Government management and overexploitation of groundwater resources absence of local community initiatives in Ardabil plain-Iran

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Abstract

Although mismanagement of groundwater resources has resulted in their destruction over centuries, climate change is speeding up this process more than ever. On the one hand, urgent action by government bodies is needed to address the challenge. On the other hand, a vast body of literature proves that bottom-up collective action, although requiring a longer time period, is a better solution to manage such resources. This research aims to address this dilemma. The groundwater resource in Ardabil plain in Iran, which has long been managed solely through government intervention, has been chosen as a case study to explore the opportunities and limitations of managing a critically endangered area from a common-pool resource perspective. Our study suggests that managing Ardabil groundwater resources should be conducted on two scales. The bottom-up institutional agreements should take place at village scale while the government should stay in charge of the overall organization at plain scale.

Keywords: *Common pool resources, Social-ecological systems framework, Groundwater, Government management, Ardabil-Iran*

1. Introduction

Managing common-pool resources (CPR), i.e., systems that produce finite quantities of resource, is one of the key challenges in environmental sustainability (Berkes and Palmer 2015; Cockerill et al. 2015; Janssen 2015). CPRs are subtractable in the sense that the units one person appropriates reduce the quantity of resource units available to others (Ostrom 2002). Fisheries, wildlife and forests are examples of well-known CPRs (Feeny et al. 1990; Hardin 1968; Leonard et al. 2015; Rosenbloom 2013; Wade 1987).

Among CPRs, water resources have special importance (Huang et al. 2016; Tharmendra and Sivakumar 2016). Some even consider water as the oil of the 21st century (Mehta 2000; Wohlers et al. 2012). Such a claim may not be true, but it emphasizes the fact that having access to water will play a critical role in the development of the global economy and of government policies in the decades to come (Wohlers et al. 2012). This is especially critical for countries in arid and semi-arid regions, particularly in the Middle East, such as Iran

(Madani 2014). On the one hand, it is predicted that surface waters, such as transboundary rivers, will lead to many conflicts in the future (Dolatyar and Gray 2016; Madani 2014; Mehta 2000; Voss et al. 2013). On the other hand, internal water issues will threaten economic, political and social stability and the existing way of life (Madani 2014; Voss et al. 2013).

Although Iran has a more advanced water management system than other countries in the Middle East, it is also facing a serious water crisis (Madani 2014). The ancient water infrastructure called "Qanat" which was invented in Iran (Ahmadi et al. 2010; Kardawani 1998; Madani 2014; Sanizadeh 2008) can no longer keep up with the country's requirements as a result of population growth, industrialization and urbanization. Furthermore, although Iran is among the five great dam builders in the world and has been making long term efforts to upgrade its irrigation systems (Madani 2014; Sanizadeh 2008), water shortages and droughts have diminished the effectiveness of such technical strategies (Yazdanpanah et al. 2014). This makes Iran's water management system more vulnerable than other countries in the region.

The Iranian government has implemented many plans to manage groundwater. This includes plans tackling overexploited plains. In Ardabil province, and especially the overexploited Ardabil plain, groundwater resources constitute the main source of drinking, agricultural and industrial water, as they do in other parts of Iran (Azizi et al. 2016; Kord and Moghaddam 2014; Yazdanpanah et al. 2014). The Ardabil aquifer has the fastest declining level of groundwater in Iran (Abanpajoh 2015). The government presence is well recognized in the overexploited Ardabil plain. Despite the fact that groundwater resources are considered classic CPRs and can therefore be self-organized at community level (Foster and Garduño 2013; Huang et al. 2016; Nibbering 1997; Ostrom 1990; Tharmendra and Sivakumar 2016), the government's management in this plain has been top-down, and the local societies often play no role.

The goal of this paper is to analyze Ardabil plain as a CPR system in order to understand the root causes of its mismanagement and to propose solutions to improve the plain's critical overexploited situation. We use the Socio-Ecological Systems (SES) framework (Ostrom 2007, 2009), which has been specifically developed for CPR systems, to identify the key variables that play a role in the sustainable community (i.e. bottom-up) management of Ardabil plain.

The SES framework provides a common set of variables which can be used to analyze various kinds of socio-ecological systems by identifying the components and their interrelationships (McGinnis and Ostrom 2014; Nagendra and Ostrom 2014; Ostrom 2014; Rockström et al. 2009). Besides providing the means to analyze CPR management situations, the SES framework, which has been applied to numerous cases around the world, is a strong basis to understand how cultural and ethnic differences play a major role in the management of CPRs. The present study is the first paper to use the aforementioned framework in Iran, and attempts to examine the issue of collective action in an Iranian cultural, social and economic context.

Taking a CPR perspective however, also faces several challenges. Community-level management of a CPR often implies long-term gradual adaptation of rules practiced by the community. Yet, in situations similar to Ardabil plain, prompt action is required. Furthermore, the CPRs that are commonly studied are limited in size, while the Ardabil plain covers a vast area of land with a large population. Therefore, in this paper, we use the CPR perspective and the SES framework as the basis but build on them to address these challenges.

The structure of the paper is as follows. In Section 2, we introduce the theoretical background of this paper and explain what CPR systems are, and how they can be analyzed by using the SES framework. In Section 3, we discuss research relating to groundwater resource management. Section 4 explains our methodological approach and data collection procedures. Section 5 provides background information on Ardabil plain. Section 6 analyses the situation in the plain by using the SES framework. Finally, in Sections 7 and 8, we discuss our findings, propose solutions for the management of the plain, and provide concluding remarks.

2. Theoretical Background

One of the fundamental issues in economics invovles allocating limited resources between competing needs (Kula 1992). CPRs, also termed common property resources, are goods from which it is difficult to exclude beneficiaries and which are very costly to reproduce as their levels decline through usage (McKean 2000). Such goods usually have a core that has to be protected in order to secure their survival (Ostrom 1990).

