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Failed Policies, Falling Aquifers: Unpacking Groundwater Overabstraction in Iran

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ABSTRACT: The rapid depletion of aquifers around the world is a growing concern. This depletion raises important questions at national and local levels about different aspects of groundwater over-exploitation and related social and political implications. Iran is a country which has historically relied on groundwater resources for development purposes, but in recent decades it has experienced a progressive decline in water levels of aquifers across the country. Groundwater policies and measures to control overabstraction have largely failed to restore the groundwater balance.

This paper explores some of the key aspects of Iran's persistent groundwater overabstraction problem. It addresses the demographic, legal, infrastructural, economic, socio-institutional, bureaucratic, and knowledge and expertise challenges as they affect water distribution and water security.

The paper illustrates how technocratic knowledge-making, myopic policymaking, and populist lawmaking related to groundwater use have caused mismanagement at the national level and overabstraction at the local level. It is therefore essential that policy reforms pertaining to groundwater be guided by transformative visions in different areas of governance. A consistent, transparent, and integrated legal and institutional framework for law enforcement must be developed; the social and political costs of enforcing regulations must be reduced; and local communities must be included in law- and policy-making as well as implementation.

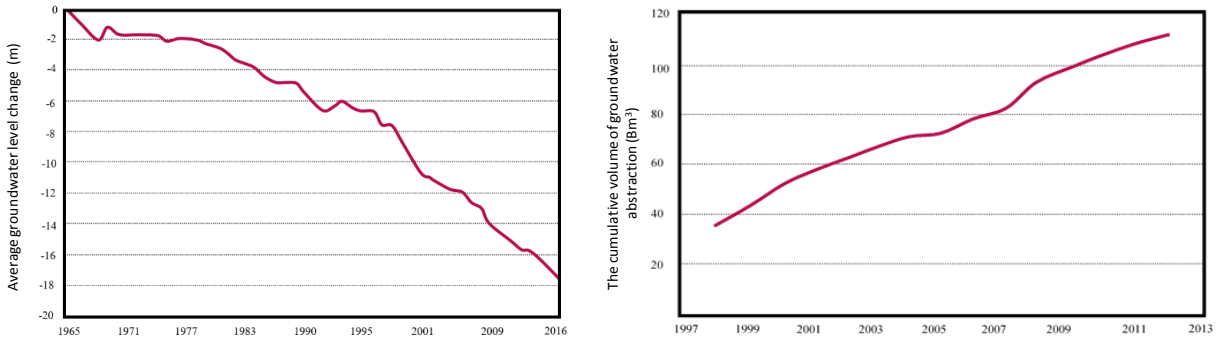
KEYWORDS: Groundwater management, overabstraction, water policy, water law, water governance, Iran

INTRODUCTION

A crisis is developing beneath Iran's semi-arid land. The full extent is unknown but its implication for the country's future is a concern. It is a crisis that, according to Iran's Head of Department of Environment, Isa Kalantari, might pose a greater threat to the country than its classic foes (Israel and the United States) – a crisis that may make Iran uninhabitable (Nabavi, 2016a). Iran is one of the world's largest consumers of groundwater (Dalin et al., 2017), and a vast majority of the population lives in areas that are highly dependent on groundwater for drinking and irrigation. Continuing the business-as-usual approach in depleting aquifers will expose Iran to food and water risks as well as social and political security issues.

Since the 1960s, there has been a steady increase in the number of irrigation wells and in the quantity of water pumped, which has led to a declining level of groundwater in many aquifers across the country (see Figures 1 and 2). The impacts are multiple: (i) a decrease in well yields; (ii) an increase in the intrusion of saline water into aquifers; (iii) increases in land subsidence; (iv) an increase in pumping costs leading to agriculture becoming more costly; (v) a decrease in the flow of groundwater into, through, and out of wetlands and rivers; and (vi) many other less direct but worrying consequences (Hojjati and Boustani, 2010; Lashkaripour and Ghafoori, 2011; Soltani and Saboohi, 2008; Torkamanitombeki et al., 2018; Fathi and Zibaee, 2011; Javidi, 2013; Motagh et al., 2008).

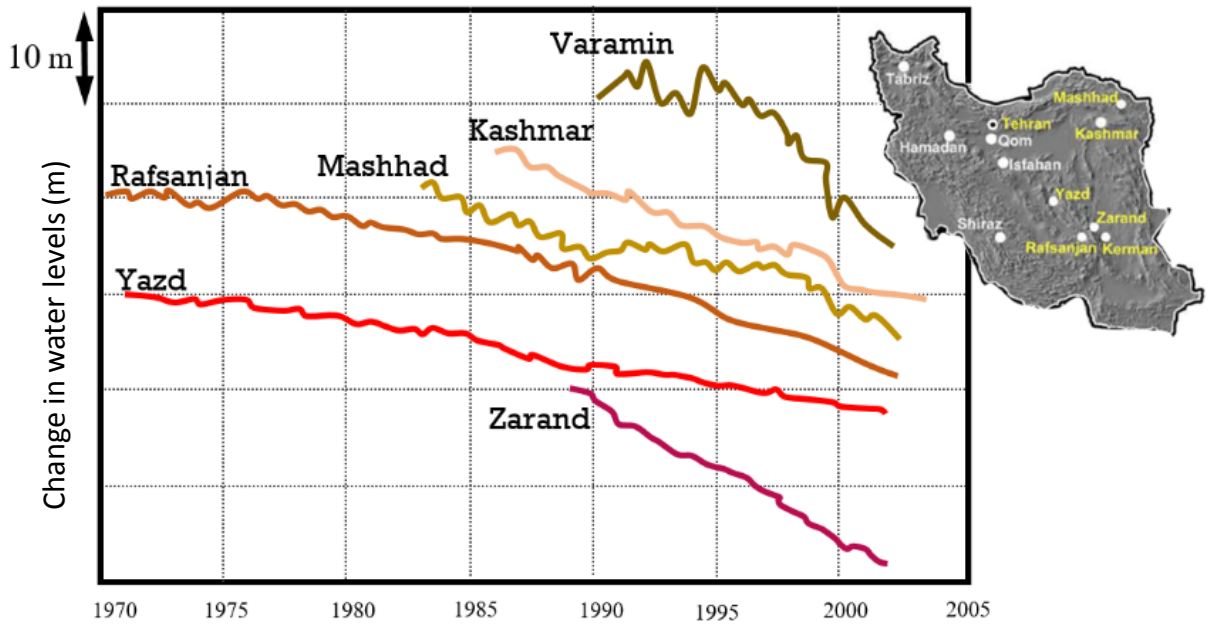
Figure 1. (a) Progressive decline of the groundwater table, and (b) volume of groundwater overabstraction in Iran.



(a) (b)

Source: Iran Water Resource Management Co. and Iranian Ministry of Energy (2014)

Figure 2. Average groundwater level change (from piezometric water table records) in Varamin (40 km southeast of Tehran), Kashmar, Mashhad, Rafsanjan, Yazd, and Zarand plains.

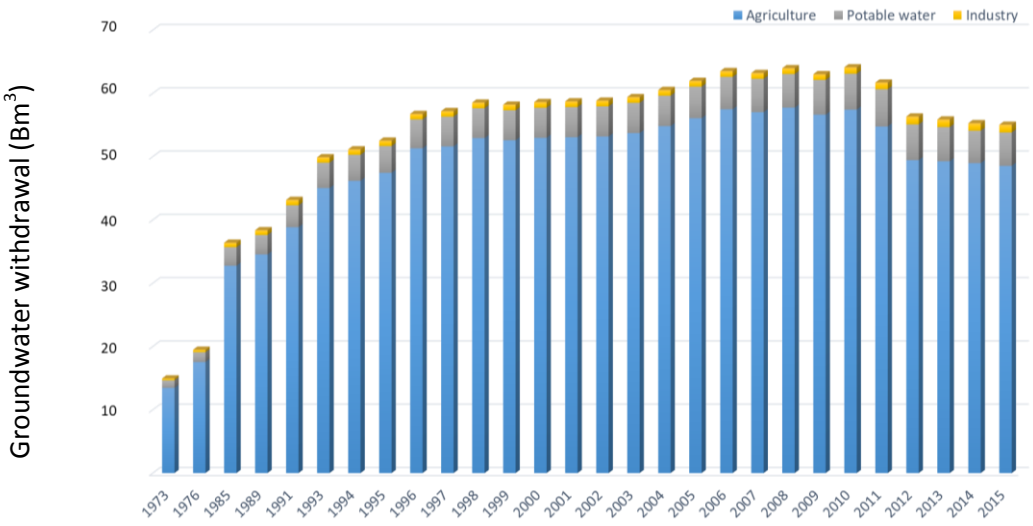


Source: Adapted from Motagh et al., 2008.

Climate change also exacerbates conditions that perpetuate overabstraction. The climate scenarios produced by most studies predict a dire future for Iran and the region, suggesting a drier climate with more extreme heat (Schewe et al., 2014; Lelieveld et al., 2016; Bucchignani et al., 2018; Pal and Eltahir, 2015), meaning that there will be a further reduction in Iran's current 250 mm average annual precipitation and 1450 m^3 per capita water availability. Recent studies also predict the adverse impact of climate change on groundwater recharge, indicating further groundwater depletion over the next two decades (e.g. Ghazavi and Ebrahimi, 2018).

