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Diving deep into legal layers: institutional grammar's insight into Iran's groundwater laws

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ABSTRACT

Groundwater management in Iran is complex, challenged by exacerbating water scarcity and groundwater depletion. Despite changes in the country's water policies and laws, groundwater depletion has intensified. This study analyses two key groundwater laws, the Equitable Distribution of Water Resources Law and the Ta'een Taklif Law, to systematically identify the challenges within these laws that may accelerate depletion. Using Institutional Grammar, the laws were analyzed according to ADICO components: Attribute, Deontic, alm, Condition, Or else. The analysis reveals that both laws are norm-based, with limited enforcement mechanisms. Attribute Components reveal a government-centric approach, making the government the primary actor and well users passive. alm Components indicate that unauthorized wells, part of the current problematic situation, may eventually be legalized. Condition Components are vague and contradictory, hindering effective enforcement. While the laws establish obligations (Deontic), they lack specified penalties (Or else) for non-compliance. The paper concludes with the need for a comprehensive change in water policy leading to laws that maintain a balanced integration of norms and rules to create a robust groundwater management.

Key words: ADICO Syntax, Groundwater Law, Illegal wells, Institutional grammar, Iranian water policy

HIGHLIGHTS

- Illegal wells contribute to Iran's water challenges.
- Despite the groundwater laws in Iran, groundwater depletion has worsened.
- Groundwater laws in Iran are normative rather than rule-based.
- Water policy should bridge the gap between established norms and enforceable rules.

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1. INTRODUCTION

About only 3% of the Earth's water is freshwater, with the remaining approximately 97% being salty oceanic water (Angelakis *et al.* 2021). Approximately 34% of the total freshwater resources available worldwide constitute groundwater resources (Mahato *et al.* 2022). UNESCO (2022) provides a global overview of groundwater use in agriculture and states that 70% of groundwater withdrawals are currently used for agricultural production of food, fiber, livestock, and industrial crops, demonstrating the critical role of groundwater in supporting agricultural activities. Nikraftar *et al.* (2024) argued that in the Middle East, a region characterized by predominantly arid and semi-arid climates, reliance on groundwater for agricultural purposes is significant. The region faces a critical

challenge in managing this vital resource sustainably, as evidenced by an average decline in groundwater storage of -5.93 mm/year (Nikraftar et al. 2024). In Iran, one of the countries in the Middle East, groundwater provides about 60% of the country's total water supply, with agriculture accounting for more than 90% of water withdrawals (Noori et al. 2021). Due to extensive water withdrawal for agricultural purposes, Iran's reservoirs were typically more than half of their capacity empty between 2003 and 2017 (Safdari et al. 2022). Groundwater pressures have increased in Iran due to the intensive development of the water sector to support the livelihoods of over 80 million people and irrigate over 5.9 million hectares of agricultural land (Noori et al. 2021). Many socioenvironmental issues, such as wetlands drying up, desertification, sand and dust storms, declining water quality, recurrent flooding, and climate migration, have been exacerbated by groundwater overdraft. In addition, it has accelerated the salinization and desertification of land and lowered the quality of groundwater due to natural processes such as saltwater intrusion (Safdari et al. 2022). Land subsidence due to groundwater depletion is now a man-made threat to vital infrastructure and people living on vulnerable plains. Increasing pressure on rural livelihoods and growing tensions between groundwater users exacerbate food and water security risks and raise issues related to rural-urban migration (Safdari et al. 2022). Figure 1 shows an excessive overdraft covering over 76% of Iran's aquifer area (\sim 77% of the country's total area). This might have serious repercussions that endanger Iran's overall socio-economic security and environmental stability if left uncontrolled (Ashraf et al. 2021).

Illegal wells are a significant issue in Iran, contributing to the country's challenges with water scarcity and groundwater depletion. According to a report by the Washington Institute (Al-Aloosy 2022) and Saatsaz (2020), out of 658,000 water wells, nearly 320,000 were unauthorized, reflecting a significant problem in the country's groundwater management system. Over the past decade, Iran has seen a sharp increase in the number of wells: From 546,000 groundwater extraction sites in 2002 to over one million in 2015. There has been an 84.9% increase in the number of wells (Safdari *et al.* 2022). As stated by Mokhtar & Aram (2017); and Nabavi (2018) (Figure 2), the increasing number of unauthorized wells in recent years supports the assumption that water policies have not been effective in limiting de facto water abstraction at the local level.

Groundwater policy in Iran is most visible in two major laws, the Equitable Distribution of Water Resources (EDWR) and the Determination of the Status of Unlicensed Wells (Ta'een Taklif Law). The EDWR law in Iran aims to regulate the fair distribution of water within the country among domestic, agricultural, and industrial consumers. According to this law, all bodies of water, including sea waters, rivers, lakes, surface waters,



Fig. 1 | The rate of groundwater overdraft during 2002–2015 (Ashraf et al. 2021, p. 6).

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Fig. 2 | The trend in the number of (un)licensed wells in Iran (Nabavi 2018).

groundwater, mineral waters, and other internal waters, are considered public water and are owned by the government (Law on Equitable Distribution of Water Resources 1983; Nabavi 2018). The law outlines the quality of usage of public water as well as the protection and rehabilitation of water resources. The law consists of 52 articles, embedded in five chapters: Public and National Ownership of Water, Groundwater, Surface Water, Duties and Responsibilities, and Compensation, Violations, Penalties, and Miscellaneous Provisions. It was enacted on April 22, 1983, and has been and still is a key component of Iran's water policy, especially given the country's challenges with water scarcity and the need for efficient water use and allocation (Law on Equitable Distribution of Water Resources 1983). Subsequently, to address the over-extraction of groundwater in Iran, partly by identifying and managing unlicensed wells, the law known as the Ta'een Taklif was passed by the Islamic Council Parliament in 2010 (Nabavi 2018). The current management of groundwater resources in Iran is fundamentally based on these two key laws, which form the legal framework of the country's groundwater policy (Bakhsijahromi *et al.* 2015).

Despite these laws' intentions, the groundwater levels in Iran continue to decline. Before 1970, the deficit in groundwater¹ reserves was quantified at a modest 123 million cubic meters. In the years that followed, however, this deficit escalated dramatically. From 1970 to 1983, the gap grew to 1.7 billion cubic meters. The period from 1983 to 2006 marked a significant increase, with the deficit ballooning to additional 68 billion cubic meters. The trend continued from 2006 to 2011 when another 34 billion cubic meters were lost. In the most recent epoch, from 2011 to 2018, the deficit has increased to a further 28 billion cubic meters. Cumulatively, these figures add up to a staggering loss of more than 130 billion cubic meters of aquifer reserves, underscoring the urgency of sustainable groundwater management (Samani 2021).