Stavins (1992) believes that renewable resources may seem non-renewable, not because of their limited availability, but because of the way they are managed. Thus, the main issue is

not the limited physical access to resources; but the inappropriate tendencies and inadequate knowledge which lead to depletion of resources (Stavins 1992).

Managing common pool resources is a common issue addressed by many theories and approaches. One of these methods is the Community-Based Natural Resource Management (CBNRM) approach. CBNRM aims at managing natural resources that are usually (but not exclusively) common pool resources (Blaikie 2006; Mbaiwa et al. 2011; Measham and Lumbasi 2013). In general, the ultimate goal of CBNRM is to achieve better results in the management of natural resources by taking advantage of local knowledge systems and by wide participation of local communities in decision-making and in management processes (Armitage 2005; Mahanty et al. 2016; Measham and Lumbasi 2013).

Another issue that is commonly addressed with regard to CPR systems is the free-rider problem. According to the free-rider problem, whenever people feel that they are not paying for a special good or service (usually environmental), they make the maximum possible use of it which can lead to the destruction of the resource base (Anderies et al. 2004; Gordon 1954; Hardin 1968; Kahn 2006). This results in overuse of the resource, which is called the tragedy of the commons (Hardin 1968).

Economists have come to believe that the existence of private or public ownership of resources provides the opportunity for their appropriate use (Anderies et al. 2004; Gordon 1954; Hardin 1968; Kula 1992). Hardin (1968) believed that freedom of the commons brings harm to all and suggested that these resources should be distributed between parties or be entrusted to the government (Anderies et al. 2004; Feeny et al. 1990; Hardin 1968; Sick 2008). This suggestion was criticized by some researchers, one of them being Elinor Ostrom. Although she does not reject Hardin's theory completely, Ostrom believed that this theory could not be applied to all CPRs because some could be managed successfully by the appropriators. Nonetheless, there are still situations in which there is less incentive for people to self-organize. These include situations where the system is very large, resulting in poor communication between people (Berkes and Palmer 2015; Janssen 2015; Ostrom 1990, 2009). Furthermore, in some CPR systems, agents are too autonomous to engage in collective action, making the costs of change very high (Janssen 2015; Ostrom 1990, 2009).

As groundwater resources are classic CPRs (Foster and Garduño 2013; Nibbering 1997; Cockerill et al. 2015), their management can be examined from the perspective of Hardin and Ostrom. On the one hand, Hardin believes that the government should take up the

management of the CPRs in order to prevent the tragedy of the commons. On the other hand, Ostrom does not see the necessity for government management of CPRs; she believes that the users can solve the issue themselves. The present study attempts to explain the role of these two theories in the management of the common pool groundwater resources of Ardabil plain in Iran by analyzing government performance over past years and studying potential community engagement in the current setting.

In order to apply Ostrom's perspective on the management of the commons, we will use the SES framework which she has specifically designed for the purpose. This framework is explained in more detail below.

The Socio-Ecological Systems (SES) Framework

Since scholars in different fields and different geographic areas and biophysical conditions use different concepts and terminologies to explain complex socio-ecological systems, it is difficult to identify the processes that lead to improvement in the condition of natural resources (del Mar Delgado-Serrano and Ramos 2015; Epstein et al. 2013; McGinnis and Ostrom 2014). Without a common framework to organize the results, the findings of different fields cannot be integrated (McGinnis and Ostrom 2014; Ostrom 2007, 2009). The SES framework (Figure 1) makes the synthesis of data from different natural and social sciences possible (*see* examples:(Binder et al. 2013; del Mar Delgado-Serrano and Ramos 2015; Epstein et al. 2013; Hinkel et al. 2014; Leslie et al. 2015; McGinnis and Ostrom 2014; Nagendra and Ostrom 2014; Ostrom 2009)).

The SES framework is used to identify the basic components of a CPR and the significant interrelationships between these components. It provides a general set of variables which can be used to analyze various kinds of socio-ecological systems (McGinnis and Ostrom 2014; Rockström et al. 2009). This framework provides a guideline for examining the social and environmental aspects of CPRs in order to facilitate their sustainable use, as well as their management (Leslie et al. 2015; Ostrom 2009).

The SES framework is, in fact, designed for the analysis of CPRs for which the variables can be adequately measured (McGinnis and Ostrom 2014). At the highest level, the framework defines four core subsystems, referred to as the first-tier variables. These four subsystems are: governance systems (GS), users (U), resource units (RU), and resource systems (RS). They have a mutual connection (I), which leads to results (O) that explain the state of the system.

The social, economic and political settings (S), as well as the related ecosystems (ECO), are considered as external variables of the framework and its environment (Basurto et al. 2013; Hinkel et al. 2014; Hinkel et al. 2015; Leslie et al. 2015; Ostrom 2009). Each of the subsystem has different variables, which are called second-tier variables (Table 1), and which can, in turn, have third-tier variables. Choosing which second or third-tier variables to analyze depends on the research question, the kind of socio-ecological system and the spatio-temporal scale of analysis (Ostrom 2009) (see Nagendra and Ostrom 2014; Ostrom 2009 for more information). The primary focus of this study is on the 10 second tier variables that are, as identified by Ostrom (Ostrom 2009), effective in forming collective action (indicated by asterisks in Table 1).

In this paper, for the first time, we evaluate and explore the conditions of the Ardabil plain in the Iranian socio-cultural context with the help of the SES framework. The SES framework (Ostrom 2009) is used to assess different institutional, environmental and socio-economic factors that lead to groundwater decline in Ardabil. The framework helps to identify and explain the variables influencing the improvement or destruction of the groundwater resources in the plain. Using the results of this analysis, the authors try to determine whether 'best practices' of community-based CPR management would be appropriate for the context. This process is a first step towards explaining and understanding the critical overexploitation problem of the plain and suggesting effective solutions for its management.