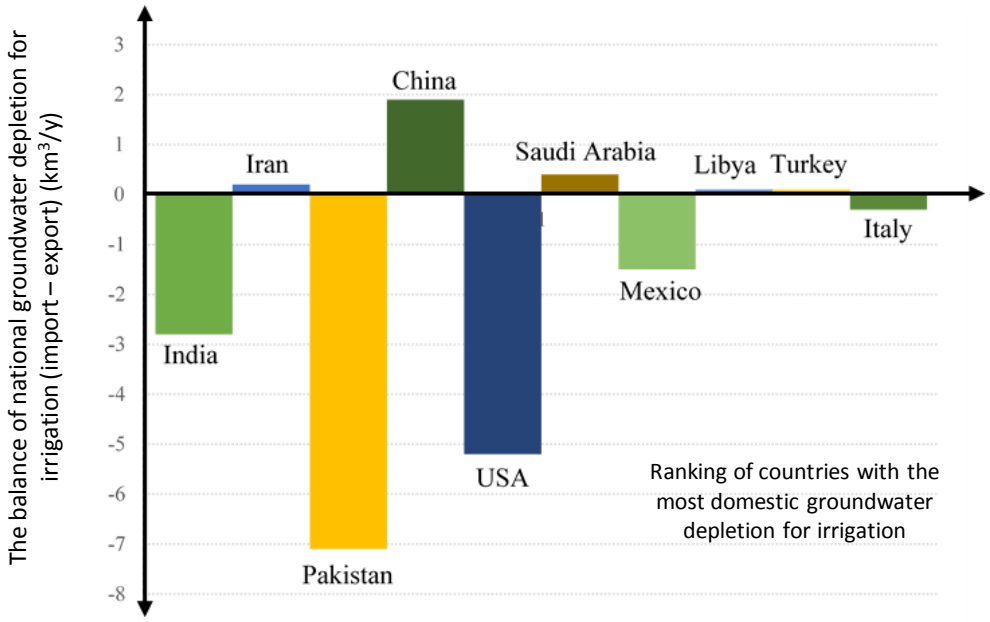
Demand for groundwater in Iran is dominated by agriculture, which uses about 92% of the country's water, 52% of which is currently supplied from groundwater resources[1] (see Figure 3). According to recent research conducted by Dalin et al. (2017), over the last two decades Iran ranked second in the world after India in terms of groundwater depletion embedded in food production and trade, constituting 15.4% of global groundwater depletion for irrigation. The country does import an almost equivalent volume of water through its food imports (see Figure 4).

Figure 3. Groundwater use for different sectors (1973-2015).



Source: Iran Water Resource Management Co.

Figure 4. The balance of national groundwater depletion for irrigation ('import' – 'export'), 2010.



Source: Dalin et al., 2017.

[1] To be precise, 92% is the share of water withdrawal for agriculture which includes the return flow.

All these issues collectively make groundwater a matter for national consideration, not only because of the country's high dependence on groundwater to meet current demands for food, but also for protecting it as a strategic freshwater reserve in case of successive droughts or international sanctions. Controlling and managing groundwater overabstraction, thus, has increasingly become a clear challenge for policymakers, managers and academics in Iran.

Case studies of groundwater overabstraction reveal the importance of institutional, social, political, and ethical considerations in explaining unauthorised groundwater use (Venot and Molle, 2008; Hoogesteger and Wester, 2015; Closas et al., 2017; Martínez-Santos et al., 2018; De Stefano and López-Gunn, 2012; Al Naber and Molle, 2017). This paper analyses Iran's groundwater management policy through a socio-political, legal, and historical lens, reflecting on the different laws, regulations, policy actions, and institutional arrangements. It provides a comprehensive and multidisciplinary picture of groundwater development in Iran, unpacking how national-level policies and regulations took shape and were established over the last century. It also explores how local actors ignore, circumvent, and adjust to them.

Subsequently, this paper lays out the basis for future analytical discussions on the politics of groundwater over-exploitation in Iran by explaining groundwater problems from various aspects, including demographic, legal, infrastructural, economic, socio-institutional, bureaucratic, and knowledge/expertise. The paper ends with a short discussion and concluding remarks. Not limited to Iran itself, studying policy failures faced by Iranian governments and society can also provide relevant insights for other countries in understanding water policy challenges, particularly countries who share similar climates and histories of water governance.

GROUNDWATER POLICIES IN IRAN

A brief overview of past legislations and policies

It is impossible to talk about Iran's groundwater without reference to the underground channels known as *qanats*, which use gravity to transport water from aquifers to the surface for irrigation and drinking. Much of the population of Iran historically depended on the qanat, and areas of population have often corresponded closely to the areas where this system was possible (Kheirabadi, 2000). It can be argued that the qanat allowed Iranian civilisation to flourish alongside other ancient civilisations there were situated along major rivers. The historical presence of the qanat in people's daily lives made it central to Iranian society, and laws evolved to manage its construction, operation, and maintenance.

Despite their long and important history, the role of qanats in Iran's water management was undermined by the advent of nation-states. Ideologies promoting modernisation profoundly affected people's livelihoods, as well as their relationship with the qanat as a sustainable system of water management, with the consequence that qanats have largely been abandoned, and have been replaced by motor pumps and modern irrigation schemes. The social institutions that evolved through history to support qanat systems also become redundant, losing their social functionality.

The importance of the qanat system to Iran's traditional agriculture resulted in two series of laws being passed in parliament (in 1930 and 1934) under the rubric of qanat laws. These laws emphasised the independence of water ownership from land ownership, recognising the rights of landowners, but giving priority to the rights of water owners. If someone, for example, wanted to construct a new qanat, or repair an existing one by digging a new well or channel, the landowner did not have the right to prevent it, providing the conditions specified in the law were met. The government's intervention in the water sector, and particularly in groundwater and qanat systems, became formalised in 1943, when the Independent Irrigation Agency was established under the Ministry of Agriculture. The establishment of this organisation marked a historic moment in Iran's system of water governance. It shifted the governance of groundwater and of the qanat systems from the local level to the national level. Nabavi

et al. (2016) argue that this marked the end of the governmental hands-off approach to groundwater management. Their historical review supports the argument that the qanat system has always been governed at the local level in the Iranian context.[2] This history has been largely overlooked in the formulation of Iran's water-related laws because of its sharp contrast with the country's modern centralised bureaucracy.

In 1962, the Land Reform law was introduced, and it was put to a national referendum in 1963. It was the most important of the 19 national legislative reform programs collectively known as the White Revolution. The Land Reform law redistributed lands owned by feudal landlords to poor rural peasants. It also changed the way infrastructure was maintained, from the previous system where exploitive feudal landlords, or 'khans', bore the sole cost of qanat maintenance, to a system where the cost of maintaining water infrastructure was shared between the many small-scale farmers and the former landlord.

As a result, 'peasants' were transformed into 'farmers' and had to negotiate the difficulties of water supply with former landlords. This changed system of ownership negatively affected the dynamics of interaction between stakeholders at the local level. In many situations, the new land reform (which was little concerned about water reform) led to conflicts between the stakeholders which led them to abandon the qanat and their land entirely. On fertile lands, however, the new small-scale farmers succeeded with the help of new water resources provided by deep wells that were more cost-effective than the qanat systems – though on many alluvial plains the superficial aquifer was also tapped by shallow wells.

