities related to issuing well licenses in the province and counties.

Participants were purposefully selected through snowball sampling method where each participant was asked to recommend others with similar experiences in. Sampling continues until new data repeats the previous findings (Corbin and Strauss, 1990).

Due to the distance of 300 km preventing in-person interviews, about 15 questionnaires with the description of the purpose of the research were sent to 11 of the officials in the water department of the counties who were willing to participate in the research. Despite expressing interest, some abandoned this process or declined the interview and only answered the questions due to political issues. To conduct more research, during a phone call, an appointment was made for an initial interview with the relevant officials in the counties and with their consent, audio recordings were collected. If another interview was needed, they were contacted again. At the end of each interview, participants were asked to nominate another potential participant related to the research. Some authorized and unauthorized farmers were contacted through the Jihad Department and visited, while other interviews were arranged through repeated requests from the Water Department via a list of authorized and unauthorized farmers. Participating farmers were asked to nominate another authorized and unauthorized farmer near their location. When the potential participants were contacted, the purpose and scope of the research was explained, and if necessary, an appointment was arranged for an interview. At the beginning of each interview, participant agreement was secured and the confidentiality of the information and its consequences were emphasized. A number of farmers, especially unauthorized ones, initially refused to be interviewed after receiving the research objectives because they thought the interviewer was an official of the water department and intended to seal their wells. After providing assurance that the information would be confidential, the interview process was carried out. In total, 23 farmers (14 authorized and 9 unauthorized)

and 30 experts were interviewed.

4.2. Second stage: data sources and their collection

Data were gathered through in-depth interviews and coupled with field observations. A primary issue in qualitative research is the adequacy of evidence which requires allocating enough time in the field and the vast scope of data (Azkia and Imani Jajarmi, 2011). Thus, the time of each interview lasted from 60 to 90 min on average.

The interviews commenced with the open-ended question: "What is the reason for drilling unauthorized wells in Bushehr province?" Interviews continued until theoretical saturation was reached; i.e. until no new information emerged from subsequent interviews. Other questions were asked as needed during the interview process.

Next, the recorded audio was transcribed word by word on paper and analyzed. Other sources of data were documents and brochures and a number of reports that were used during the analysis, and gradually the previous experiences and studies of the researcher were included and analyzed in the research which finalized data collection. Accordingly, the data consists of 80 pages of manuscripts, field notes and documents acquired from the participants after 20 days of interviewing.

4.3. Third stage: data analysis

Data collection and analysis occurred simultaneously, with theoretical sampling guiding the process (Goulding, 2002; Stol et al., 2016; Yazdanpanah et al., 2025). Data analysis followed the steps of open, axial, and selective coding. Open coding is an interpretive process through which data is analyzed and aims to provide new concepts by breaking down the data (Corbin and Strauss, 1990). Open coding requires reading and examining the data carefully (Charmaz, 2008). Researchers compare the data in open coding word by word, line by line or paragraph by paragraph and begin to conceptualize. In other words, the raw data related to the phenomenon are carefully "named" and categorized as concepts in open coding. In axial coding, data that has been broken down in open coding (concepts) are linked to create connections. Finally, selective coding is the process of choosing a core category and relating all other categories to develop the storyline. It is worth noting that applying rich and accurate description, reviewing the data frequently, as well as reviewing the data by other researchers were used to ensure quality control in data collection and coding. The results of 3 coding stages are presented in the following.

5. Results and discussion

All respondents were male the experts were between the age of 28 and 60 years. Also, the age of 14 authorized farmers was with a mean score of 50.44 and a standard deviation of 8.93, ranged between 27 and 60, and the age of 9 unauthorized farmers was with a mean score of 52.44 and a standard deviation of 11.78 ranged between 40 and 70.

According to Table 1, the highest frequency for the authorized farmers' educational level was bachelor (80.0 %) and the lowest was for those with diploma (3.3 %) while most of the unauthorized farmers were whether diploma or under diploma.

6. Qualitative data analysis (grounded theory)

1. Open Coding

All texts in the transcribed interviews were scrutinized for analysis and open coding. In other words, transcripts were analyzed line by line and paragraph by paragraph, and they were considered as incidents or events placed on the right side of a table, and the concepts derived from one or more sentences and paragraphs were written on the left. To create a concept, the data should be observed, and authors should ask themselves what the data represent. Hence, using the procedures of this question and comparing them and repeatedly referring to the data, raw data were converted into a total of 322 concepts. Since this process is complex, an example of emergent concepts is explained in the following to illustrate the procedure. The phrases in parenthesis are the concepts derived from the manuscript of interview (Table 2).

Next, the raw data of this study and the concepts derived from them were depicted in the table, and an example of the data text (due to the large number of raw data) can be observed on Table 3.