Despite the implementation of the laws, the decline in groundwater levels has not only continued but has intensified. Many scholars (Bakhsijahromi *et al.* 2015; Amiri *et al.* 2017; Mirnezami & Bagheri 2017; Nabavi 2017, 2018; Vijeh & Miri 2017; Davari *et al.* 2019; Maleki *et al.* 2022) argued that the difficulties that have arisen in Iran's water sector are mainly the result of laws. Water law and water policy require mutual adjustment and

¹ A deficit in groundwater refers to a situation where the amount of groundwater being extracted exceeds the amount being replenished. This can lead to a decline in groundwater levels over time.

refinement over time for their successful implementation, while water administration is supposed to implement water law and water policy on the ground within the established institutional framework (Singh *et al.* 2024). Therefore, the purpose of this study is to analyze the texts of the EDWR and Ta'een Taklif laws and systematically identify the linguistic challenges to express the deontic logic embedded in these laws that may contribute to accelerating groundwater depletion. To achieve this, we employ the analytical lens of Institutional Grammar (IG), as conceptualized by Crawford & Ostrom (1995), which provides a robust framework for analyzing and interpreting these laws. Codified policies such as laws and constitutions are defined as formal institutions (North 1991; Greif & Kingston 2011). The IG facilitates a deeper understanding of how both formal and informal institutions work and outlines a multi-step approach to dissecting institutions for their better understanding and analysis (Crawford & Ostrom 1995; Schülter & Theesfeld 2010). Kamran & Shivakoti (2013) pointed out that the use of IG helps to understand complex policy issues and to identify knowledge gaps in the policy formulation and implementation process. A clear breakdown of these laws into their basic components using IG can reveal the challenges in the laws, as well as opportunities for policy reform.

Although many studies have been conducted on the role of laws in Iran's water-related issues, to our knowledge, none have explicitly used IG to analyze the content of the two aforementioned laws and systematically identify the challenges inherent in them. In this research, we aim to broaden the scope beyond the EDWR law (Amiri *et al.* 2017) to include an examination of the Ta'een Taklif law, which serves as the cornerstone law governing groundwater and the regulation of unauthorized wells. Therefore, this study contributes to the literature on IG by demonstrating the applicability of IG to a groundwater case and providing a systematic way to identify inconsistencies in groundwater laws, thus forming a basis for water policy recommendations.

The structure of the paper is as follows: First, the conceptual basis for the IG is laid out. It then presents a synthesis of relevant empirical studies that have used IG as an analytical tool. This is followed by a presentation of the exact coding procedure, a description of the study results, and a discussion. The paper concludes by addressing the limitations of the study and suggestions for future research, as well as offering recommendations for policy-makers.

2. CONCEPTUAL BASIS FOR THE IG

Analyzing and understanding the role and impact of water institutions is critical, as they should address physical, economic, institutional, and policy constraints for a sustainable and holistic approach to improving water sector performance (Chopra & Ramachandran 2021). *Institutions* are fundamental components of societies, shaping interactions, behaviors, and outcomes. They encompass rules, procedures, and organizations that guide individuals and groups in achieving desired goals (Arsyad 2005). Siddiki *et al.* (2022) stated that institutions may be formally codified (i.e., institution-in-form), such as public policies, or tacitly understood (i.e., institution-in-use), such as social norms or practices. In this paper, our attention is on formal institutions which are defined as written (or codified) rules or constraints. These include laws, policies, regulations, constitutions, contracts, property rights, and formal agreements (North 1991). Crawford & Ostrom (1995) and Ostrom (2005) developed the IG as an analytical tool to enable a comprehensive analysis of institutions by examining their institutional statements.

Crawford & Ostrom (1995) defined institutions as the regulators of human actions, constituted and reconstituted by rules, norms, and shared strategies, underscoring their pivotal role in shaping human behavior and interactions in frequently occurring or repetitive situations. Crawford & Ostrom (1995) delineated three primary approaches to understanding institutions: institutions as equilibria, institutions as norms, and institutions as rules. They argued that the three approaches are not mutually exclusive and that each approach focuses on different types of constraints or opportunities and suggested that rather than debating whether institutions are rules, norms, or strategies, the broad term the *Institutional Statement* can be used to encompass all three concepts.

The institutional statement is a fundamental concept in institutional analysis, as it reflects the norms, rules, and strategies that govern behavior within organizations and societies (Schülter & Theesfeld 2010). Moreover, the definition of the institutional statement aligns with the broader framework of Institutional Analysis and Development (IAD), emphasizing the role of shared linguistic constraints in influencing the behavior of actors within institutional settings (Basurto *et al.* 2010; Carter *et al.* 2015).

The institutional statement refers to a 'shared linguistic constraint or opportunity that prescribes, permits or advises actions or outcomes for actors (both individual and corporate), and they are spoken, written, or tacitly understood in a form intelligible to actors in an empirical setting' (Crawford & Ostrom 1995, p. 583). This definition emphasizes the role of language in shaping the behaviors and decisions of individuals and organizations within an institutional context. It highlights the significance of common linguistic understanding in guiding actions and outcomes, thereby influencing the functioning of institutions (Schülter & Theesfeld 2010). It underscores the communicative and regulatory nature of institutional statements, which play a crucial role in shaping institutional dynamics and interactions (Schülter & Theesfeld 2010; Geary *et al.* 2019).

IG provides a tool for analyzing the structure and content of institutions, particularly in the context of policy design and analysis, providing a systematic method for analyzing policy designs and institutional arrangements (Siddiki *et al.* 2022). The IG has been developed to capture content-specific aspects of discretion and to classify institutional text according to syntactic components, leveraging computational text analysis and natural language processing techniques (Dörrenbächer & Mastenbroek 2019; Siddiki & Frantz 2021; Siddiki *et al.* 2022). This tool breaks institutional statements into shared strategies, norms, and rules to understand the structure of written policies, laws, and other documents (Roditis *et al.* 2015).