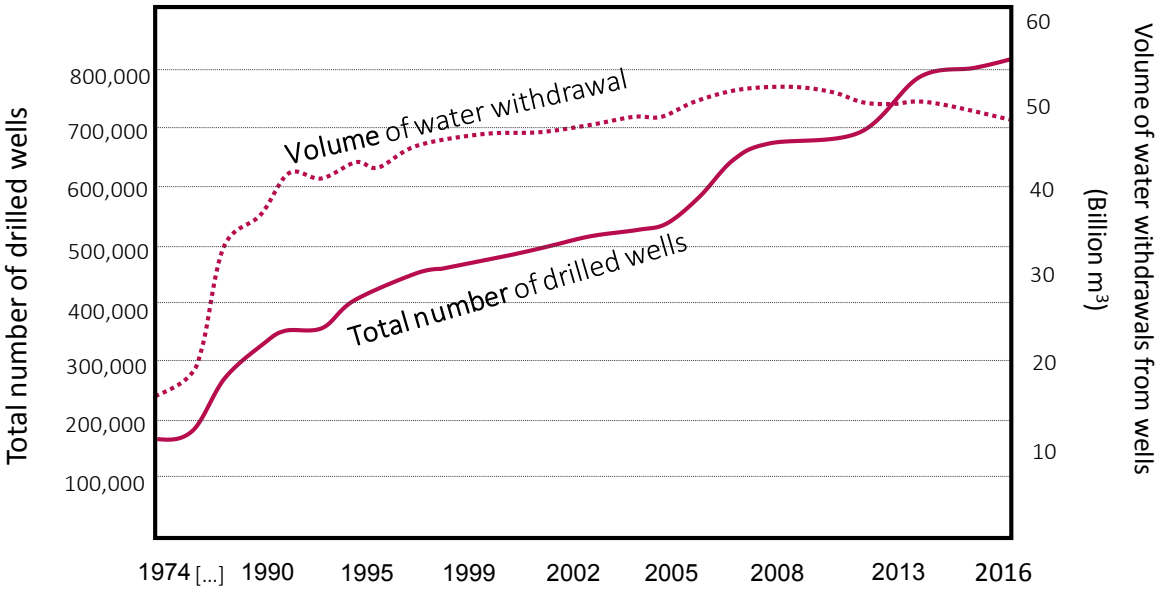
Between 1966 and 1978, a number of laws were passed to limit some of the adverse impacts of development on natural resources, especially groundwater, including the Groundwater Resources Preservation Act, the Water Law, and the Manner of Water Nationalization. The concepts and terminology introduced and used in these laws later became the basis of groundwater management. For example, the key concept of *dasht-e mamnooe*,[3] (prohibited plain) is defined in these laws. It introduced a hydrogeological equation to guide policymakers in legislating the issuance of well-digging permits. Dasht-e-mamnooe became the cornerstone of a series of regulatory policies (including banning wells) to control overabstraction and restrict access to groundwater. However, the regulatory policies associated with this term have largely failed to control water abstraction at the local level, as clearly demonstrated by the soaring numbers of both prohibited plains and drilled wells over the ensuing four decades (shown in Figures 5). The key factors that drove this increase are explained in a later Section.

Iran's 1979 revolution created a new environment in which the modernity discourse which was pursued zealously by the Shah gave way to an emphasis on justice and equity. Anything belonging to the past was associated with the idolatrous Shah regime and seen as contrary to the revolution's ideal of justice. Even the water laws which were meant to be the cornerstone of future sustainable policymaking (Agah and Hassani-Saadi, 2015) were ignored and replaced in 1983 by the 'Law of Fair Water Distribution' (FWD), the new basis of Iran's water policy. The attempt to change the legal, political, and economic structures of water management in the early years following the revolution was mainly driven by a strong belief that poor and marginalised people had been overlooked by the previous government. The laws crafted and approved under the Shah's regime were largely perceived and framed as anti-farmer and anti-poor, and the common argument was that they had no other intention than to "wipe out the agriculture" from the country's political agenda (Majles-Shora, 1981).

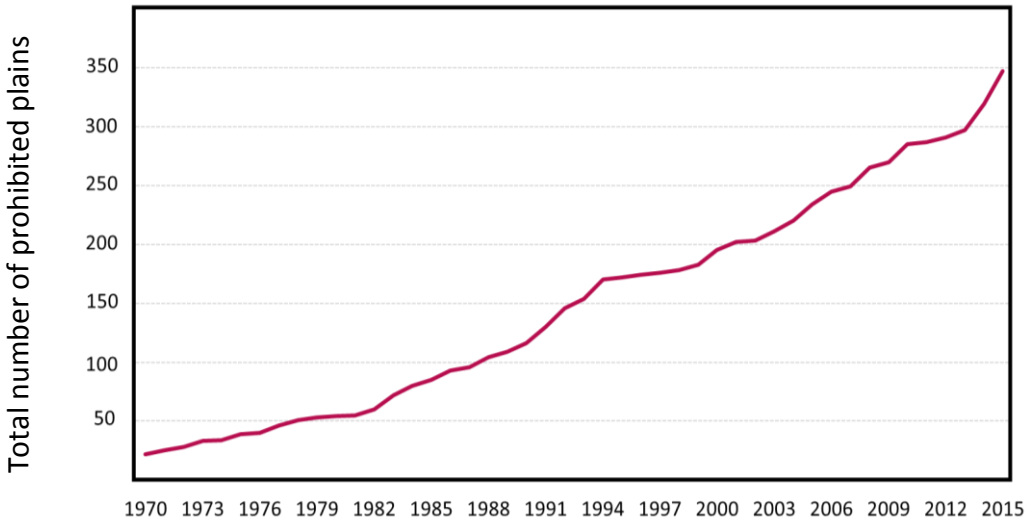
[2] Nevertheless, qanat building has historically been supported by central governing bodies, particularly in the form of policy incentives. For example, Polybius, a Greek historian of the Hellenistic period, reports that a resident of a region would be exempted from paying tax for up to five generations if the landowner invests in the construction and maintenance of a qanat (Briant, 2002).

[3] This is the word used in Persian: دشت ممنوعه.

Figure 5. (a) Changing trends in the number of drilled wells and the volume of water withdrawn; (b) Total number of prohibited plains.



(a)



(b)

Source: Iran Water Resource Management Co.

Given this background, the FWD law was passed in order to send the message that groundwater is common property and belongs to the nation, not just to those with enough money to drill deep wells. To put the law into practice, the Ministry of Energy issued abstraction permits, allocating water to different sectors and provinces. The new law repealed the former definition of prohibited plain and devolved to local water authorities the power to decide whether water abstraction in a plain was forbidden or not. Through this law, the parliament also urged the government to issue permits for the unlicensed deep wells that were dug during the early years of the revolution (1979 to 1983). One of the main rationales for issuing permits was to promote fairness of access to water. Another presumption was that by issuing licences and registrations, the new government could expand its influence and control, and limit illegal wells.

Recent groundwater policies and strategies

In 2006, regional water authorities began a new program to stop the unabated growth of illegal wells, which they knew would not be an easy task. Water authorities began to work with military, judicial, and other relevant authorities to close and, in some cases, destroy existing illegal wells, giving rise to considerable social resistance. In response, the parliament (under the direction of the Commission created through Article 90 of the Constitution[4]), stopped the program. The lawmakers' response to the situation was similar to that of their colleagues two decades earlier when they passed the FWD law. In 2010, parliament passed a law known as *Ta'een Taklif* [determining the status of unlicensed wells], in the midst of a very controversial public debate. The law urged the Ministry of Energy to issue abstraction permits for illegal active wells which had been dug before 2005 (Majles-Shora, 2010). Similar to the FWD law, the new law responded to the soaring number of unlicensed wells and to pressure from local constituencies to give water to people for farming. The law also dictated that water delivered to all agricultural water wells should be metered based on their license, with the Ministry of Energy responsible for paying for procuring and installing the meters. Progress on this has been very slow and in some areas imperceptible.

In 2014, Iran's Supreme Council of Water (directed by the president) approved a new plan, including 15 executive projects, to protect and rehabilitate groundwater resources by detecting and regulating overabstraction (Iranian Ministry of Energy, 2014). The plan mandated installing 'smart metering' systems in wells, GPSs on drilling machines, and recruiting hundreds of groups for patrolling and inspection. These policing mechanisms form the main strategy of this plan[5].

In 2005, the 'Water Independence of Provinces' law was passed. This law also went beyond its initial bureaucratic purpose, producing a new form of communication among local-level stakeholders. It was based on a three-layer mode of water governance consisting of the national, basin, and provincial levels. Based on this law, the Ministry of Energy became responsible for establishing a water authority in provinces that did not have their own, and existing regional companies were broken up into independent provincial companies. While the new law devolved power to the provinces[6], the Ministry retained authority in key areas including: authorising comprehensive studies in the basins; setting water resource development policy; allocating water to different sectors; regulating inter-basin water transfers; and determining the economic value of water. The provincial water authorities were devised for the purpose of harmonising with other provincial administrative and political authorities.

According to this law, the government was supposed to establish river basin organisations to manage water resources at the basin level, however the development of these organisations was suspended. This suspension caused water management in Iran to become divided into administrative units that were inconsistent with river basin boundaries. The structure of policymaking on water remained almost unchanged from the previous centralised system, but the new law changed the way stakeholders understood (ground)water, by shifting the governance structure from basin boundaries to political boundaries. As a result, the groundwater problem was recast into a provincial challenge rather than a basin challenge. Since the law facilitated competition between equally powerful provincial water companies, a new regime of conflict between provinces over water extraction began to emerge.[7]

[4] Article 90 of Iran's Constitution puts the Parliament in charge of investigating complaints made about the operation of the Executive, the Judiciary, and the Parliament.

[5] Other projects in the plan include: creating local water market, creating Water User Associations, and replacing irrigation wells in the prohibited plains with recycled water.

[6] The previous regional water company (RWC) was designed to manage water issues based on river basins, with an RWC potentially including one or multiple provinces. The new law converted RWCs which covered more than one province to provincial-level RWCs, so as to localise water management at the provincial administrative unit.

[7] e.g. the Zayandeh-Rood basin conflict described in Nabavi, 2015; Nabavi et al., 2017.