3. Related Research on ground water management

While there are many instances of successful collective action in the management of irrigation systems in small scale and other surface water systems, the management of groundwater resources is a much more difficult challenge (Aarnoudse et al. 2012; Bruns 2015; Wester et al. 2011). A review of the literature related to groundwater resources as a classic CPR reveals many studies on this subject. Topics include the management of groundwater resources using game theory (Madani and Dinar 2012a, 2013), the role of non-cooperative institutions in managing CPRs (Madani and Dinar 2012b), the effect of a subsidy on groundwater resources (Ashwell and Peterson 2013) and on governing water resources (Bruns 2015; Foster and Garduño 2013; Kulkarni et al. 2011; Ostrom 1965). In Iran, however, as far as the authors are informed, no study has been conducted regarding CPRs, and its theories, particularly the SES framework and groundwater resources.

The studies that have been conducted in Iran on groundwater resources are mainly limited to technical and physical dimensions. Some studies deal with the quality of groundwater (Pourbayramin and Espahbod 2012; Daneshvar Vousoughi and Dinpashoh 2013; Daneshvar Vousoughi et al. 2012; Kord and Asghari moghaddam 2015; Kord and Moghaddam 2014), the water level (Daneshvar Vousoughi et al. 2011; Esfandyari dar abad et al. 2015; Nourani et al. 2015), and climate change and subsidence of the plain as a result of declining groundwater (Aalipour erdi 2014; Abedini 2013; Amirahmadi et al. 2014; Maali Ahari 2011). None of the studies address the role of government and other major players (beneficiaries) active in the plain. This could potentially be one of the reasons for a lack of improvement in the critical conditions of the plain to date.

4. Methodology and Data Collection

In this research, we first analyzed the conditions of the restricted[1] Ardabil plain and studied the performance of past and current policies. Consequently, we explored the opportunities and obstacles for enabling community engagement in the plain, using the SES framework.

To achieve these objectives , as a first step, in order to explore the conditions of groundwater resources in Ardabil plain, and to understand the role of the government in its management, the policies implemented in the plain, mostly by the government, were identified either from existing scientific publications or from government documents (Abanpajoh 2009, 2015; GhodsNiroo 2009). Scientific articles (mentioned in Section 3) regarding the conditions in the plain were also studied (Aalipour erdi 2014; Asghari moghaddam 2014; Azizi et al. 2016; Maali Ahari 2011). Several published interviews by the people in charge of the plain were also thoroughly studied.

In the second step, in order to delineate the physical conditions of the plain, including the level of decline in groundwater in Ardabil plain, a geographical information system was used. Additionally, for identifying the changes in land-use, the multi-temporal Landsat TM and ETM+ images were used. The images were first geometrically corrected, and land-use changes between 1989 and 2014 were identified using the ENVI software along with the geographical information system (refer to Azizi et al. 2016 for more information).

[1] Meaning that it is strictly forbidden to dig new wells and exceed a specific amount of groundwater usage in order to manage overexploitation of groundwater and prevent groundwater depletion,

In Step 3, a field study was conducted. Although one of the authors[2] lives in the plain and is very familiar with the socio-cultural issues in the region, field study was conducted during a one year period to provide more in-depth knowledge. A sample of 16 villages was studied to gain more knowledge about the social setting in the plain, using field observations and interviews with farmers and elders from each village.

The sample of the 16 villages was selected, primarily based on geographical distribution. The plain was divided into four grid zones. In each zone, four villages were selected: the biggest village, the most populated village, the village with the best known cooperative behavior and the village with the most conflict between users. Semi-structured interviews were used to survey historic and existing water-management practices in the plain, farmers' demands and beliefs, their problems, conflicts and areas of cooperation. The variables in the SES framework were used as a guideline to semi-structure the interviews.

In each village, interviews were conducted with elder(s) and with five farmers. Also, interviews and two discussion workshops were organized with the government organizations responsible for the management of water in the plain. These organizations were Ardabil Regional Water Authority, Environmental Organization of Ardabil Province and Jahad Agricultural Organization of Ardabil Province. Additionally, field study and discussions with rural communities were carried out mostly in local Teahouses where community gatherings take place. The collected data provided an in-depth understanding of some important variables in the SES framework. In Step 4, the SES framework was further used as a diagnostic tool to analyze critical variables that might affect local collective action in Ardabil plain.

In Step 5, after identifying and selecting important factors that help to form self-organization and collective action, attributes of the Ardabil plain as a socio-ecological system were determined by second-tier variables.

5. Ardabil plain

In this section, we introduce Ardabil plain and describe its past and current setting. We refer to SES variables in this section in order to create links to the analysis in the subsequent sections.

[2] ------

5.1. Introducing the case

Ardabil plain (Figure 2) is located at the center of Ardabil province, at an elevation of approximately 1400m (Azizi et al. 2016; Daneshvar Vousoughi and Dinpashoh 2013). The plain has around 564,365 inhabitants (Azizi et al. 2016). With its vast area, the plain is the main center for habitation and work in Ardabil province, and is important for agriculture and the economy in Iran (GhodsNiroo 2009). Its lands, with their fertile soil and adequate water, grow strategic crops such as potatoes. Table 2 shows the attributes of Ardabil plain as a socio-ecological system. Its drainage basin is around 900 square kilometers (RS3), and stretches from the north to mountains at the Iran-Azerbaijan border, from the east to the Talesh mountains, from the south to the Arpa Chay river, and from the west to the Sabalan mountain range (RS2) (Aalipour erdi 2014). The plain has three main rivers, Gharehsou, Balighloo Chay, and Ghuri Chay. The average precipitation is 300 mm per year (Azizi et al. 2016).