As mentioned, because there are many raw data that were converted into incidents or events, only the emerging concepts were

Table 1
The level of respondents' education (experts, authorized farmers, unauthorized farmers).

Education	experts	%	authorized farmers	%	unauthorized farmers	%
No education			1	7.1	2	20
Primary education			3	21.4	2	20
Secondary school education			3	21.4	1	10
Diploma	1	3.3	1	7.1	2	20
Bachelor	24	80.0	5	35.7	1	10
Master	5	16.7	1	7.1	1	10
Total	30	100	14	100	9	100

presented on Table 3.

2. Axial Coding

After determining the concepts, the open coding stage ends and the concepts needed to be placed in a logical order to create a theory. Before this can be done, it is necessary to refine and separate the concepts and determine their relationship with each other. Therefore, at this stage, some concepts may be removed or moved to other categories. Accordingly, during axial coding, the relationships among the 322 extracted concepts were identified. Exploring the internal logic between concepts, they were summarized and integrated into subcategories. At this stage, 21 categories were formed by refining the concepts (Table 4).

3. Selective Coding

Selective coding is the process of choosing the core category and relating all other categories to that category and the main idea for developing the story. During selective coding axial coding continues at a higher abstract level. In this stage, the formation and connection of each category with other groups is explained and the analysis goes beyond the descriptive level to describe the story line. The concept is attributed to the main phenomenon of the story and is related to other categories. The result of selective coding is presented as a paradigm model.

The paradigm model of the causes of illegal well drilling is depicted in Fig. 1. As illustrated, the causal conditions leading to the main phenomenon (Causes of illegal well drilling) included economic factors such as lack of job opportunities, economic and livelihood issues, and inducing motivation to earn profit due to the profitability of some products. Natural factors such as climate conditions and geographical location of the region as well as legal factors such as ineffective and weak laws and affected the main phenomenon. In addition, cultural factors such as lack of education and culture and incorrect beliefs, social factors such as nonparticipation of users themselves in the water management process along with the facility of well drilling methods were contextual conditions that affected the main phenomenon. Furthermore, social norms, policy factors (e.g. inappropriate policies, political pressures and the influence of powerful agents, insufficient budget) and institutional factors such as inefficiency of related structures and institutions and officials were as intervening conditions resulting in the main phenomenon. The acquired strategies included creating and preparing legal bases, external and internal control and monitoring, studying and implementing watershed management plans, creating correct cultivation development patterns, as well as cultural and educational strategies. Nonetheless, not properly managing water resources could be the consequences of illegal well drilling.

7. Conclusion

This study investigated factors of illegal well drilling in Bushehr province (Iran). According to the acquired paradigm model livelihood and economic issues are the main cause of the illegal well drilling phenomenon in this region. This finding indicates unemployment and lack of job opportunities as well as the lack of job provision in other sectors has caused an influx of individuals without adequate knowledge and expertise working in farming and consequently putting pressure on the agricultural sector. Climate conditions and geographical location of the region such as drought and lack of surface water in the region exacerbate the situation. Hence, the issue of individuals' livelihood in relation to the agricultural sector and agricultural development policies in the region will act as a barrier to any policy developed to control the negative effects of using groundwater and will hinder politicians' decision-making about the future of water resources in line with sustainable development. Furthermore, inefficient and weak laws are also the significant factor to lead to illegal well drilling. The water authorities have used several strategies to implement the laws. Nevertheless, they have not stopped the increase in illegal exploitation as there are wells and unauthorized exploitation that have not yet been identified. The inability of the water authorities to prevent these activities is on account of the lack of management tools and legal pressures. lack of education and culture and incorrect beliefs along with nonparticipation of users themselves in the water management process as well as the facility of well drilling methods provide the context for illegal groundwater withdrawal. Policy and institutional factors besides social norms intervene the phenomenon. Accordingly, the following strategies are acquired some of which strategies were used in the region, but not efficiently.

Creating and preparing legal bases seems necessary. Even though, some laws have been passed, but they were not implemented firmly, because there have been general rules without considering the farmers' livelihood, climate condition, etc. Thus, it is suggested that laws should be passed by a committee including water authorities as well as leading farmers and the farmers' livelihood should be

Table 2
An example of converting raw data into concepts.

Because there is no occupation (Lack of job and income), many people turn to farming.
Officials and organizations responsible for creating employment are not doing their job well (irresponsibility of officials and not being familiar with their duties) and the allocated budgets are spent elsewhere or are not spent where they should be (Misuse of financial resources by officials).
On the other hand, people who turn to farming due to lack of sufficient knowledge and literacy cannot use the resources properly (Lack of sufficient knowledge of farming profession and lack of proper use of resources).
One of the reasons for drilling unauthorized wells is unbalanced development. The lack of occupation in other sectors (Lack of job opportunities) causes that people looking for job (Lack of job and income) consider farming as the most available job with the view that water belongs to everyone and is accessible (Not knowing the actual value of water), and unfortunately, they flock to it without paying the real cost (Not knowing the actual value of water).