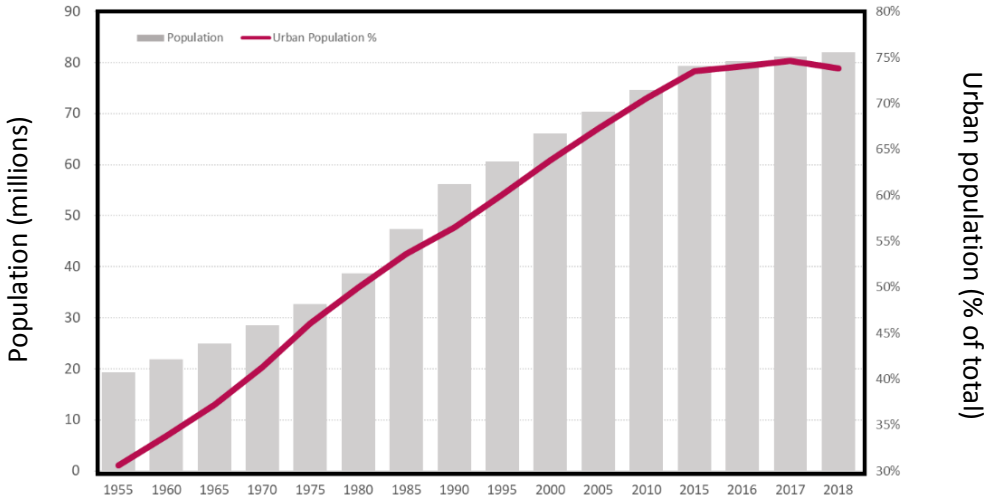
EXPLAINING THE PERSISTENCE OF OVERABSTRACTION

This section examines some of the key drivers of Iran's groundwater problems. It considers national policies and regulations that directly or indirectly have shaped and influenced the persistence of overabstraction. It also discusses policymakers' responses to water deficits, and the reaction from local stakeholders and experts.

Demographic changes

Iran's population has increased dramatically from less than 22 million in 1960 to 80 million in 2018, though the rate of population growth is slowing. Compared to many countries in the region, a very large proportion of Iranian people live in urban areas (73.4%, as compared to 38.8% in Pakistan and 43.14% in Egypt) (Trading Economics, 2015) (see Figure 6). This urbanisation has driven new patterns of consumption of energy and water. The 18% of Iran's population that lives in the Tehran metropolitan area, for example, uses a relatively large amount of water per capita per day (325 litres per capita per day, – three times what Berliners use) (Salian and Anton, 2010). Since in most urban areas across the country access to surface water is very limited, drinking water and also water for maintaining green spaces are often entirely supplied from underground resources. Increasing food security has also remained an important policy objective since the revolution, particularly because of the region's geopolitics and the risk of international sanctions. At the time of the revolution, Iran was importing 65% of its food, but it now produces 66% (Heslot, 2014). This goal of food self-sufficiency, against the backdrop of growing population, rising living standards, and changing lifestyles, increase pressure on land and groundwater resources leading to a countrywide imbalance between water demand and resources.

Figure 6. Iran's total population from 1955 to 2018 and urban population (% of total).



Agricultural policy

Agricultural policy and the history of regulation are key to understanding the groundwater overabstraction problem. Iranian agriculture has undergone two profound socioeconomic and political changes over the last half-century: (1) land reform laws in the 1960s, and (2) the revolution. These two major events, along with the impact of rapid urbanisation and economic development, changed the face of Iran's agricultural policy.

Since land reform laws were instituted at the national level, they caused profound changes in national-level agricultural policy. Under these laws, half of the agricultural land was redistributed to the sharecroppers and tenant farmers. The traditional landlord-peasant land tenure system was converted to family farms and commercial holdings. This had major social impact: it changed Iran's agrarian society through transforming peasants into farmers who owned their own land (for more elaboration see Ajami, 2005).

Pro-agricultural policies and agribusiness development evolved after the revolution as the countryside and the agricultural sector received more attention. Improving the living conditions of the poor[8] became the new government's highest priority. Increased production, enhanced productivity, improved farmers' welfare, and food self-sufficiency became overarching political goals in post-revolutionary policies. All these terms found a firm foothold in the policymakers' rhetoric and were translated into a range of laws and policies (see Mojtahed and Esfahani, 1989; Yazdanpanah et al., 2013; Balali, 2009).

After the revolution, the large-scale public and private agricultural production systems that were developed prior to the revolution – including agribusinesses, farm corporations, and the agricultural production cooperatives – were dismantled. They were replaced by individual, family, and group peasantry holdings (Lahsaeizadeh, 1990; Azkia, 1994, 2002). In order to deliver on the revolution's promise to aid the poor,[9] the post-revolutionary development institutions, particularly *Jahad-e Sazandegi* (Construction Jihad), redirected available resources towards smaller investment projects that benefited small farmers and promoted rural development.[10] Low-interest loans for small farmers, as well as subsidised fertilisers, seeds, and agricultural machinery, changed the power dynamic between small and large farmers and narrowed the divide between rich and poor (Behdad, 1989).

All these factors explain why groundwater was nearly an open-access resource with a relaxed regulatory regime after the revolution. Marginalised people – mainly peasants – were proclaimed from the very early days of the revolution to be 'the owners of the revolution', so policymakers in the post-revolutionary period were mainly concerned with securing support in the countryside. Because of this, and because of pressure by local constituencies on members of parliament, during the last four decades it has not been possible to challenge policies giving water to farmers. It also explains why proposals such as 'national austerity' (Karami, 2015), which aim to significantly reduce agricultural activities, are not welcomed or considered by government.

Technological and infrastructural bias

The country's fascination with technology and its attitude to modernisation are key to unpacking the groundwater crisis. The following two sections briefly describe and explain the technological bias influencing both past and current policymaking. This section takes the position that the large investment in infrastructure that was intended by the government to increase efficiency and social welfare has in fact backfired, and has resulted in more water withdrawal. The reason for this is that policies supporting improved efficiency were not accompanied by robust accounting measures or effective use of sanctions and incentives.

[8] The revolution proclaimed itself as the revolution of the disinherited (*mostaza'fin*) and barefooted (*pa-berahnegan*). Article 29 of Iran's constitution considers a person's right to "social protection in retirement, unemployment, old age, disability (...) which the government is committed to provide".

[9] Salehi-Isfahani (2006) strongly argues that the revolution has delivered on this promise. In an economic analysis he shows that the poor were much better off in 2006 than they were before the revolution, despite changes in policies and priorities.

[10] See Mojtahed and Esfahani (1989) for a further elaboration on Iran's agriculture policy in 1980s.

Modernisation program and efficiency

Qanat

Like most other countries, Iran's policies and subsidy programs have mostly focused on improving 'efficiency' in the water sector. This trend can be traced back to the country's modernisation project in the 1960s and 1970s, when qanats symbolised 'backwardness' that needed to be replaced by pumps and modern irrigation schemes (Ehlers and Saidi, 1989; Molle et al., 2003). The speech by Mansour Rouhani, Iran's Minister for Water and Power, at the International Conference on Water for Peace in May, 1967 accurately and revealingly reflects Iranian technocrats' underlying perception of the inefficiency of the qanat system and of indigenous and local knowledge:

> Although Qanats were the main source of water for the country's agriculture in the past, now that we are supposed to use the maximum potential of the country's water resources they are just barriers in further groundwater abstraction. Given this explanation, Qanats have no role in Iran's future economy, and their drying-up is sure thing. As a consequence, 35 thousand villages relying on Qanat are doomed to change in terms of reshaping and merging into massive agricultural development projects. This enormous transformation means disappearance of small and uneconomical village unites and their replacement with bigger villages similar to ones in the developing countries (Rouhani, 1967).

Governments at that point stopped investing in the construction of new qanats. Instead, dams and diesel-powered wells were increasingly hailed in policy circles as the most efficient means of accessing water, and the best way to improve social welfare and economic development. Dam construction dramatically increased over the next four decades with the purpose of securing more water for irrigation and helping rural areas to achieve their potential. Although the number of dams increased by more than 1200% over a 30-year period, this growth in number did not bring the same increase in the volume of regulated water, however it did increase water demand and changed people's mindsets about its availability (Nabavi, 2017b).

Irrigation schemes

After years of investment in water-distribution infrastructure – including building of irrigation canals, drains, and reservoirs – the government is currently developing capital-intensive policies to enhance efficiency by introducing new irrigation technologies such as drip irrigation. This efficiency-driven policy is quite popular among many of the experts who argue that one of the major failures of the government's groundwater management is the 'inefficient' agricultural water use, uncompleted hydraulic infrastructure and lack of water resources for future development schemes (e.g. Darvish, 2014; Madani et al., 2016). According to this view, the government's previous investment in this area is insufficient or incomplete. By the same token, inefficiency is framed as one of the main underlying causes of the current water problems, following from which the strongly advocated solution is investment in infrastructure to modernise irrigation and increase current irrigation efficiency (which currently is 33-37%). In 2017/18, the government sanctioned 81 million dollars for the development of new irrigation systems. An on-going project to improve irrigation efficiency, which started in 1990, has converted 23% of Iran's agricultural lands to pressurised systems (IRNA, 2017). The policy has, however, created a debate in water circles. Iranian policymakers believe that this particular program has been successful in saving water (7.5 Bm^3), but water researchers – referring to the concept of a 'rebound effect' in irrigation – argue that increasing irrigation efficiency in the absence of prior control over water allocations increases water consumption (Perry et al., 2017; Grafton et al., 2018).