In Ardabil, and especially the overexploited Ardabil plain, groundwater resources (RS1) constitute the main source of drinking, agricultural and industrial water (Kord and Moghaddam 2014). About 89% of the water demand is provided by groundwater and the other 11% by surface waters. There are 2,622 wells (almost all of them belonging to farmers), 36 Qanats (RS4), and 77 springs in the plain (Kord and Asghari moghaddam 2015). The major production in the plain is potatoes and irrigated wheat.

Recent information suggests that irrigated lands constitute about 60% of the land surface; and water-use efficiency is 45% (Abanpajoh 2009). Currently, the Ardabil aquifer faces a negative balance of about 550 million cubic meters; and the groundwater level (O2) declines by 20-30cm per year, which makes it the fastest declining, among the plains of Iran (Abanpajoh 2015).

5.2. Evolution of Groundwater Development and Management in the Ardabil Plain

In the Ardabil plain, the groundwater tables have always been important. In the past half century, the plains have been the main source for drinking, agricultural and industrial water (U8). Before the last three decades, there were only a limited number of deep and semi-deep wells (U9), which consequently limited the use of the groundwater tables. According to the statistics, there were 390 wells in 1971 (GhodsNiroo 2009). This number increased to 4,106 in 2001. In fact, 3,700 wells have been dug in 30 years, which amounts to 123 wells per year (GhodsNiroo 2009).

As agriculture developed and the uncontrolled use of the groundwater tables increased in the 1980s, the aforementioned resource began to decline from 1984 onwards. This situation continued in the subsequent years and the plain's water levels have become critical. This has already caused major environmental consequences, such as salinization of shallow groundwater resources, and land subsidence. In order to control the decline, in 1989 two thirds of the plain, and in 2008 all of the plain, was declared restricted by the ministry of energy (GS1) (Maali Ahari 2011).

There are about 89 villages in the plain, and their major occupation is agriculture. In the past, the farmers in each village obtained their required water from the surface waters, springs and traditional wells. Water consumption for each farmer was based on principles which were accepted by all the members of that society. These principles were practically the same across the whole plain.

In the past, each village was ruled by a chieftain. The chieftain controlled the village and divided public resources. The use of the public resources was supervised by both the chieftain and the local community. In the case of violation, it was up to the chieftain to punish the violator. The level of trust was high and the spirit of collective action was dominant in and between the villages. Besides the chieftain, which was a formal position, there was also an elder who led the village spiritually, and who resolved any conflicts within the village, or with other villages. Today, the villages of the plain no longer have chieftains, but the elders still do the same work as before. The people in these villages have strong social relationships, and most of them are relatives, or from the same tribe, which accounts for their social homogeneity.

5.3. Current Situation

Despite its high economic potential, especially in agriculture, the province of Ardabil suffers from water (RU) shortage on a strategic scale; and the issue of water resource destruction has become a serious challenge to the economic, social and cultural life (S) of this province. Currently, the decline in groundwater resources is reported to be 10 meters, and the negative balance of the reservoir is around 550 million cubic-meters. The large number of deep and semi-deep wells in this plain, the excessive and uncontrolled use of water (I1) by farmers, and the continuous droughts (ECO1) intensify the critical condition of the Ardabil plain.

The current condition of the plain has had a negative influence on the farmers as its main users (Ua). They cannot further expand their activities and even their current production is at

risk. In order to maintain their crops, the farmers dig unauthorized wells or overexploit existing wells. In 2011, 389 out of 2,730 wells were overexploited and 118 unauthorized wells were used in the plain (Maali Ahari 2011).

Intensive harvesting of the groundwater tables by farmers has brought most harm to the farmers themselves. For instance, many of their Qanats (33 out of 88 in 2001) have dried up (GhodsNiroo 2009). This not only deprives them of water, but also increases their costs. They have to use wells instead of Qanats to irrigate their farms, which costs money and energy.

6. Analysis of Ardabil plain as a socio-ecological system

The primary focus of this analysis is on the 10 second-tier variables, as identified by Ostrom (Ostrom 2009), that are effective in forming community-level action (indicated by asterisks in Table 1). According to the field studies, and given the ecological, cultural and social setting of the region under study, 9 of the 10 variables from the general SES framework were highly influential: Size of resource system (RS3), Productivity of system (RS5), Predictability of system dynamics (RS7), Importance of resource (U8), Number of users (U1), Leadership (U5), Social capital (U6), Knowledge of SES (U7), and Resource unit mobility (RU1) (see Ostrom (2009) for explanations of the variables).

Besides these variables emphasized by Ostrom (2009), other variables have also been considered from the SES framework to be influential, as either obstacle or aid, in forming collective action and in the sustainable management of the plain. Two kinds of *interactions* are considered: high harvesting (I1) and conflicts (I4), and two kinds of *outcomes*: sustainable collective action (O1) as the social outcome and the decline in groundwater resources, (O2) as the ecological outcome. Besides these internal variables, the social, economic and political settings (S) and the related ecosystems (ECO) will also be considered as external influencing variables on the system.

6.1. Factors leading to the current situation

The development of agriculture (S4), uncontrolled population growth (S2), the increasing need to expand the area under cultivation (S5), the change in the pattern and the form of cultivation (S5) in order to grow products with a high water demand, which happen to be strategic products for the region and the country, the development of industry (S5) and providing people with fresh water (S4), all account for the increasing need for water in the plain. Also, the droughts in recent years have intensified the factors mentioned above, and

caused a significant decline in groundwater levels in the country, especially the Ardabil plain, which is at its most critical condition (Abanpajoh 2009). The international sanctions and the subsequent attempt by the government and the people for self-sufficiency have also been influential in reaching this critical condition (Madani 2014; Madani and Dinar 2012b; Mashhadi and Rashidi 2015; Mirshahi and Bayat 2010). This made the government officials use the resources increasingly and without any appropriate plan. There is still disagreement between the officials as to how much use should be made of groundwater resources, and whether national self-sufficiency or safeguarding groundwater resources should be the priority. Another influential factor worth mentioning here is that Ardabil became a province in 1993. When Ardabil was separated from East Azerbaijan province, industrialization and the movement of the population to its center (at the Ardabil plain) accelerated.