Table 3
An example of data text.

Incidents or events	Concepts
• Because there is no occupation, • Unemployment • People are unemployed and don't have a job, all their capital is this garden. • They are breadwinners of their wife and children, so they have to dig wells. • Many people are unemployed and turn to farming.	•Lack of job and income
• Officials and organizations which oversee creating employment do not perform their duties well.	•Officials are not familiar with their duties
• Unfortunately, Agricultural Jihad either does not know correctly their duty or does not perform it.	
• Allocated funds are spent elsewhere.	•Incorrect use of financial resources
• It belongs to everyone and is accessible, and unfortunately, they flock to it without paying the actual cost. • When an unauthorized well is dug, water has no value for that person.	•The lack of understanding the actual value of water
• Laws are approved in the parliament to deal with the digging of unauthorized wells and prevent it, but when it is implemented by the water organization, the farmers resort to the governor, religious factors, district administration or the court in order not to fill the well.	
• In addition, when the people who drill an illegal well are identified, they should be dealt with by the Judicial system, but it takes about 2–3 years to issue a license to deal with this individual. As a result, during this time, this individual has exploited a lot of groundwater and has made billions in profit.	•Stop enforcing the rules
• The government cannot deal. • Violations are not prevented. • The judiciary thwarted.	•The government's inability to enforce laws
• People are stopping us from filling the wells by requesting religious factors and so on, and the well cannot be filled.	
• The Agricultural Jihad refuses to provide a lot of information to other departments (by Jihad for Water Affairs), which causes delays in the performance of duties. On the other hand, there are some organizations that don't allow us to have our own routine and make excuses that you prevent people from being breadwinner, you take money for people's cultivation, and many of our works are prevented by agricultural jihad.	•Obstructing organizations to enforce laws
• They think that groundwater is connected to sea water and is indefinite. • Many of them think that they have nothing to do with them. • We do many of the tasks, which are the duties of Jihad. The absence of a substitute cultivation pattern is of Jihad duties, which is carried out by the regional water affairs department.	•Incorrect beliefs
• There are profits and benefits that are exchanged.	•Irresponsibility of employees and organizations
• There are many people who want to get votes or want to run for office somewhere (for example, to be a village head), so they try to solve people's problems in terms of illegal wells.	•Having an individual view and thinking

Table 4
The categories of Axial Coding.

• Economic and livelihood issues	• Lack of education and culture
• Lack of job opportunities	• Climatic conditions and geographical location of the region
• Inducing motivation to earn profit due to the profitability of some products	• Insufficient budget
• Ineffective and weak laws	• Nonparticipation of users themselves in the water management process
• Inefficiency of related structures and institutions and officials	• External control and monitoring
• Political pressures and the influence of powerful agents	• Internal control and monitoring
• Inappropriate policies	• Studying and implementing watershed management plans
• The facility of well drilling methods	• Creating correct cultivation development patterns
• Not properly managing water resources	• Cultural and educational strategies
• Incorrect beliefs	•Creating and preparing legal bases
•Social norms	

taken into account. In addition, all illegal wells should be designated, the amount of harvest for each farmer should be determined, water management should be carried out by the responsible departments according to the crop, proper irrigation methods should be used, provided that the responsible departments have the budget and strong monitoring over it.

It is also needed to provide external control and monitoring. The passed laws should be monitored firmly, which is not observed in the region.

Internal control and monitoring should be taken into consideration. Using experienced extension agents should be employed to raise awareness among farmers about the issue. participatory promotion approach can also be helpful to make farmers involved in monitoring.

Watershed management plans are needed to be studied, implemented and monitored. Nonetheless, its implementation is very low in the region due to lack of budget, lack of experienced contractors and lack of monitoring on them. Therefore, planners and authorities should allocate a budget for implementing watershed management plans. In addition, it is suggested that experienced contractors could be employed from other provinces and also be monitored by authorities. Furthermore, the efficiency and effectiveness of these plans should be evaluated over time, and corruption among departmental employees in providing budgets for projects and contractors'