The literature contains a number of examples that highlight the fallacy that modernisation of irrigation and increased efficiency result in water conservation on a basin level (for example see Perry, 2007; Pfeiffer and Lin, 2014; Gomez and Gutierrez, 2011). The study by Nabavi (2011) on the Zayandeh-Rood Basin in central Iran also shows that policies focusing on increasing efficiency in the basin do not deliver expected long-term outcomes. The research also illustrates that claims about 'water savings

through better technology' in the basin failed to account for return flows that recharge aquifers and contribute to downstream river flows. Earlier, Molle et al. (2004) suggested that projects such as canal lining, which focused on increasing efficiency for water conservation in the basin, did not deliver expected water savings. Rather, such projects "only led to having more water spread and depleted locally to the detriment of users downstream". Put simply, increasing efficiency increases water consumption. This is because both consumption per unit area increases, and the irrigated area increases. Ultimately more water is consumed, which translates into aquifers being further depleted.

Years of observation in various disciplines have also shown that many attempts initially designed to improve sectoral efficiency have often been quite ineffective in the long run in achieving sustainable systemic improvement. This phenomenon, also known as the rebound effect or Jevons paradox,[11] suggests that increased water efficiency: (i) makes the use of water and energy relatively cheaper, thus encouraging increased use; (ii) leads to increased economic growth, which drives more water consumption; and (iii) multiplies the use of all the companion technologies, products, and services that were being restrained by it (see Nabavi, 2017a). The rebound effect implies that focusing attention purely on infrastructural aspects when addressing Iran's groundwater problem is incomplete and ineffective, if not misleading. Results of recent research on irrigation cases in Spain (Gomez and Gutierrez, 2011; Berbel et al., 2015) and the US (Pfeiffer and Lin, 2014), also highlight the negative consequences of increasing plot-level efficiency. In the case of Iran, it is thus argued that focusing all policy attention on drip irrigation without also controlling water allocations may exacerbate the water problem. Moreover, paying 65 to 85% of the costs of this capital-intensive policy through state-subsidised payments and low-interest loans imposes a heavy burden on public finances.

In addition to the technical controversies around increasing efficiency, Jafary and Bradley (2018) point to another important social aspect of increasing efficiency: the different ways in which 'efficiency' as a concept is understood by the different actors involved. In their empirical study in central Iran, Jafary and Bradley show that to local farmers 'improved efficiency' means more access to water rights and more agricultural production. By contrast, for government agencies efficiency means controlling overabstraction and ensuring water availability. They succinctly connect this difference between local- and national-level actors in their perceptions of 'irrigation efficiency' to the lack of cooperation between them. More detailed information on the quality of the relationship between state and local actors is presented later.

Alternative water sources

Iranian policymakers have shown a strong inclination towards large investments in projects designed to diversify water sources, such as interbasin transfer projects, desalination plants, water recycling projects. The government also recently shows interest in tapping into the country's underground supplies of fossil water, and karst water resources (PressTV, 2016; Tehran Times, 2018). The overarching goal has been to lower the state's reliance on traditional water resources. Among these large projects, interbasin water transfer projects have received considerable public attention, mostly because over the last decade they have run into problems at various social and political levels. The most controversial of these project is a water-diversion project that transferred water from the Karoun River to the Zayandeh-Rood River – a river that flows into the Central Plateau and city of Isfahan. The flow of the Zayandeh-Rood was doubled, encouraging people to migrate and industries to expand. Economic development was increasingly centred on water, leading to more consumption at all levels. However,

[11] The increasing efficiency paradox was made explicit in 1865 when Jevons (1906) documented the paradoxical relationship between increasing efficiency and coal consumption.

very soon after the project was finished, the water supply problem reappeared and farmers dug even deeper to get to more groundwater.[12]

Along with interbasin water transfers, two high-profile water transfer projects are currently being put in place to solve water problems. These projects aim to transfer desalinated water to central Iran from the Caspian Sea, the Persian Gulf, and the Sea of Oman. Transferring water from the Persian Gulf and the Sea of Oman is the most ambitious of the projects. It aims to desalinate water on the coasts, then transfer it to 16 central provinces to supply drinking water to 47 million people. In 2016, the government allocated $400 million from the country's National Development Fund to launch the initiative (Tasnim News, 2016).

All of the above projects demonstrate strong tendencies towards large-scale irrigation and hydraulic works. As identified in the seminal work by Molle et al. (2009), these tendencies stem from the bureaucratic power of technocrats across different government bodies and the financial interests of large corporations.

Economic incentives

Lower drilling costs, the ease of abstraction, and government subsidy and loan programs in the early 1970s increased the demand for deep wells. At the same time, an Agricultural Credit and Rural Development Bank was established to provide credit to cooperative groups and finance purchases of farm equipment.[13] Thus, the deep tube well technology became increasingly prevalent. For farmers it meant they could transition from their 'old' climate-dependent qanat system to a 'modern' climate-free system that provided them with a permanent water supply to produce high-value agricultural products.

Like many other places around the world, water is not an economic good in Iran. According to the FWD law, the cost of water is calculated based on actual costs: that is, if water is abstracted by water authorities, the cost of water equals the extraction cost. For the private sector actors, the net cost of water is the cost of producing water plus the cost of monitoring and management by the water authorities.

In the 1980s, during the war between Iran and Iraq, the government began to use subsidies to assist people in accessing food and basic necessities. However, the subsidies mainly pertained to energy and food, without focusing on any particular group of people. Farmers in the rural areas were supported by energy subsidies, at a level as high as 93 to 97% of the water-pumping cost. This massive subsidy program in support of the agriculture sector was justified in two ways: first, it achieved food self-sufficiency for the country, and, second, it diversified the economy. The agriculture sector thus received governmental assistance, tax exemptions, and short-term credit facilities. The argument was that a boost in agriculture production could help the government to bolster international trade by increasing non-oil exports.

The large subsidies for the agriculture sector, however, impacted the water and energy sectors. The subsidies removed incentives for preserving groundwater, and for implementing sustainable water use, including the production of less-water-intensive crops. Examples of unsustainable water use are multiple, such as farmers extracting groundwater for irrigating rice in regions that were already dealing with drought (e.g. in Kermanshah and Mazandaran provinces); pumping groundwater from a depth of 450 metres (Fars Province); or pumping water up 600 metres in order to water trees in the mountains

[12] See Tavakoli Nabavi (2010) for an explanation of how this water transfer solution backfired.

[13] Most of this lending to agriculture was in the form of large loans to large agriculturists, merchants, and agribusinesses. According to Rezazadeh (1979), various bureaucratic constraints deprived the majority of small farmers of access to institutional and commercial credit. (Rezazadeh, 1979 for a detailed discussion on bank loans and agricultural credit after land reform; see Richards, 1975).

or to grow crops (Charmahal-Bakhtiari Province). In fact, water and energy costs are not limiting factors in farmers' decision-making, rather they reinforce the wasteful use of water and energy at this extreme level. Clearly, the failure to integrate economic aspects into groundwater management needs to be addressed.

Energy and water-pricing policies could be effective in controlling the growing water demand in agriculture, however if the market is not saturated and there is demand for agricultural products – which is the case in Iran's agricultural market – increasing the prices of inputs such as water can be compensated for by a rise in product prices. It is also important to be mindful of the risks of large increases in water and energy costs. Iran's experience of removing fuel subsidies is illustrative of how focusing on one policy – presenting it as a silver bullet for problems – can lead to counterproductive results. The subsidy reform policy introduced in 2010 was expected (besides many other promised results) to reduce demand for fuel. Instead, petroleum consumption has increased 33% since 2012. The policy not only failed to change people's behaviour with regard to using cars and consuming fuel, it also substantially raised other prices. The study by Venot et al. (2007) on the Lower Jordan River Basin is another example of the complex relationship between high energy prices and groundwater extraction. Their study shows that increasing the cost of irrigation water beyond a level acceptable to farmers is unlikely to bring about significant water savings, defeating its intended purpose. Instead it reinforces the advantages of more capital-intensive farming, transferring the value added from local stakeholders to major entrepreneurs and state agencies.

Social aspects

Loss of social capital: Wells and individual strategies

Diesel-powered pumps not only lowered groundwater tables, but also eliminated the local management of water resources that had characterised the qanat system. Installation of pumps negatively affected the traditional collective action around construction, operation, and maintenance of qanats. Importantly, the shift to pumps also destroyed the collective organisation referred to as *Boneh* – a social hierarchy with defined roles and responsibilities around water management which created solidarity and a sense of belonging at local levels. Balali (2009) argued that other cooperative systems that emerged after the land reforms of 1962 were not as successful as the Boneh system in organising collective action. Cohesiveness and public participation disintegrated when farmers abandoned Boneh. They began drilling pumped wells and became self-interested. Two examples below from Moghimi (2017) clearly show an individualistic and self-oriented attitude amongst farmers who were seriously suffering from water shortage:

> When I see my neighbour digs wells and abstracts water, why shouldn't I? … This is my right … This water is the farmers' share … if I do not use it now, it may not be there tomorrow … if we are going to have a water crisis in 10 years' time, then … I'd prefer to use my full potential now to get the most out of my gardens – so as to grow rich by taking the advantage of this 10 years' circumstances.