Crawford & Ostrom (1995) and Ostrom (2005) proposed the general syntax of the IG that contains five components including Attributes, Deontic, aIm, Condition, and Or else (ADICO) (Table 1). Each element is distinguished as follows (Basurto *et al.* 2010; Schülter & Theesfeld 2010; Ghorbani & Bravo 2016; Siddiki *et al.* 2022);

- *Attribute:* The Attribute represents actors involved in or affected by the statement. It may be a specific position (e.g. commissioner) or a set of relevant characteristics that define to whom the institutional statement applies (e.g. individuals over the age of 18 years). The Attribute must be an individual or collective actor, such as a company or organization, with the capacity to act.
- *Deontic:* The deontic is a type of obligation or permission expressed in the statement that specifies whether the action specified in the aIm is permitted, obliged, or forbidden; it is the expected behavior. Typically, common words such as may (not), should (not), must (not), or shall (not) serve as the deontic of an institutional statement. Deontic is almost always explicit in institutional statements, although there are certain cases where they may be implied.
- *aIm:* The aIm describes the action or outcome regulated by an institutional statement. It clarifies the intended objective or purpose that is required, permitted, or recommended by the statement. Each institutional statement has at least one aIm, usually indicated by a verb, and includes any modifiers that add detail to the action.
- **Conditions:** Conditions constrain the temporal, spatial, procedural, and objective scope of the aIm by specifying when, where, or why it is to be carried out. Time specifications may be relative, such as after the completion of another action, or absolute, such as on a particular date. Location conditions may refer to a particular place or a jurisdictional boundary. Procedural conditions can identify circumstances that are prerequisites to or preclude

Component	Abbreviation	Definition			
Attribute	А	Defines to whom and what the institutional statement applies			
Deontic	D	Indicates whether actions within institutional statements are permitted, required, or prohibited			
aIm	Ι	Describes specific actions or outcomes within institutional statements			
Condition	С	Defines when and where an action or outcome is permitted, required, or prohibited			
Or else	0	Specifies the consequence of not following a rule			
Examples					
Farmers (A) must (D) reduce their groundwater usage by 20% (I) during summer months (C), or else they face a fine (O).		Rule (ADICO)			
Farmers (A) should (D) only irrigate at night (I) when evaporation rates are lowest (C)		Norm (ADIC)			
Farmers (A) constructing recharge ponds to increase the groundwater levels (I) during the rainy seasons (C)		Shared strategies (AIC)			

Table 1 | The general syntax of the IG and groundwater examples of determining rules, norms, and shared strategies.

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the aIm. All institutional statements contain at least one condition. Where no condition is explicitly stated, the default implicit condition is 'at all times' or 'under all circumstances'.

• Or else: The Or else specifies the sanction to be applied to the Attribute in the case of non-compliance with an institutional statement's prescription.

One element has lately been added to the syntax of the IG by Siddiki et al. (2022), called the oBject. The oBject is an inanimate or animate element, as well as any qualifying descriptors, that the institutional statement designates as the receiver of the aIm. In our research, we focused on the ADICO syntax including the Attributes, Deontic, aIm, Conditions, and Or else components, because the objective of our study is well aligned with the established ADICO component and does not particularly focus on a qualifying descriptor.

Determining the statement type requires knowing whether a certain component is present: a rule contains all five components (ADICO), a norm contains all but an Or else (ADIC), and a shared strategy has all but a deontic and an Or else (AIC), or in Ostrom's words, 'regulatory rules are one grammatical step away from norms and two steps away from strategies' (Ostrom 2005, p. 138) (Figure 3).

We have given some examples of IG syntax in Table 1, but many rules, norms, and strategies are not formulated in such an easily recognizable way as in these examples or are often only implicit. However, the researchers will be able to reformulate any institution into an institutional statement consisting of the building blocks mentioned above (Schülter & Theesfeld 2010).



Fig. 3 | Common language of institutions.

3. IG APPLICATIONS: DISENTANGLING NORMS AND RULES IN ENVIRONMENTAL RESEARCH

IG is a powerful analytical tool for analyzing and understanding the complexities of institutions and it has been used in many fields such as environmental governance, public policy, urban planning, healthcare, and natural resource management (Siddiki & Frantz 2021). In this section, we provide a summary of case studies on the use of IG in water-related issues and environmental research, as well as its application in the case of Iran. This diverse body of work provides a comprehensive understanding of how IG can be applied in practice. For instance, Watkins & Westphal (2015) explored the application of the ADICO syntax to ecological restoration decision-making in the Chicago Wilderness region. The result of this research showed that norms, and not just rules, are prevalent and particularly meaningful guides for people's actions. This insight highlights the significance of norms in shaping behavior within institutional settings, providing valuable implications for understanding and analyzing institutional dynamics. Noori *et al.* (2020) analyzed the concept of industrial symbiosis in the context of the Persian Gulf Mining and Metal Industries Special Economic Zone in Iran. The institutional analysis using IG revealed the current formal rules and regulations may not effectively encourage the development of new industrial symbiosis collaborations due to unclear and ineffective institutional statements.

Prior (2016) explored how sustainability efforts are changing the norms, rules, and values related to cleaning up polluted environments. The study provides a systematic analysis of the norms, rules, and motivational values in sustainable remediation processes at three Australian sites. It applied IG to identify the guiding principles of

participants' actions. They found a core set of 16 norms and 18 rules (sanctions), which define participants' roles, incorporate sustainability into existing practices, and outline what sustainable remediation entails. They also realized that there is a strong link between the norms and rules within the remediation processes and the broader environmental management principles. Bastakoti & Shivakoti (2012) focused on the ADICO syntax to analyze policy effectiveness in irrigation systems in Nepal. They discovered that regulations developed by the farmers themselves are more aligned with the local conditions compared to the ones imposed by governmental bodies. Novo & Garrido (2014) using IG, aimed to identify the barriers related to the implementation of Nicaragua's new Water Law. They found that most tasks in the National Water Authority in Nicaragua are concentrated in the form of strategies that describe a type of action but do not contain any prescriptive element. Finally, Amiri *et al.* (2017) analyzed Iran's proposed Comprehensive Water Law in comparison to the existing water law, the EDWR, using IG as an analytical tool. The findings revealed that despite different titles and implicit mandates, the draft and the current law do not differ significantly. This short summary shows how the application of IG as a robustness and versatility tool can help us to decompose the institutional statements into their syntactic components and provides insights into the design and effectiveness of these two laws in groundwater management.

4. CODING PROCEDURE

This research focuses on the main laws in groundwater management to understand their core components and how they set the stage for subsequent regulations and clarifications. Therefore, we first obtained the two relevant laws from the official website of the Islamic Parliament Research Center of the Islamic Republic of Iran. After the acquisition, we undertook a meticulous data-cleaning process. This involved extracting introductory elements, glossaries, expository sections, and appendices from the main legislative content that were deemed irrelevant to the analytical scope of our research. The EDWR law is divided into five distinct chapters, with the comprehensive second chapter, comprising Articles 3 through 17, devoted to the intricacies of groundwater management. This includes a total of 14 articles accompanied by 8 specific provisions. Similarly, the Ta'een Taklif law is concisely composed of a single article but expands into 7 detailed provisions, all of which focus on addressing the critical issue of groundwater depletion in the country.

Since institutional statements serve as the primary unit of analysis, the implementation of IG involves a multistep process of identifying, splitting, parsing, and coding institutional statements to prepare data for analysis (Watkins & Westphal 2015).

This approach provides a baseline understanding of the institutional design, which is crucial for comprehending how subsequent rules and clarifications build upon it. Future research could certainly benefit from incorporating subordinate legislation to provide a more comprehensive analysis. However, the focus on the main law in this study is a deliberate methodological choice to establish a clear and concise understanding of the primary institutional framework.