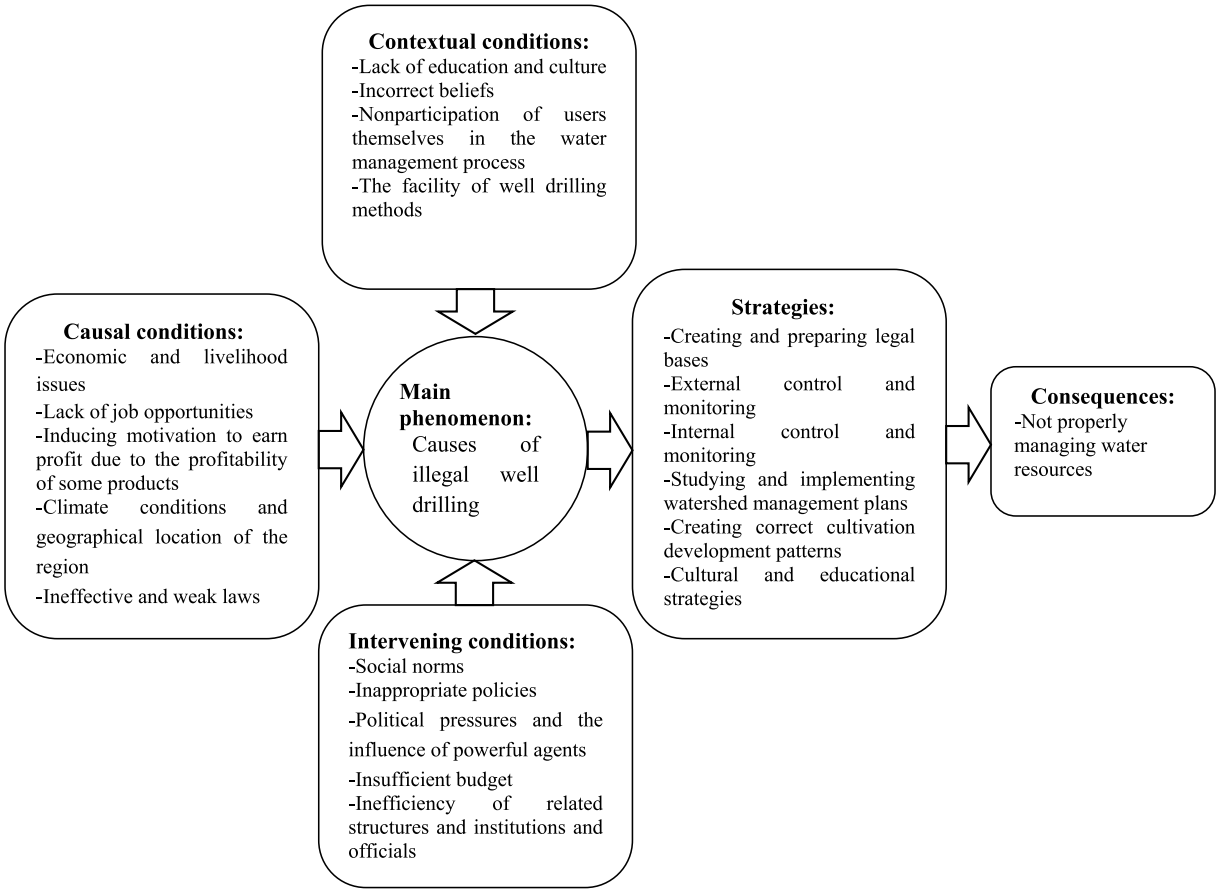

Fig. 1. Paradigm model of the causes of illegal well drilling.

collusion should be closely monitored.

Correct cultivation development patterns needed to be carefully noticed. Even though replacement crops were introduced in the development plans, it was not effective due to lack of a suitable market, lack of familiarity with the market and marketing methods. Thus, a careful study by various researchers is required for creating cultivation development patterns. both marketing methods for replacement crops should be taught, and farmers should be supported for marketing. For example, the authorities can make a contribution with private companies to find market for farmers.

Cultural and educational strategies may also be helpful. It is worth noting that people are aware that there is a water shortage. Nevertheless, due to necessity and unemployment, they are forced to use products that are market-friendly. Therefore, along with educational strategies, all departments should coordinate with each other and create jobs to eliminate unemployment in the province. In other word, providing job opportunities should be one of the province's priority. the potential opportunities in the province should be recognizing by authorities to reduce unemployment.

8. Limitation

The research encountered several limitations. First, since it was about illegal well drilling, most farmers were reluctant to give information as they thought their well might be sealed. Therefore, the authors had to build a lot of trust. Second, the research was conducted in the whole province. Therefore, it was not easy to gain access to the respondents (farmers and experts). In addition, lack of proper transportation and old rural roads made access challenging. Third, there were limited references available in this issue. Last, lack of sufficient funding for the research has led to a lengthy research process.

CRediT authorship contribution statement

Masoud Yazdanpanah: Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Fatemeh Zahra Romina:** Investigation, Formal analysis, Data curation. **Zeinab Sharifi:** Writing – original draft, Visualization, Validation, Conceptualization. **Katharina Löhr:** Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Michelle Bonatti:** Writing – original draft,

Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Stefan Sieber:** Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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