> Right now my well has no more than only 3 m water which will last just for 4 years … I'm going to go deeper or dig another well, once it's depleted … I can do it now, but there is a risk that [water authorities] come and reduce my water entitlement … so I am putting it off until they change the general manager [of the regional water authority], then I can get a new licence without any reduction of water abstraction quotas on my well.

Social capital is a crucial factor when considering the underlying challenges Iran is facing in incentivising social learning and collective action for improving groundwater management. Social capital includes different aspects such as trust and trustworthiness, civic engagement and cooperation, and social cohesion and inclusion, which are key to groundwater governance (López-Gunn, 2012). Similar to other contexts experiencing overabstraction and unauthorised water use, Iranian groundwater management

suffers from a growing distrust between the water authorities and water users (Azizi Khalkheili and Zamani, 2009; Jafary, 2016; Arabi et al., 2015; Najafi and Shirvanian, 2006).[14] Lack of trust and lax enforcement (see later Section) lead to the decreased legitimacy of the water authorities and to enforcement problems. Loss of social capital, however, is not limited to the relationship between government and local water users, rather it has also led to a vicious cycle of mistrust between local community members. There are many complex reasons why trust among local actors has declined, including the history of arbitrary government decision-making and failed policies, farmers perceiving an unjust distribution of costs and benefits, and the omission of farmers' perspectives from implemented policy due to their lack of involvement in policy development.

State-citizen relationships: Participation

Among the major hurdles facing policymakers are: the disconnect between local farmers and the state's policymaking; the resulting mistrust; lack of public participation; and lack of political power at the local level. This lack of participation has not been overcome by lawmakers, particularly after land reforms when the new water bureaucracy took over. In fact, the government replaced large landowners without forming the state-citizen relationships that would ensure the sustainability of water resources. Since then, all-new cooperatives have been established in a top-down fashion with minimum respect for the social value of the qanat system, indigenous water knowledge, and people's rights to water and land. Although land reform assigned agricultural property to individuals and groups, it was not considered to be a right but rather a privilege. Here, Katouzian (1997) describes the political context after land reform:

> there was no law outside the will of the state, which stood above the society, despite a body of rules which were subject to rapid and unpredictable change. The state's legitimacy was not founded in law and the consent of the influential social classes…

Thus, public participation and deliberation was not given a firm place in either crafting or implementing groundwater-related laws. Even when public participation was incorporated into law, especially over the last decade, many stakeholders found the participation process inauthentic and disingenuous (Nabavi, 2017b).

Box 1. Examples of farmers' attitudes towards authorities and other members of the community (extracted from Moghimi's interviews (2017) in south and central Iran)

"If there is a way to do bad things, I assure you farmers will do it … even if water authorities install metering systems [to monitor groundwater abstraction], people won't resist; but they will learn how to find a way around it".

"When a motor pump that is next to mine has a licence for 40 lit/s compare to 10 lit/s of mine [given we are the same] … and [government] still want to reduce my water quota, I will react anyway; I even steal his pistachios (the main crop in Rafsanjan region), if I have to…".

"the [new] illegal wells are not being liquidated … instead authorities buttonhole old farmers like me spent decades working on lands, force me to reduce my water share and kill my trees".

"Yes, I made mistakes but when I saw that the government have no discipline or makes no rational decisions so I decided to act like that…".

"Right now there is a water well that was sealed two days ago but today it got opened by the irrigation office…".

[14] See Renani and Moayedfar (2011) for further elaboration on the decline of social capital in Iran.

Lack of social learning[15] experiences is another important source of regulatory dysfunction in Iran's groundwater management. The learning capacity of formal and informal institutions in Iran is quite low as social learning processes are hampered by a lack of responsibility for, and ownership of, outcomes. This has led to low levels of institutional and organisational adaptation to environmental change.

The study by Moghimi (2017) shows that formal and informal institutions are not adapting to the dramatic changes that Iranians face in their daily lives, including the groundwater problem. The general insight from case studies in south and central Iran is that farmers' reactions to the problem depend on the level of difficulty they are experiencing in water extraction.[16] For example, in the downstream areas of the Rafsanjan plain, where farmers have to dig deeper to reach water (e.g. 350 m in Nough) the level of trust and cooperation among stakeholders is higher than in the upstream region where abstraction of water is easier (e.g. 150 m in Kaboutar-khan). This difference in the farmers' attitudes is a result of the social learning process that has been partly shaped by the hardship experienced due to overabstraction. Those residing downstream better understand the negative impacts of overabstraction, making them more inclined towards less-individualistic attitudes and greater collective behaviour.

Knowledge and expertise

Iranian water legislation and policymaking have always hinged on the question of 'water access' and how the country can use its full hydraulic potential for the purpose of development. Large-scale hydropower dams and modern irrigation schemes have become symbols of progress and prosperity, and the scientific knowledge and engineering skills underpinning them provide the necessary foundation for the state to recast itself as a modern society, liberated from old-fashioned customs and traditions. While engineering is increasingly vital to the country's modernisation project, indigenous knowledge and local technologies are deliberately ignored and perceived as barriers.

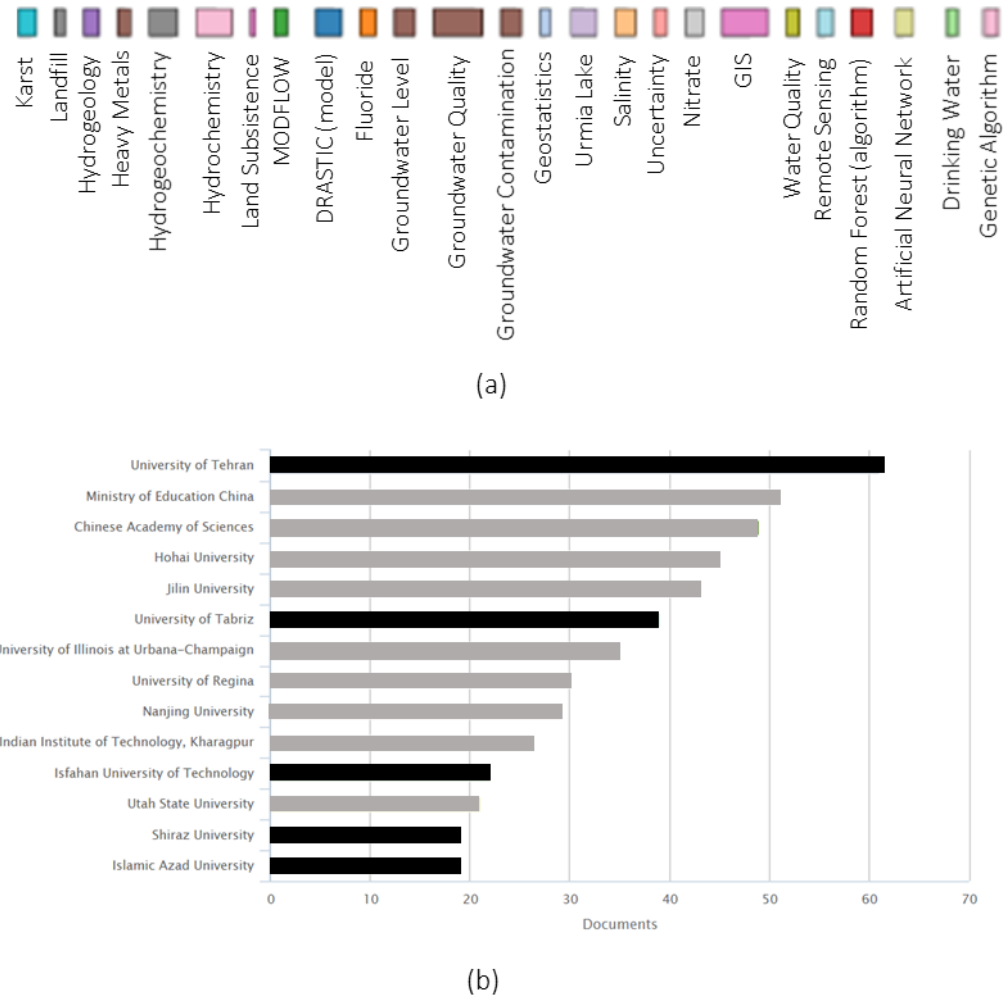
Iran produces over 233,000 engineers annually, and is currently one of the top-five members of the club of engineer-producing states, alongside Russia, the United States, China, and India. Percentage-wise, this is equal to about 40% of all Iranian graduates – the highest average percentage of graduates of engineering in the world (Nabavi, 2016b).