Second, we identified the institutional statements: When an institutional statement had multiple components, it was broken down into several different statements for clarity. Some of these were relatively easy to identify, while others required more thought. In textual materials, institutional statements can be identified by breaking down the content into smaller segments. This begins with the identification of section and subsection titles, semicolons, and numbers, and eventually distills the text down to individual sentences. Although a single sentence usually corresponds to an institutional statement, there are cases where a statement may span several sentences or, conversely, a sentence may contain several institutional statements (Watkins & Westphal 2015). Following the guidance of Siddiki *et al.* (2011, p. 89), 'when applicable, imply components when they are not explicitly provided', our study identified 92 statements related to the EDWR law and 38 related to the Ta'een Taklif law.

Once the institutional statements were identified, third, they were coded according to the ADICO syntax. It should be noted that the coding analysis was originally conducted in Persian. Kamran & Shivakoti (2013) emphasize that the direct translation of institutional statements into English may miss their implicit meanings. This needs to be considered when applying IG in different cultural and linguistic contexts, as the written rules may not explicitly convey their implicit meanings after translation into other languages. It highlights the importance of considering local language nuances and cultural contexts in IG studies. Kamran & Shivakoti (2013) suggest that future research could adapt IG to account for linguistic diversity, thereby increasing its applicability in different situations and studies.

It is also important to note that the scope and aim of this study were well aligned with the capabilities of the primary version of IG (Institutional Grammar 1.0), which has been extensively validated in previous research. Although IG 2.0 offers advanced features and refinements, the primary focus of this study is to build on the existing body of knowledge using IG 1.0. Future research could certainly benefit from incorporating IG 2.0 to explore additional dimensions and further enhance the analysis.

Fourth, to improve the accuracy of the codes, the researchers implemented two key techniques known as intracoder and inter-coder reliability. First, to ensure intra-coder reliability, a single researcher responsible for coding performed the procedure twice at two different intervals. O'Connor & Joffe (2020) emphasized that intra-coder reliability refers to the consistency of how the same person codes data at different points in time. That is, if the same person returns to the data at a different time, will they code it consistently? Evaluating intra-coder reliability can be a useful exercise in promoting researcher reflexivity. However, reliability in qualitative research more commonly refers to inter-coder reliability, which involves multiple coders (O'Connor & Joffe 2020). Inter-coder reliability refers to the degree to which different coders or observers consistently use a coding scheme to systematically classify or categorize data. This metric serves as an essential indicator of consensus among coders, which is critical to ensuring that qualitative research findings are invariant across different coders. High inter-coder reliability indicates that the coding scheme is clear and can be applied consistently, leading to more reliable and valid results (Siddiki et al. 2010; O'Connor & Joffe 2020; Mohd Zabidi et al. 2022). Therefore, the research team recruited a Persian scholar not involved in the study. After several days of explaining the purpose of the study and training on the analytical tool, the scholar was tasked with isolating the statements and coding them according to the ADICO syntax. After the initial coding by the second coder, both coders met to discuss and agree on their respective codes. This joint discussion aimed to ensure consistency and accuracy in the coding process. The coders then re-coded the statements independently. The codes were compared for a second time to identify any discrepancies and to reach a final consensus.

Inter-coder reliability was determined by assessing inter-coder agreement and the observed rates of agreement between the two coders were 80.43% for the EDWR law and 84.21% for the Ta'een Taklif law. Such a level of agreement from the initial inter-coder reliability assessment is indicative of a highly reliable coding process (Watkins & Westphal 2015).

Fifth, we shared the codes with experts in the field and asked them to give us their feedback on the codes and their relevance. These experts were drawn from the country's regional water authority, who could provide insight, validate the coding process, and contribute to the interpretation of the data. For example, one expert recommended using the code for 'in any' and 'in all' places in the country to highlight the whole geographical area within the country (see CT1 and CE1 in Table 4). This valuable suggestion was taken on board and is reflected in our findings. Another expert highlighted the importance of temporal aspects in our coding approach. This process is often referred to as 'expert validation' or 'peer debriefing'. It's a form of qualitative validation where researchers discuss their findings with experienced individuals in the field to ensure the accuracy and reliability of their results (Sandelowski 1998). In Figure 4, we have provided a schematic representation of the coding procedure used in our study.



Fig. 4 | The structure of textual data collection and analysis.

5. FINDINGS

In this section, we provide a comprehensive overview of the findings. First, we present all ADICO components to provide a holistic perspective, then we look at each ADICO component individually to ensure that the findings are transparent and easy to understand.

5.1. Overview of all ADICO components

The analysis of the EDWR law shows that out of 92 statements, 81 (88%) are categorized as a norm, which includes ADIC. In contrast, only 11 (12%) statements qualify as a rule (ADICO), each of which includes an Or else component to specify consequences. This law does not contain any statement to shared strategies, with the inclusion of the AIC.

On the other hand, the Ta'een Taklif law shows a reduction in the number of rule-based statements; out of 38 statements only two (5%) is a rule that includes an Or else component. This means that a staggering 36 statements (95%) are a norm without an Or else component, such as punishments or fines. Notably, this law also does not contain any statements classified as shared strategies.

In the EDWR law, the majority of statements are categorized as norms, which may indicate a significant reliance on informal structures in groundwater management in Iran. The few statements categorized as rules highlight the minimal use of formal sanctions to enforce behavior. The Ta'een Taklif law takes this trend even further, with the overwhelming majority of statements being norms. The analysis revealed that the predominant nature of both laws is norm-based, with minimal use of formal sanctions to enforce behavior; they are more normative than explicitly rule-based (Figure 5).



Fig. 5 | Frequency of rules, norms, and strategies in the EDWR and Ta'een Taklif laws. Source: own data.

5.2. Attribute component

In this section, we discuss the diversity of actors involved in two key groundwater laws in Iran, i.e., the EDWR and the Ta'een Taklif. As Table 2 shows, in the EDWR law the government (Ministry of Energy) and well users are considered as the main actors, with 48% (44 out of 92 statements) and 38% (35 out of 92 statements), respectively. The Ta'een Taklif law shows a different pattern. The government's involvement (Ministry of Energy) has increased to 79% (30 out of 38 statements). Remarkably, the number of statements by well-users has decreased from 35 to none (Table 2). This finding is consistent with Amiri *et al.*'s (2017) study of water law in Iran, which found that the government was the subject of 22 out of 52 institutional statements. Amiri *et al.* (2017) found that the government, driven by personal interests rather than societal benefits, perceived an increase in activity as an expansion of authority rather than an increase in duties and responsibilities.

Table 2 also shows that private sector involvement in water management is almost non-existent. Additionally, future generations, who are important stakeholders, are absent and overlooked in both laws. The results in Table 2 show that the Ta'een Taklif law introduced a new actor, the 'Commission for the Investigation of Ground-water Affairs' which is responsible for adjudicating disputes arising from the application of the law. This commission has the capacity to review cases and provide guidance on the issuance or denial of water use licenses.