The changes in plain land-use between 1989 and 2014 (Figure 3 and 4) show an increase in agricultural use; and this increase constitutes about 139 square kilometers of the region. The effect of population growth, and the increasing need for nourishment on the one hand (S5), and the patronage of the government (S4) on the other, has been considered the main cause for this.

The increasing drinking usage by the urban population (Ub), alongside industrial usage (Uc), has also been influential. Though these usages are lower than agriculture, in devoting water to different sections, they are given priority, which is detrimental to the farmers. The limited availability of groundwater (RS5) in the aquifer in the plain, overuse, the increasing development of agricultural, drinking, and industrial usage, incommensurate use and its irreplaceability because of the climatological droughts have all caused a decline in the water table for the aquifer, and the decrease in its reservoir volume (Kord and Asghari Moghaddam 2015).

Although annual fluctuations in weather influence the hydration of groundwater resources and the volume of their reserves, the main cause of their decline is the increase in the number of wells. The popularity of wells in the region is mainly because they increase the accessibility of water from any location (S4), and help meet the increase in water demand as a result of population growth (GhodsNiroo 2009).

6.2. Past government actions and the beneficiaries' reactions

A review of the history of agriculture from 1956 to 1978 shows that, although wells were dug during this period, they were limited in number; 160 wells were dug, many of which were semi-deep wells. During this time, the royal government tried to change the traditional management of the villages and mechanize exploitation methods. However, the villagers' lack of knowledge and their financial inefficiency paralyzed the government's plans.

In the following years, between 1978 and 1981, 401 new wells were dug. After the Islamic Revolution and formation of the new government (1979), the farmers were patronized and given all kinds of subsidy (S4). Thus, the government intervened (S4) and the farmers began to dig more wells to develop their agriculture; the greatest number being 1,048 wells, which were dug between 1981 and 1986 (GhodsNiroo 2009). This intervention by the government can be considered as the most important cause of the present critical condition of the plain.

The farmers initially gained from this short-term government plan. However, when the government reconsidered its policies and tried to stop the destruction of the plain, the farmers and the government were, to some extent, set against each other (I4). The farmers could not overlook their cultivation and short-term profit, while the government aimed at a long-term plan to save the plain. Besides the farmers and the government, the urban population and the industrialists also entered the exploitation circle. As previously indicated, since the level of their use was lower than that of agriculture, the government privileged them. This added to the farmers' discontent. This opposition between the farmers and the government led to the unauthorized digging of wells and their overexploitation.

The interactions and the conflicts between the actors in the plain have had consequences which threaten all of them today. The decline in water for agricultural use threatens the current level of agricultural production; the decline in the groundwater level means greater cost to pump water from lower depths; the subsidence of the land threatens agricultural, urban and industrial facilities. Finally, the government's inability to manage the plain has rendered the government inefficient and has led to general discontent over the government's policies and action plans.

6.3. Latest Government actions and the beneficiaries' reactions

The ministry of energy declared two thirds of the plain as restricted in 1989 in the hope of reducing the overexploitation of the groundwater tables. However, as the process of decline

in groundwater levels continued, in 2008, twenty years after the first announcement, the whole plain was declared restricted. Although this is expected to have long-term positive effects on the groundwater tables, in the short-term it was largely the farmers who were adversely affected. The government resorted to new ideas to provide water and to lessen the discontent. One of these ideas was a change in cultivation pattern (S4) by the ministry of agriculture (GS1). In this plan, water-demanding crops were replaced by products with low water demand. This initiative was not met with positive responses from the farmers, and thus, was not realized. The reason was that the farmers had gained experience in the cultivation of certain crops over time (U3), and had adapted their life conditions to these crops. Moreover, the favourable market developed (S5) over the course of many years and the consumption culture of the people has created demand (S5) for the existing crops, which was of course influential in the farmers' decision. Potatoes are a good example of this.

Apart from the change in cultivation patterns, the other solutions from the government were to 1) fill unauthorized wells (GS8a), 2) to stop overexploitation by installing smart meters (GS8b) for water and energy, 3) to educate and increase users' knowledge with regard to groundwater, and 4) to provide part of the drinking water from dams instead of groundwater. Filling unauthorized wells and stopping overexploitation by installing smart meters for water and energy were two main methods employed by the government to deal with the issue of the decline in groundwater levels.

These two approaches were applied not only to the restricted Ardabil plain, but also to open mountainous regions around the plain. According to the statistics, between the years 2008 and 2015, 261 wells were filled in the restricted areas of the plain and 418 wells in the areas around the plain. The same statistic shows that with the installation of 895 smart meters, a significant level of overexploitation of the authorized wells was prevented. As already mentioned, although these two methods can decrease the pressure on the level of groundwater resources, the process of decline in the water level suggests that the performance of the government in the Ardabil plain is not completely effective. Moreover, these methods have led to conflict between the government and the farmers who, as the main users of groundwater resources, oppose these methods. As a consequence of this opposition, the farmers dig and exploit the filled wells or dig unauthorized wells.

Another method worth mentioning is water transportation (S4) from other basins, a method which is still at the research stage by the government. Water transportation from the Ghezel

Ozan river in southern Ardabil is one of these plans. This plan has its own problems, as the farmers in other provinces downstream of Ghezel Ozan basin will not welcome it. Yet, this plan can be considered the government's most serious plan to compensate for the decline in the groundwater levels, and to lessen the discontent.