Due to the massive educational investment in the hard sciences, it is not surprising to see that engineering and mathematics are increasingly mandatory for decision-making regarding groundwater. Immersed in the realm of mathematical modelling, Iranian water experts are the world's top producers of research on groundwater resources that uses sophisticated computational algorithms. Figure 7(a) shows the main keywords for the articles published about groundwater in Iran. Optimisation algorithms and models such as Artificial Neural Network, Genetic, Random Forest, MODFLOW, and DRASTIC have secured a foothold among Iranian water experts seeking solutions for the groundwater problem. Iranian universities, shown by the black bar in Figure 7(b), are also the main producers of this type of knowledge across the world. In Iran's academic and policymaking circles, engineering and mathematical knowledge prevails and humanities and indigenous knowledge are rarely taken into consideration. Non-engineering management options find less room to be fully considered. Instead, options stemming from command-and-control approaches and engineered solutions are viewed as reasonable policy actions.

[15] Social learning refers to learning processes among a group of people who seek to improve a common situation and take action collectively. It emphasises the importance of effective communication between involved parties to better understand different perspectives, and develop processes for collective action and reflection over time.

[16] Moghimi's (2017) finding is mostly valid within the study area. Although it may be true, more investigation is needed before it can be generalised to the whole country.

Figure 7. (a) Important keywords regarding groundwater in Iran; (b) number of technical papers on groundwater by academic sources.



Note: (a) search on keywords in 'groundwater' AND 'Iran', (b) search on the number of papers by affiliation on 'artificial neural network' OR 'genetic algorithm' OR 'fuzzy' AND 'groundwater' (Source: Scopus, March 2018).

Institutional and political aspects

As discussed earlier, the new laws and regulations introduced in different phases of Iran's development (re)created new organisations and forms of bureaucracy. For example, the land reform law caused a major change in the relationship between the state and local stakeholders. When the law went into effect in 1963, the traditional local rulers and village heads – the *kadkhudas*, khans, and landlords who acted as intermediaries between local farmers and the state – became redundant and irrelevant. For the first time in Iranian history, local farmers had to face the state's massive bureaucracy directly. The law also led to the collapse of local institutions which had evolved historically and which had made farmers resilient to climate variabilities (see Hashemi et al., 2017). The new series of regulations formalised and legalised the government's interference in all aspects of daily life. The law was a game-changer in that it gave the government an extreme level of control over its citizens. The bureaucracy penetrated so thoroughly into local dynamics that in 1974 the government began to reorganise the countryside by depopulating some regions and repopulating others (Abrahamian, 1982). It was part of the government's paternal role to guide the people "toward the great civilization" that the Shah promised (Pahlavi, 1977). Obviously, the bureaucracy was not politically and operationally coherent. It

produced its own unique set of complex and interdependent organisations (including ministries) with different levels of autonomy and capacity, and even with contradictory roles in the country's development plan.

The revolution added another set of values and regulations inspired by revolutionary principles. As a result, special organisations were created to fulfil the goals set out by the revolution. The most important organisation, which became a government ministry in 1984, was *Jahad-e Sazandegi*. The organisation's original purpose was to focus on rural areas and agriculture, and improve the livelihoods of smallholder farmers. There was a strong belief among revolutionaries that the previous regime's zealous efforts to transform Iran into a replica of western urban and industrialised societies had largely neglected villages and agriculture. However, over time Jahad's 'social justice' orientation clashed with more bureaucratic and pro-private attitudes in conventional ministries, particularly the Ministry of Agriculture. This executive conflict grew intense at some stages and was finally resolved when *Jahad Sazandegi* was merged with the Agriculture Ministry in 2001, and renamed Ministry of *Jahad-e Keshavarzi* (Agricultural Jihad).

Development of agribusinesses and improving irrigation efficiency through drip irrigation is the priority of the Ministry of Jahad-e Keshavarzi. The Ministry of Energy, on the other hand, tries to address the water scarcity problem through regulating and policing illegal abstraction, and introducing new sources of supply to the existing network (e.g. interbasin transfer projects, desalination plants, and water recycling projects).

The Department of Environment is another important government body that is dealing with groundwater challenges. Given its non-ministerial status,[17] the department has limited lobbying ability and financial capacity within the central government, compared to the Ministry of Agriculture and the Ministry of Energy. As a result, environmental concerns are less likely to be raised and taken into consideration in high-level policymaking. This lack of influence has provided more space for competition between water bureaucrats (represented by the Ministry of Energy) and the agricultural bureaucracy (advocated for by the Ministry of Agriculture), without any major actor representing the environment.[18]

The competition in Iran, however, has not led to a reasonable division of work between government organisations to address groundwater challenges. This is mostly because these organisations have conflicting professional ideologies and organisational missions, different budgeting and regulatory capacity, and because they of course have different roles and responsibilities in the country's development plan. These problems of coordination and cooperation between organisations, lack of effective communication, and silo-based decision-making are of great concern to those addressing the groundwater problem.

Lax enforcement

Political costs

Lax enforcement is another reason for continued overabstraction. A lack of political will prevails generally, and is linked to the extreme political costs of enforcing restrictions on groundwater resources which force farmers to live within hydrological limits. This reluctance to impose regulations is especially compelling in a context where such restrictions conflict with the state's desire to boost food production and support rural incomes. In other words, punishing illegal water pumping, and closing or destroying

[17] The department is run under the supervision of the president.

[18] This type of competition is commonly documented in the literature, in which the government ministry in charge of water is responsible for large-scale infrastructure and the agricultural ministry is in charge of smaller engineering projects (see Molle et al., 2009).

wells, are not easy tasks for the state as they come with high political costs, and have no short-term benefit for politicians. One of the Khorasan water authorities summarises the challenge of law enforcement as follows:

> It is not easy to close an unauthorized well or prevent unauthorized water abstraction. It requires substantial time, effort, coordination, and political will. Moreover, no one sees it and cuts a ribbon for… [even when] we send illegal cases to courts, the sentences are not proportional to the crime. In some cases, even the offender is exonerated. The problem is that judges often estimate the damage based on the amount of product harvested from that amount of water, instead of on the cost of replacing the same amount of water (Mohamadzadeh in Fekri, 2013).

There are two other social aspects linked to lax enforcement that need to be discussed. The first relates to the lack of social stigma around illegal action (and thus a relaxed attitude towards it), and the second relates to emerging bureaucratic corruption.

Social stigma and compliance

While there is almost no literature specific to water, it is not difficult to find examples showing the lack of social stigma associated with non-compliance to government regulations.[19] This factor significantly contributes to why all regulatory measures including registering, banning, metering, and sanctioning become ineffective, leading to further potential behavioural problems in the long run. Examples provided in Box 1 illustrates some aspects of this issue, where farmers adopt illegal practices as a way to resist policies and regulations.

Government policies and regulations also play an important role in non-compliance behaviour. In the context of groundwater, farmers have learned over the years that if they break the law and bypass regulations, later they can negotiate with authorities to get exempted from the penalties, and also get a licence for their well.

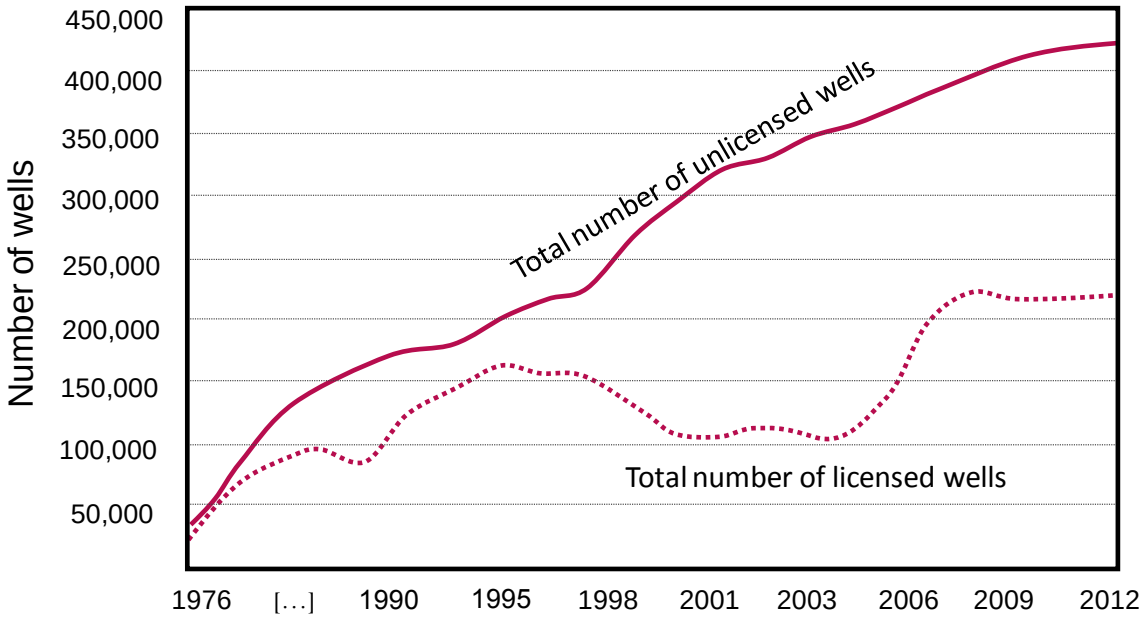
The most evident example in this case is the Ta'een Taklif law passed in 2006. The law urged the Ministry of Energy to issue abstraction permits for illegal active wells which were dug before 2005 (see earlier Section). Similar to FWD law, this law again sent a message to the public that although unlicensed groundwater pumping is illegal, it is negotiable. In fact, a local farmer can infer from this that he can dig an illegal well regardless of existing regulations, and then can wait until the government legalises the well by issuing a licence. Figure 8 shows how this lax enforcement of the legislation, and other contributing factors, have led to a soaring number of unauthorised wells over the past four decades.[20]

Apparently, this situation is not limited to Iran. De Stefano and López-Gunn (2012) describe a similar case in Spain where the regional and central governments negotiated with farmers to control olive tree irrigation, arriving at a solution that has led to illegal and unauthorised water abstraction (90% of wells lack abstraction licences). Spain's solution was to partially legalise unlicensed irrigation on farms. In fact, in the case of both Iran and Spain, the policy instruments there were used developed a society-wide perception that breaching the law carries a greater prospect of gain than of loss. The outcome is a public sphere in which breaching or bypassing the law can become routine and is the most rational thing to do. That is why it is often heard from farmers that they have few alternatives but to breach the law as they are heavily reliant on groundwater (see Box 1).