5.3. Aim component

According to the amendment of Article 3 of the EDWR law and Article 1 of the Ta'een Taklif law, the responsibility for issuing licenses for unauthorized wells has been assigned to the Ministry of Energy since the date of enactment of these laws. Table 3 presents two institutional statements from the above Articles in their English translation to illustrate the aIm component.

After the EDWR law was passed in 1983, this law allowed many violators to enter the process of obtaining licenses for the unauthorized wells they had dug. This process is in line with Article 3 of the EDWR law, which requires previously unauthorized wells to seek approval from the Ministry of Energy. A study by Mirnezami & Bagheri (2017) shows that many unauthorized wells were able to obtain licenses under this law, resulting in the legalization and licensing of 150,000 unauthorized wells.

Despite these efforts to regulate unauthorized wells, the Ta'een Taklif law, which was later enacted, once again gave the Ministry of Energy responsibility for issuing licenses for agricultural water wells. This is reflected in the

Attribute	Statements of the EDWR Law	Statements of the Ta'een Taklif Law	
The Government (Ministry of Energy)	44 (48%)	30 (79%)	
Well-users	35 (38%)	0	
Diggers (individuals and legal entities)	4 (4%)	2 (5%)	
Landowners	2 (2%)	0	
Court	2 (2%)	0	
Ministry of Agriculture	2 (2%)	0	
Local Institutions	3 (3%)	0	
Commission for the Investigation of Groundwater Affairs	0	4 (11%)	
Council of Ministers	0	2 (5%)	
Sum	92	38	

Table 2 | Frequency of statements according to the Attribute.

Source: Own data.

Legislation	Article	No. of the statement	ADIO	CO syntax
EDWR law	Article 3	6	A D I C O	Ministry of Energy Must Issuance of licenses for drilling and operation of wells From the date of the entry into force of this law The violators will be dealt with according to Article 45 of this law
Ta'een Taklif law	Article 1	5	A D I C O	Ministry of Energy Must Issuance of licenses for drilling and operation of wells Drilled before the end of the year 2006 –

Table 3 | An illustration of two statements according to ADICO syntax.

Source: Own data.

Article 1 of the Ta'een Taklif law, which requires the Ministry of Energy to issue exploitation permits for all active, unlicensed agricultural wells identified before the end of 2006. This law, as supported by Bakhsijahromi *et al.* (2015), seems to inadvertently protect violators by implying that anyone who digs an unlicensed well can eventually obtain a license, effectively legalizing their actions over time.

Furthermore, both laws included activities such as issuing licenses to operate wells, renewing licenses, sealing wells, providing technical advice, installing meters, confiscating unauthorized drilling equipment, etc. as government responsibilities. Activities introduced for well-users include obtaining a well permit, submitting water use reports, preventing contamination of well water, installing valves and gates, obtaining a drilling qualification license, paying well-deepening costs, etc. The activities outlined in both laws are primarily concerned with the technical dimensions of water management and do not address the social dimensions, which are linked to people's livelihoods, occupations, and daily existence.

5.4. Condition component

This section analyses the terms in Condition components, that allow the government to grant a license for the unauthorized wells. The laws contain Condition components that are often vague and sometimes contradictory. For example, as Table 4 shows, the Ta'een Taklif law (Article 1) mandates that upon its promulgation, the Ministry of Energy must issue a license for all unauthorized agricultural wells 'located in all plains² of the country' (CT_1), provided that they were dug 'before the end of 2006' (CT_5). This is subject to 'the water capacity of the relevant plains' (CT_8) and the condition that the license does 'not cause harm to others' (CT_9). The original Article is translated into English as follows:

• The Ministry of Energy is obligated to provide comprehensive and effective information to stakeholders. Within two years of the promulgation of this law, it must issue operating licenses for all active, unauthorized agricultural water wells in all the plains of the country that were drilled before the end of 2006 and have been identified by the Ministry of Energy and its provincial agencies. This is subject to the water capacity of the relevant plain, compliance with the buffer zones of authorized wells, no harm to others or the public, and the condition that the applicant implements pressurized irrigation.

 $^{^{2}}$ A "plain" is typically defined as a large area of relatively flat land with minimal changes in elevation, often formed by sediment deposition over long periods of time. Plains can be found in a variety of environments, including river valleys, coastal regions and areas between mountains.

Legislation	Condition components				
The Ta'een Taklif	CT ₁ : Located in all the plains of the country				
Law	CT_2 : Within two full years after the promulgation of this law				
	CT ₃ : With effective notice to stakeholders				
	CT ₄ : For all active unauthorized agricultural water wells				
	CT ₅ : Drilled before the end of the year 2006				
	CT_6 : Identified by the Ministry of Energy and its provincial affiliates				
	CT ₇ : Observing the buffer zone of authorized wells				
	CT ₈ : Based on the water capacity of the relevant plains				
	CT ₉ : Without causing harm to others				
	CT ₁₀ : Subject to implementation of pressurized irrigation by well-users				
The EDWR Law	CE ₁ : In any region of the country				
	CE ₂ : With the exception of the cases referred to in Article 5 of this law				
	CE ₃ : Consideration of the hydrological characteristics of the region (identification of soil layers and groundwater)				
	CE ₄ : From the date of enactment of this law				
	CE₅: Approved by two experts from the Ministry of Energy				
	CE ₆ : No harm to the public interest				
	CE ₇ : Whether or not the well has been exploited				

 Table 4 | Condition components in the EDWR (Article 3, Provision 1) and Ta'een Taklif (Article 1) laws to grant a license for the unauthorized wells.

CT: Condition components in the Ta'een Taklif law.

CE: Condition components in the EDWR law.

Source: own data.

The code 'located in all the plains of the country' (CT_1) suggests that these wells may even be in prohibited plains³, and the legislatures have made no exceptions for prohibited and critical plains. Additionally, the codes 'without causing harm to others' (CT_9) or 'no harm to the public interest' (CE_6) are very general and can have multiple and different meanings and interpretations. Questions arise as to whether 'others and the public' include future generations, whether 'no harm to others and the public' refers to the 'physical nuisance' of the wells and their facilities to neighbors and passersby, whether the negative social consequences of groundwater extraction are in the public interest, or whether the economic and environmental consequences are considered.