Despite the government's plans, since 1989, the groundwater levels in the plain are still declining because of overexploitation, drought for more than a decade, and limited natural replenishment (Maali Ahari 2011).

7. Discussion: The feasibility of community engagement in Ardabil plain

According to Hardin, government intervention and ownership can prevent the tragedy of the commons (Hardin 1968), yet the present case study shows the opposite. The royal government before the Islamic Revolution played no significant role in managing the plain, for the reasons stated above; thus, its role can be overlooked. As described in detail above, after the 1979 Islamic Revolution, the role of the government in managing the plain was intensified. The government initially provided the farmers with subsidies, energy and financial resources, which developed agriculture and, naturally, increased the number of farmers' wells. Agricultural development and the industrial use of the groundwater resources increased to such a critical level in 12 years that the government itself entered the scene to prevent the tragedy of the commons.

The solutions implemented by the government, however, all neglected the root cause of the problem which is the economic incentives for water use. Rather than managing the needs of the people (i.e. redirecting the incentive), the government has long tried to fulfill those (problematic) needs, by for example, increasing water supply with technical solutions. As the first important technocratic solutions, in 1989, the government declared two thirds of the Ardabil plain as restricted in order to reduce the use of groundwater resources. However, with the development of agriculture, industry and population, which the government itself had encouraged, not only was there no reduction in demand, but an ongoing increase. As in other parts of Iran, the growth in population and the development of agriculture and industry were seriously encouraged by the government. As discussed above, this has resulted in the deterioration of the plain.

As the second important technocratic solution, twenty years after the government's intervention, in 2008, the whole plain was declared restricted by the government. However, to date, policy actions such as preventing the digging of wells, installing smart meters and

building dams upstream of the plain have not been effective in solving the problems, and the condition of the plain remains critical.

It appears that a root cause of the failure to save the plain lies in the fact that cultural, social and political solutions which, in fact, need longer to take effect have been entirely neglected and replaced by short-term solutions.

As discussed throughout this article, the existing management of Ardabil plain has mainly been top-down, in which the local societies often have no role. An important issue in the course of the government management of the plain is the lack of cooperation by the users. The traditional supervision of the people, which still exists, has been neglected during this period. Government intervention has intensified competition for the CPR, and the traditional sense of cooperation between the villages has almost disappeared.

The great number of users, the large scale of the resource, the system reproduction rate, the substantial cost of monitoring at the plain scale, the absence of a leadership role at plain scale and the tribal conflicts between the villages has created a short-term vision among the villagers. The weakening of the sense of cooperation and trust during the period of government intervention is another problem in forming collective action for the management of the plain.

Therefore, according to the SES variables that have been used throughout the preceding sections and have been summarized in Tables 2 and 3, a possible solution to tackle the critical condition of the Ardabil plain is to use multiple scales of governance both at community-level and government-level. Given the historical and cultural context, community-level management can take place at village scale, while government management can be more influential at plain scale.

Given the large scale of Ardabil plain, its sustainable management and formation of collective action are undoubtedly difficult. Despite the low number of users in the villages (farmers) in comparison to urban and industrial users, this group takes 89% of groundwater usage and can therefore play a pivotal role in ensuring its sustainability. These local communities can take on the responsibility for managing the CPR at village level and for solving local problems.

Some of the positive variables influential in motivating community action at village level in Ardabil plain are: presence of a strong leader at village level, despite its inefficiency at the

plain scale; strong social capital among the villagers and internal solidarity within the villages; the background of traditional, sustainable management in villages; the innate value of the groundwater resources for the inhabitants of the plain and the knowledge of the short-term and long-term consequences of the decline in groundwater. Other than the items mentioned above, there are other variables, both at village level and at plain scale, that can potentially lead to, or prevent, collective action for the sustainable management of the plain. Table 3 lists the positive and negative variables in forming collective action in Ardabil plain.

Successful attempts in each village will lead to successful and sustainable management of groundwater resources at plain scale. At plain scale, every village is considered as an actor and can negotiate commons issues (cf. composite actors (Scharpf 1997)) while the government can play a mediator role. Therefore, two layers of management will exist. The first layer includes the village, in which the local communities in each village will maintain and manage the CPR, given the high potential of villages and the elders. In the second layer – plain scale – each village is considered an actor and will cooperate with other villages to maintain the resource. The government will serve as a mediator for communication and will pave the way for collective cooperation. The government can also increase investment in educating people about water consumption. It can also involve local people in plain-scale management by supporting non-governmental organizations.

8. Conclusion

In this paper, we used the SES framework to analyze the critical conditions of the Ardabil plain groundwater resource. We focused on the 10 variables emphasized by Ostrom (2009) in order to estimate the potential for forming collective action for organizing the local communities in the Ardabil plain. It is shown that 3 of the variables facilitate collective action at plain scale, while the other 7 impede it. Nonetheless, most of these variables still serve as facilitators at village scale and provide a potential opportunity to form collective management at village level. The sustainable management at village level allows collective action to be formed according to the characteristics of the local societies. The effectiveness of the collective action at this scale can ensure success at plain scale, facilitated by the government, which would result in the sustainability of the groundwater resource.

Role of Government

An evaluation of government performance in Ardabil plain indicates a lack of success, and success is not expected in the future. The government has served more as a facilitator for the overexploitation of the CPR, and has created the sense of competition and weakened the collective spirit in the user community. As a consequence, the management of the plain cannot be handed over to the local communities immediately, especially with the critical condition of the plain.

In order to encourage the collective management of the plain, the government has to reduce its exclusive role. This can only happen gradually so that, during this period, the users (farmers, industrialists, and urban users) are prepared for (inter-village) collective action through education and training provided by the government. The government has to encourage non-governmental organizations (GS2), not only as a way of decreasing its direct role, but also to provide education and training for people. Non-governmental organizations, in turn, have to adapt training to the culture and beliefs of the people and make use of the past experience of these people in collective action in local communities.