[19] See Rezaee, 2005; Banakar and Ziaee, 2018 for more elaboration on the sources of non-compliance with law and regulations in Iran; Ali-Babaee and Firooz Hajiyan, 2009.

[20] The number of unlicensed wells announced by the government does not necessarily include all illegal wells.

Figure 8. Trend in the number of (un)licenced wells in Iran.



Source: Iran Water Resource Management Co.

Bureaucratic inconsistency and corruption

Given all these years of water legislation at the national level, there has been a constant demand from local stakeholders for equality in law enforcement, highlighting the problem of arbitrary law enforcement and bureaucratic inconsistency in dealing with illegal water abstraction. Many farmers complain that water authorities are selective and unfair in enforcing the law. The way illegal wells are treated by authorities is an example of this bureaucratic inconsistency. Mashhad plain is the second-most populous area of the country after Tehran, and is experiencing rapid population and industrial growth and falling water levels (0.7 m annually). There is a report from this area that 41% of overabstraction in the agriculture sector is related to 2% of the wells (Omranian, 2017). This implies that overabstraction and illegal activities in Mashhad plain can potentially be reduced by 60% by controlling only 2% of the wells. However, for both political and social reasons, there is no public transparency around who these well owners are and why authorities are not being proactive in tackling the issue. The problem of overabstraction is also not only about illegal wells: it is more about illegal abstraction from legal wells. According to one of Mashhad's water authorities, illegal water abstraction from legal wells in the Mashhad plain is four times more than what is abstracted from illegal wells (Fekri, 2013).

The entrenched top-down approach within government organisations has also excluded the public from policymaking and participation, and increased bureaucratic corruption, particularly when it comes to issuing permits for water abstraction. Azizi Khalkheili and Zamani (2009) conducted a survey study in Doroodzan Dam Irrigation Network in Fars Province to identify the factors affecting farmers' participation in irrigation management. Their findings showed that "unequal distribution of water among farms" and "dissatisfaction with water authority operator" were among the top problems and obstacles affecting farmer participation.

This lack of public participation and public scrutiny has increasingly led to corruption at bureaucratic levels. In some cases, farmers pay staff to turn a blind eye to their illegal well, or use forged

government licenses so that they may continue to abstract water from their deep wells, ignoring the critical condition of the aquifers.[21] Nevertheless, there is almost no literature on this subject, and these issues require further engagement.

DISCUSSION AND CONCLUSION

Groundwater resources play a pivotal role in sustaining environmental ecosystems and enabling societies to adapt to climate variability and change. The strategic importance to governments of these invaluable stocks of freshwater, especially in developing countries, will be intensified as climate change brings more extreme events such as droughts and floods, increasing the variability in available water. This suggests that Iran's current groundwater problems – including falling groundwater levels and land subsidence caused by overabstraction – might be exacerbated if the country does not act urgently to manage the situation.

Since the 1966 ban on groundwater extraction in areas of the plains where critical conditions prevail (*dasht-e mamnooe*), a wide range of policy instruments have been implemented at various political and administrative levels to control overuse. Many of the regulatory strategies have failed to achieve the intended goals, and they have often backfired, reinforcing the vicious cycle of overabstraction.

This paper provided a comprehensive overview of Iran's groundwater challenges, including technical, political, and economic problems and solutions, a profiling of the problems within social institutions, a review of the scientific aspects of water management, and the interactions among all of these. It implicated policies and regulations which provide grounds for overabstraction and unauthorised groundwater use. This paper broadly set the stage for future studies through identifying the key themes that are critical for addressing Iran's groundwater problem. Each theme highlighted some of the key contributing factors resulting in the groundwater crisis, including rapid population changes; policy myopia; government's technological and infrastructural biases in future thinking; pro-agricultural investment and subsidies of rural public goods; self-sufficiency rhetoric; lack of robust water accounting and measurement; lack of participation and deliberation at local levels in the process of law- and policymaking; lack of understanding of the incentives and local actors' behaviour; overlooking indigenous water knowledge; and lax enforcement.

The review also provided several lessons with regard to policies designed to regulate groundwater overabstraction. As the Iranian case shows, regulatory mechanisms need to be accompanied by complementary actions such as: (1) clear and transparent legal and institutional frameworks; (2) an integrated legal and institutional framework for law enforcement that takes a holistic view of policing and partnering with community organisations; (3) reducing the social and political costs of enforcing regulations; (4) including local communities in lawmaking and policymaking, as well as in implementation. Without these changes, regulations will be counterproductive, worsening the problem of groundwater depletion.

However, all these concerns have not been fully reflected in Iran's new plan to protect and rehabilitate groundwater resources (Iranian Ministry of Energy, 2014). Although the plan suggests projects on water market and water user associations, it mostly focuses on policing mechanisms to address groundwater overabstraction. It includes installing smart-metering systems on wells and GPSs on drilling machines, and recruiting personnel for patrolling and inspection. The challenge is that applying these policing-oriented strategies without fully considering the above-mentioned

[21] e.g. Ardabil Province case, see MehrNews, 2018.

complementary actions is likely to generate further resistance in farming communities, leading to counterproductive results.[22]

Policies developed to control illegal abstraction by requiring registration of unlicensed wells have become one of the biggest failures in Iran's current history of water policymaking. The main technical expectation in developing such policies was that by issuing licences, the government could control the number of illegal wells, preventing the expansion of illegal abstraction. The strategy, however, turned out to be counterproductive and even worsened the problem because farmers learned to break the law by digging new wells or deepening old ones. There are no repercussions for farmers because they then wait until the government announces that they can acquire a permit. This has significantly undermined the authority of the state among farmers, water user communities, and the society as a whole. In other words, the negative impact of the government's failure to control groundwater overabstraction has not been limited to declining water quality and quantity for registered water permit holders: circumventing regulations also results in the deterioration of state-citizen relationships, the government's institutional credibility, and decision-makers' legitimacy.

The government's pro-agricultural investment, including water and energy subsidies and financial incentives for technology improvements, also need to be revisited. Continuing the current subsidy measures will fuel intensification and extension of farming, and will ultimately result in more overabstraction.

The capacity of lawmakers and policymakers also needs to be improved in two major areas: first, by enabling them to avoid myopic planning decisions. (It may be critical to consider what kinds of incentives may encourage the development of this capacity). Second, they need to know how to co-manage groundwater resources.

Decision-makers that are too often in a rush for short-term gains need to be more mindful of the long-term effects of their policies on the environment, society, culture, and politics. Iran has historically been a *jame'eye kotah-moddat* – a "short-term society" (Katouzian, 2004). Changing this myopic attitude in Iran is thus challenging when change – even important and fundamental change – tends to be a short-term phenomenon.

The second area is groundwater co-management. The co-management of groundwater by users and the state is imperative as an alternative to the government's current command-and-control strategy, which has shown its shortcomings as a resource management strategy. In fact, the large number of groundwater users, their anticipated greater dependence on it in the coming years, combined with subtractability and low excludability and other characteristics of groundwater, leave no other option for the state and water users *but* co-management. Clearly, public participation and cooperation remain central in this process. There is quite promising recent work in the Khorasan-Razavi Province by NGOs and farmer syndicates on detecting illegal abstraction (even from wells equipped with smart meters), and on local-level regulation of abstraction. Another good example to replicate is the city of Mojen in Semnan Province, where farmers have successfully developed their own water user association and implemented an efficient water market over the last 40 years (Bohlolvand et al., 2015). Looking at these examples and other strategies for co-management of groundwater resources can provide Iranian policymakers with valuable insights into the elements that are key to designing and implementing effective regulations for collective action, and addressing Iran's groundwater problem.

[22] Recent experiences in Jordan and Australia, where farmers tamper with or bypass meters, illustrate the universal nature of this challenge (Al Naber and Molle, 2017; Greiner et al., 2016; Horn, 2017).

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