Table 4 shows that the EDWR law (Provision 1) states that owners of unauthorized wells drilled before the enactment of the law may obtain a license if 'approved by two experts from the Ministry of Energy' (CE_5). The original Article and its provision are translated into English as follows:

- Article 3: The exploitation of groundwater resources through the drilling of any type of well and Qanat and the development of springs in any region of the country, except for the cases mentioned in Article 5 of this Law, must be subject to the authorization and approval of the Ministry of Energy. The Ministry must issue the necessary drilling and exploitation permits, taking into account the hydrogeological characteristics of the region (identification of soil layers and groundwater) and the provisions of this Law.
- Provision 1: From the date of the enactment of this law, the owners of all wells dug in the past without the permission of the Ministry of Energy, whether they have been exploited or not, are obligated to follow the

³ Plains where, due to the decline of the groundwater level, the drilling of new wells is not permitted and the extraction must be carried out according to the established laws.

published notice, contact the Ministry of Energy and obtain an operating license. If the Ministry of Energy deems any of these wells to be **harmful to the public interest**, **at least according to the opinion of two of its experts**, the well will be sealed without any compensation, its use will be prohibited, and the violators will be dealt with according to Article 45 of this law. Those who disagree with the decision of the Ministry of Energy may appeal to the competent courts.

According to the code 'approved by two experts from the Ministry of Energy', the opinion of two experts from the Ministry of Energy takes precedence over all the standard and specific studies that should be conducted to assess the limits of the plains. This may open the field for the exercise of personal discretion and possible collusion, as Mirnezami & Bagheri (2017) state in their study that many unauthorized wells have been licensed due to political influence and power, corruption, and judicial authorities without proper expertise in the field.

Both laws mention the codes 'in any region of the country' (CE_1) and 'located in all the plains of the country' (CT_1), which means that the legislators did not differentiate between the different geographical areas in Iran, and both laws were formulated uniformly for the whole country, without taking into account environmental characteristics, economic conditions, climatic status, etc. A generalized application of these laws to the different climatic regions of Iran, without taking into account the differences in aquifer characteristics, soil quality, and production needs, is of concern.

5.5. Deontic and Or else components

As Table 5 reveals the government is guided by 44 statements in the EDWR law and 30 statements in the Ta'een Taklif law that explicitly state what the government (Ministry of Energy) is obliged to do (Deontic component). However, the results of applying the ADICO syntax show a lack of consequences (Or else) for non-compliance, indicating that there are no specified penalties for government actors if they do not comply with these statements. This absence is consistent across all statements in both laws, as noted in Table 5. Under the Ta'een Taklif law, it's the responsibility of the Ministry of Energy to tell people how to get licenses for their wells. But the law doesn't say what happens if the ministry doesn't fulfill this duty correctly – if they don't give the information at all, or if the information they give is incomplete. This raises the question, what are the consequences for well-users if the Ministry fails to keep them informed? It seems regulations for government officials appear to be drafted without specifying punitive measures.

Legislation	Attributes	Deontic	Or else
The EDWR law	The government (Ministry of Energy)	44	0
	Well-users	35	7
	Diggers (individuals and legal entities)	4	4
	Landowners	2	0
	Court	2	0
	Ministry of agriculture	2	0
	Local institutions	3	0
	Sum	92	11
The Ta'een Taklif law	The government (Ministry of Energy)	30	0
	Commission for the Investigation of Groundwater Affairs	4	0
	Council of Ministers	2	0
	Diggers (individuals and legal entities)	2	2
	Sum	38	2

Table 5 | The frequency distribution of Deontic and Or else components for different actors in the EDWR and Ta'een Taklif laws.

Source: Own data.

Moreover, the lack of penalties in this law extends beyond this case. The results show that within the EDWR law, only 11 of the total 92 statements contain a specific consequence or Or else component (Table 5). This applies to 7 statements concerning users and 4 concerning diggers, which state that any user found to be drilling without a permit must be subject to the measures outlined in Article 45 of the same law. According to Article 45 of the EDWR law, 'If someone digs a well illegally or uses underground water without following the rules, they will face consequences. Not only will they have to repair the damage they've caused and make things right, but they could also be punished with corporal punishment ranging from 10 to 50 lashes or short-term imprisonment ranging from 15 days to three months. The exact punishment is determined by a Sharia judge based on the specifics of the offense'.

The situation has allegedly worsened with the enactment of the Ta'een Taklif law. As Table 5 shows, only two out of the 38 statements specify a clear consequence or an Or else component targeting diggers. This law not only removed the punishment for violators but actually granted them privileges. Previously, under the EDWR law, committing such an offense would result in consequences and penalties. But now, under this law, not only has the criminal liability of the violators been removed, but the same act is now considered a merit and forms the basis for the issuance of a license.

6. **DISCUSSION**

This section aims to contextualize and interpret the findings presented in the previous section, highlighting their implications and significance. Through each of the ADICO components, we explore the nuances and interpretation of the broader implications of the findings.

The presence of norms in the laws suggests a reliance on collective understanding and voluntary compliance to guide action that may have been overlooked or unaddressed by the government in the context of the critical issue of groundwater depletion in the country. It may also indicate a gap in the legal framework where consequences for violations are not clearly defined. This gap could be problematic if the assumption of the collective action in the communities is inaccurate. If, in practice, there is a lack of cooperation among users, this reliance on norms without the support of rules could lead to challenges in effectively managing groundwater depletion. Bastakoti & Shivakoti's (2012) study of policy effectiveness in irrigation systems in Nepal supports our finding of limited Or else components, suggesting that while norms are more prevalent, the presence of enforceable rules, although few, is crucial for desired institutional performance. They argue for the formation of new rules that take full account of community beliefs and ideas. This is particularly relevant to our analysis as it highlights the need for a better understanding of how norms and rules can be harmoniously integrated to promote robust institutional performance.

Noori *et al.* (2020), in analyzing the concept of industrial symbiosis in the context of the Persian Gulf Mining and Metal Industries Special Economic Zone in Iran, found likewise similar results to our study. They identified 19 out of 183 statements as rules, 137 as norms without clear sanctions for non-compliance, and 27 as strategies. They emphasize that, in the absence of clear and effective institutional statements, the absence of formal rules can hinder the emergence of new collaborative efforts. This finding indicates the importance of a balanced interplay between norms and rules to promote both the stability of self-organizing systems and the growth potential of formalized incentives. Similarly, Novo & Garrido's (2014) research on the implementation of Nicaragua's new water law found that the total number of institutional statements in the law is 190, of which 79 correspond to strategies, 111 to norms, and zero to rules, despite a separate section in the law dealing with sanctions. Their discussion shows that most tasks are concentrated in the National Water Authority in the form of strategies, which describe a type of action but do not include any prescriptive element. Rules in the grammar sense must have an Or else component that requires tangible sanctions, such as punishments or fines, to be classified as a rule. The distinction between norms and rules is nuanced and often depends on the severity and enforceability of the sanctions associated with the Or else component. This distinction can be based on the continuum of severity of sanctionability, ranging from automatic, internal, and external emotional factors to more tangible fines and penalties (Schülter & Theesfeld 2010).