The government could pay for the consequences of the decline in groundwater at the beginning of the process, rather than at the end. Since new activities that decrease water usage have to be encouraged, the government could pioneer this positive movement, by financially supporting the farmers. In order to change the pattern of cultivation, the government could also provide guaranteed purchase for the crops with low water usage, so that the farmers will be motivated to change their cultivation pattern.

Role of Village Communities

Because of the vastness of the plain and the large number of users, it is better to set the management of the CPRs at village scale, and to run management plans according to the level of usage, knowledge, and enthusiasm of the people from each village. In order to do this, some groups have to be established in the villages, not only to organize and form collective action, but also to supervise user activities and to deal socially with overexploitation. This has a high potential for success because of the existing social capital in the villages. Education regarding the change in cultivation from water-demanding crops to those that require little water is another factor in motivating people in the villages.

Role of Industry and Urban population

The industrialists must be encouraged to reduce their water usage, be rewarded for doing so, and be penalized in cases of excessive usage, so that the punishment will prevent the excessive use of water. Forming a process of industrial ecology for using water resources can also be considered. This could also be recommended for the urban use of water. Since the price of urban water usage is a lot lower than its real price in Iran, an appropriate price increase in cases of excessive use could also be effective.

In summary, it can be concluded that top-down government management will not be successful in the future, as past experience shows, and will thus be unable to prevent the tragedy of the commons. On the other hand, vastness and the high number of users, along with the new sense of competition formed between the users, make it difficult to apply the common pool self-organization theories successfully at plain scale. Thus, a two-layered management approach may be an effective solution to manage the restricted Ardabil plain: the government at the plain scale, as the organizer and facilitator of communication and cooperation between the villages, and meanwhile, entrusting the management of the CPRs at village scale to the local communities.

The SES framework and the variables it provides proved to be highly instrumental in untangling the complex context of the Ardabil plain in Iran, and thus act as a tool to conduct a thorough analysis. Yet, the use of the framework may not necessarily lead to a self-organization, community-level management solution for a CPR. Factors such as the size of the resource or its critical condition, threaten the success of such bottom-up approaches. Our study of Ardabil plain showed that the ecological vulnerability of the resource is a major variable that influences the formation and success of collective action. In other words, the level of groundwater declines 20-30 cm per year in Ardabil plain, which` makes it the fastest declining among the plains of Iran and thus the most vulnerable. Yet, in the SES framework, the ‘importance of resource’ (U8) as one of the general SES variables is the only concept that comes close to this vulnerability issue. Therefore, we recommend ‘ecological vulnerability of resource’ as a variable that plays a major role in the formation of collective action for the study of CPR management situations.

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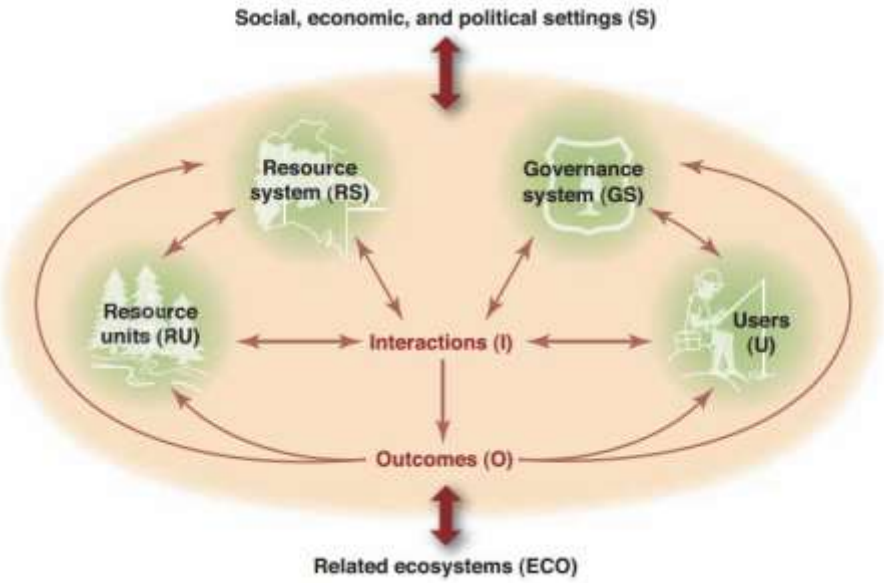

Fig 1: Basic structure of the social-ecological system framework (Ostrom 2009)