The results indicate a significant shift in the involvement of actors between the two laws, highlighting the government's increasing dominance and the diminishing role of well-users. Although the EDWR law includes 35 statements about well-users, as Maleki *et al.* (2022) point out, it is the government that takes the central role as 'principal' (active actor), while well-users are positioned as 'respondents' (passive actor). This argument is supported, for example, by Article 3 of the EDWR law, which stipulates that the use of groundwater resources is subject to the permission and approval of the Ministry of Energy, thus emphasizing the Ministry's control over resource allocation. Conversely, Article 6 of the same law assigns responsibility for preventing water pollution to well owners, emphasizing the transfer of duty to individuals rather than the government. Similarly, Provision 1 of the single Article of the Ta'een Taklif law states that the requirement to install smart meters for volumetric delivery of water in all agricultural wells, with the cost to be borne by the well owners, indicates a shift of responsibility and financial burden to individuals. Our findings are in support of this argument, as the government is the most prominent actor in both laws under discussion.

The near absence of private sector involvement suggests that management and related activities are predominantly carried out by government agencies, leaving little room for private initiatives or contributions. The central role of the government in legislation is not only limited to these two laws, but according to the Constitution of the Islamic Republic of Iran (Article 45)⁴, the government has been given the responsibility of preserving, authorizing, and supervising the use of all water resources. This centralized approach ignores the potential contributions of well-users, who could actually play an important role in protecting water resources (Lam 2001). The omission of future generations as stakeholders undermines the potential for sustainable resource management by failing to consider the long-term availability and quality of water resources. Maleki et al. (2022) reinforce this concern by revealing that after the Islamic Revolution, the focus on self-sufficiency and independence from strategic food products was emphasized as one of the ideals of the Islamic Republic. In this context, the agricultural sector was considered the axis of development and the mobilization of all national resources and economic sectors was prioritized to achieve self-sufficiency in the production of essential agricultural goods, which became the top economic priority of the government. It appears that policy-makers have concentrated on self-sufficiency in agricultural production and achieving food security, while water security and sustainable use for future generations have received limited attention. This focus may have inadvertently contributed to the neglect of sustainable water management practices and the exclusion of key stakeholders in legislation.

It would be expected that those who dig unauthorized wells would be identified and punished. However, the analysis indicates that the intent of these laws is to provide legal permits to such violators, effectively legitimizing unauthorized wells. The amendment to Article 3 of the EDWR law enabled many violators to obtain licenses for wells they had previously dug illegally. Mirnezami & Bagheri (2017) demonstrate that this led to the legalization of approximately 150,000 unauthorized wells, highlighting a significant shift in enforcement dynamics. Under the Ta'een Taklif law, the re-assignment of licensing responsibility to the Ministry of Energy may further facilitate the legalization of unlicensed wells. Bakhsijahromi *et al.* (2015) critique this approach, suggesting that the law

⁴ Article 45 of the Iranian Constitution (enacted in 1982): Public wealth and property, such as uncultivated or abandoned lands, mineral deposits, seas, lakes, rivers and other public waterways, mountains, valleys, forests, marshlands, natural forests, unenclosed pastureland, legacies without heirs, property of undetermined ownership, and public property recovered from usurpers, shall be at the disposal of the Islamic Government for its use in accordance with the public interest.

inadvertently protects violators by implying that anyone who digs an unauthorized well can eventually obtain a license. They metaphorically state: 'It's as if the laws are saying, 'Go ahead and dig an unauthorized well; the government will legalize it for you later' (Bakhsijahromi et al. 2015).

The focus on technical activities within both laws neglects the social implications of water management policies. While the government assumes responsibilities like issuing and renewing licenses or installing meters, well-users are burdened with obligations such as obtaining permits and preventing contamination without adequate support or consideration of their socio-economic context. This disconnect is evident in the findings of Mirnezami & Bagheri (2017), who claim that when government officials visit to close illegal wells, farmers' survival is threatened, as the closure of the well poses a serious risk to their livelihood. Amiri *et al.* (2017) also reinforce that by arguing that the activities of the government in the EDWR law are characterized by the exercise of authority and the granting of competencies. In contrast, the activities imposed on users consist of obligations and responsibilities dictated by the government. This dynamic establishes the government as the agent of action and the well-users as the recipients of action, potentially leading to tensions and resistance among local communities.

The exclusion of social dimensions from legislation overlooks critical aspects of sustainable water management. By failing to address the livelihoods and daily realities of those most affected by groundwater policies, these laws may inadvertently exacerbate vulnerabilities and undermine compliance. The legitimization of unauthorized wells without addressing the root causes of illegal drilling suggests the need for more holistic policies that integrate both technical and social considerations. Cullet & Gupta (2009) also highlight similar issues of groundwater depletion in their research in India. A key challenge in India is the rapid depletion of groundwater, particularly for irrigation, prompting the central government to draft the Model Bill to Regulate and Control the Development and Management of Groundwater. However, this law is not fully effective as it allows existing users to continue their current water use simply by registering it, thus failing to address the root problem of overuse, especially in water-scarce areas. The tension between ambitious legal goals and the practical realities of implementation underscores the need for effective water governance to take into account local realities and the various historical and social influences in the region. For laws with negative socio-economic impacts to succeed, it's important to highlight their often unrecognized indirect benefits to gain social legitimacy. Education and awareness-raising among communities can help them foresee the private benefits of implementing the law in the long term and increase their willingness to support it (Kumar 2024).

The vague and sometimes contradictory nature of Condition components creates room for different interpretations and potential misuse. The codes 'without causing harm to others' and 'no harm to the public interest' lack specificity, leading to questions about their true meaning and scope. Maleki *et al.* (2022) confirm this in their study on the discourse analysis of the EDWR Law in Iran, and believe that the term 'public interest' in this law does not have a precise definition. In their research, they point out that the laws do not focus on the people but on the government's development goals and economic interests. They add that development and construction projects take precedence over the conservation of nature and the environment, and the damage caused to nature is compensated by fines paid to individuals or the government. No provision has been made for the expenditure of the fines received by the government. This means that the fines collected are not used to improve and enhance the quality of the same ecosystem, but are deposited into the government's account and used as a source of revenue for non-environmental purposes (Maleki *et al.* 2022). The laws must be explicit and straightforward, avoiding any possibility of multiple interpretations. This is crucial because law is a profession of words, and the precision of language is important (Kumar 2024).

Furthermore, the codes 'water capacity of the relevant plains' and 'no harm to others or the public' highlight a contradiction in the conditions set by the law. This is because, in prohibited and critical plains where the water

balance is negative, any new extraction would exacerbate the situation and potentially harm the community that depends on that water source. Therefore, licenses should not and cannot be granted for unauthorized wells, especially those located in prohibited areas. This highlights the need for stricter and more precise regulations to prevent licenses from being granted in such areas.

Proving the date of drilling is another major challenge, as the Ta'een Taklif law specifies the date of drilling as 'before the end of 2006'. Accordingly, if a well was drilled after the specified date, it is not subject to this law. The question is, why did the legislature choose 2006? Bakhsijahromi *et al.* (2015) also add to this issue that proving the time of drilling is not easy, and apparently, the legislature was unaware of this problem. They note in their research that determining the year a well was drilled is very difficult and in most cases impossible. If the government cannot find any documents or evidence that a well was drilled after 2006, it will inevitably, under pressure from the owner or local authorities, set the drilling year as before 2006 (Bakhsijahromi *et al.* 2015). This can result in a large number of licenses being issued for unauthorized wells.

Molle & Closas (2020) confirm this in their research on the complexities and difficulties associated with groundwater licensing, which is essential for controlling groundwater use and managing the resource volumetrically. Despite its importance, the process often faces significant challenges, particularly in agricultural areas with many dispersed users. Key issues include user disengagement and the failure of licensing efforts due to the perceived complexity and cost of compliance. In addition, governmental challenges such as lack of capacity and political will hinder effective licensing processes. Molle & Closas (2020) identify a 'groundwater licensing dilemma' where inadequate resources and efforts are applied too late, undermining the success of licensing initiatives. They conclude that while groundwater licensing is critical for sustainable management, its implementation requires careful consideration of local conditions and proactive engagement by both users and government agencies. De Stefani & Lopez-Gunn (2012) identify several key findings on unauthorized groundwater use in terms of institutional, social, and ethical aspects. They examine the root causes of unauthorized use, pointing to imperfect institutions and inadequate enforcement of existing regulations, and argue that these institutional weaknesses contribute to the persistence of illegal practices. The paper emphasizes the need for improved regulatory frameworks and stronger enforcement mechanisms to effectively address these issues. The paper also suggests that increased public awareness and participation, along with better institutional coordination, can help mitigate the problem of unauthorized groundwater use.

The findings show that regulations for government officials appear to be drafted without specifying punitive measures. Amiri et al. (2017) raise this concern in their research on water law in Iran, noting that there appears to be no accountability; no one has held the Ministry of Energy accountable for ensuring that notifications are properly made, as required by law, to protect the interests of those affected. Amiri et al. (2017) add that this approach is prevalent in all Iranian laws and the rationale is that these laws operate within a command-based, hierarchical framework. It's taken for granted that officials, under their employment status, are obligated to perform their duties. If they fail to do so, they are subject to disciplinary action in accordance with the applicable administrative regulations. This research underscores Mirnezami & Bagheri's (2017) findings that judicial decisions may be influenced by a lack of awareness and sufficient knowledge about the negative impacts of illegal resource extraction, resulting in sentences that do not deter such violations. Judges may not fully understand how damaging these unauthorized activities can be. Consequently, violators are more likely to get away with their actions. Our findings are also in line with Bakhsijahromi et al. (2015), who argue that the enactment of the Ta'een Taklif law has failed to address the negative groundwater balance, and the problem remains unresolved. Instead, it has encouraged lawlessness and further emboldened those who illegally exploit groundwater. Davari et al. (2019) also state in their research that before the revolution, an executive regulation called 'water police' was established to enhance



Fig. 6 | Challenges in the EDWR and Ta'een Taklif laws according to the ADICO syntax. Source: own data.

the protection of water resources, but this initiative was neglected in the post-revolutionary period (the Islamic Revolution of 1979) in Iranian water law.

The diagram presented in Figure 6 illustrates the identified systematic challenges inherent in the EDWR and Ta'een Taklif laws. It shows that both laws primarily conform to a normative structure with various challenges, each of which is uniquely associated with the respective components of the ADICO syntax.

7. CONCLUSION

The study highlights the critical issue of groundwater depletion in Iran, which is exacerbated by the widespread digging of unauthorized wells. To address this challenge, the EDWR and the 'Determination of the Status of Unlicensed Wells' (Ta'een Taklif) laws were enacted in 1983 and 2010 respectively to manage and regulate groundwater resources in the country. However, the implementation of these laws has not stopped the decline of groundwater levels; rather, the pace of depletion has accelerated and Iran's water policy faces significant challenges in effectively managing the sector. Undoubtedly, the effectiveness of these laws is a major aspect in Iran's water policy. Thus, the purpose of this study is to analyze the texts of the EDWR and Ta'een Taklif laws and systematically identify the challenges embedded in these laws that may contribute to groundwater depletion. Using Institutional Grammar (IG) as an analytical lens, the paper decomposes these laws to understand their structure and linguistic specificity when expressing the deontic. The IG through its ADICO syntax allows us to classify different institutional statements within the individual clauses of the laws.

The analysis of Iran's groundwater laws revealed prevailing norm-based statements. The EDWR law consists mostly of norms, with a small percentage of statements containing Or else components, the key requirement to count as a rule. The Ta'een Taklif law further reduces the rule-based statements, with the overwhelming majority being norms without tangible punishments or fines (Or else). Both laws contain statements of what should or should not be done but lack specific penalties for non-compliance. This lack of consequences undermines accountability and may encourage the unauthorized exploitation of groundwater resources. The analysis also pointed out that the laws provide a backdoor for violators, allowing them to legalize the unauthorized wells they have dug. This legal feature may reflect that societal compliance with norms is sufficient for regulation, or it may indicate a gap in the legal framework where consequences for violations are not clearly defined.

The focus on Iran's groundwater laws provides valuable insights into the country's water policy from a certain perspective, but it is important to note that it also limits the generalizability of the findings. Comparative studies with other countries facing similar challenges would enhance the applicability of the findings. We found that the IG is a powerful tool for analyzing legal texts, but it may not capture the full complexity of socio-economic and environmental interactions in water management. To achieve this comprehensive view, the IG can be combined with studies using the Socio-Ecological Systems (SES) or the IAD frameworks as heuristic tools. The IG has to be further developed and applied widely in the water sector, for instance providing for simultaneous analysis of formal and informal rules to provide a more comprehensive understanding of water management and the impact of water policies. Additionally, there may be an incongruity of institutional statements in the formal laws and their practical implementation, which could limit the understanding of the legislation's real impact. Therefore, conducting empirical research from the perspectives of different actors can be crucial to understanding the effectiveness of the legal framework.

The findings point to the need for comprehensive legal and institutional reform that not only includes clear consequences for non-compliance and enforceability mechanisms, but also takes into account the social realities of groundwater use in Iran. Such water policy reforms should aim to maintain a balanced integration of norms and rules to create a robust and responsive groundwater management system and bridge the gap between prevailing norms and enforceable rules.

Policy making should encourage the active participation of all stakeholders, especially local users, in the legislative process to ensure that prevailing norms are well understood and depicted in the formal rules. If that is the case, less formal monitoring and enforcement is needed to make the regulation effective. With that a move towards decentralization and devolution of power is required, empowering local communities and authorities to make decisions that are best suited to their environmental and socio-economic conditions.

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All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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