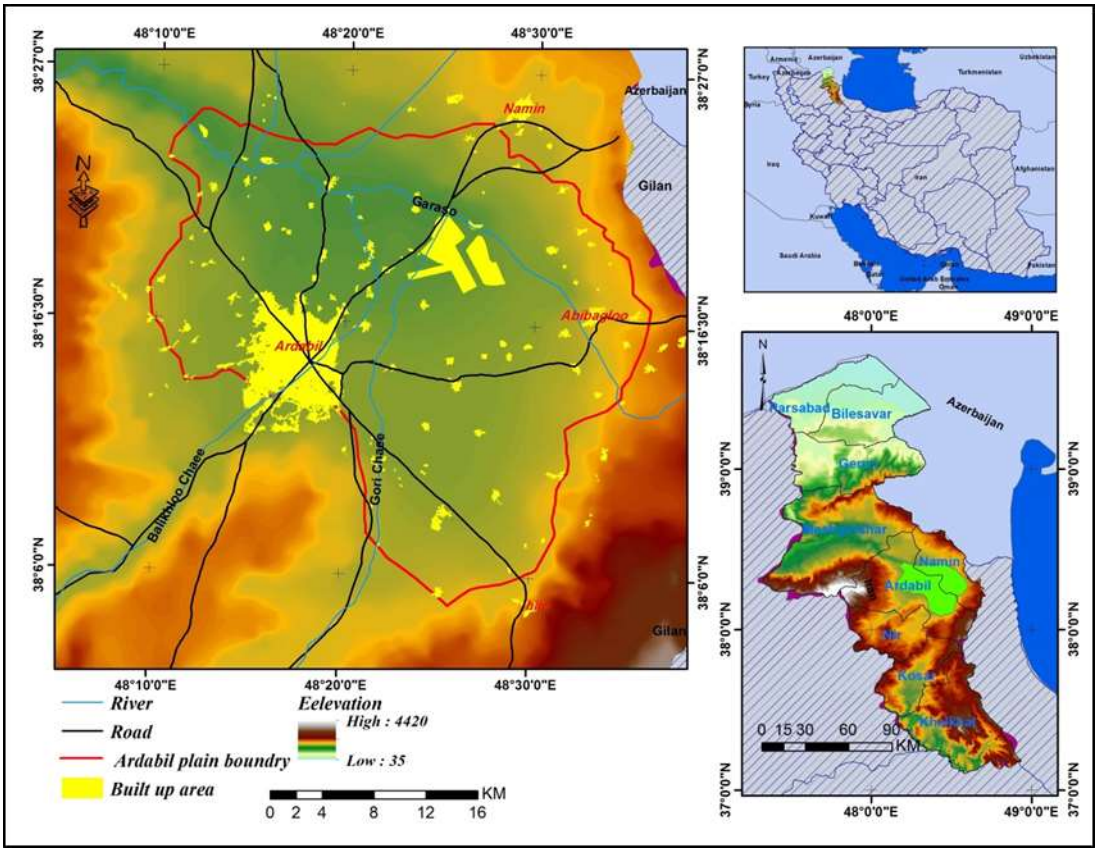

Fig 2: Location of the Ardabil Plain in Ardabil province-Iran

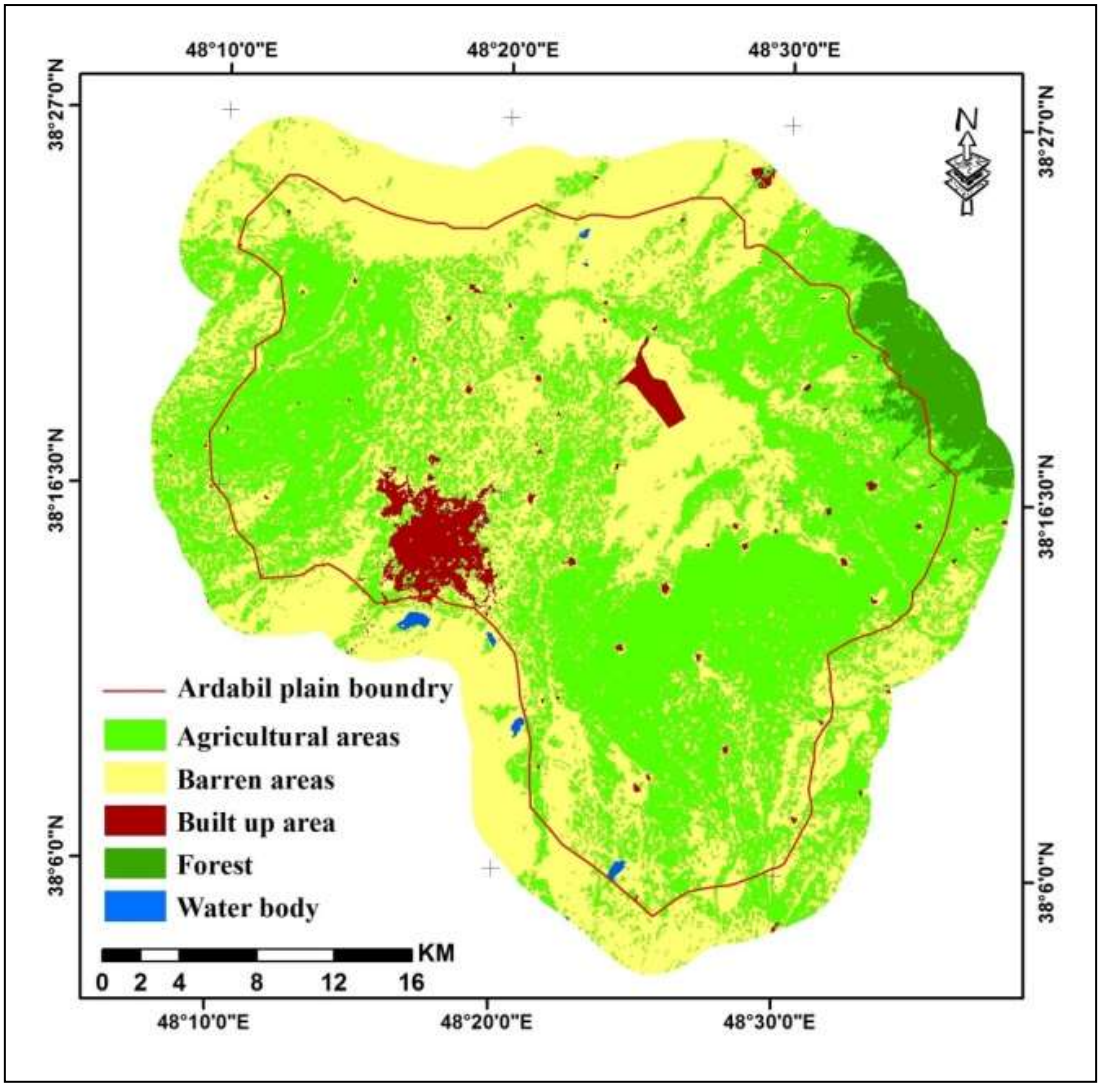

Fig 3. Ardabil Plain Land-use map classification for 1989

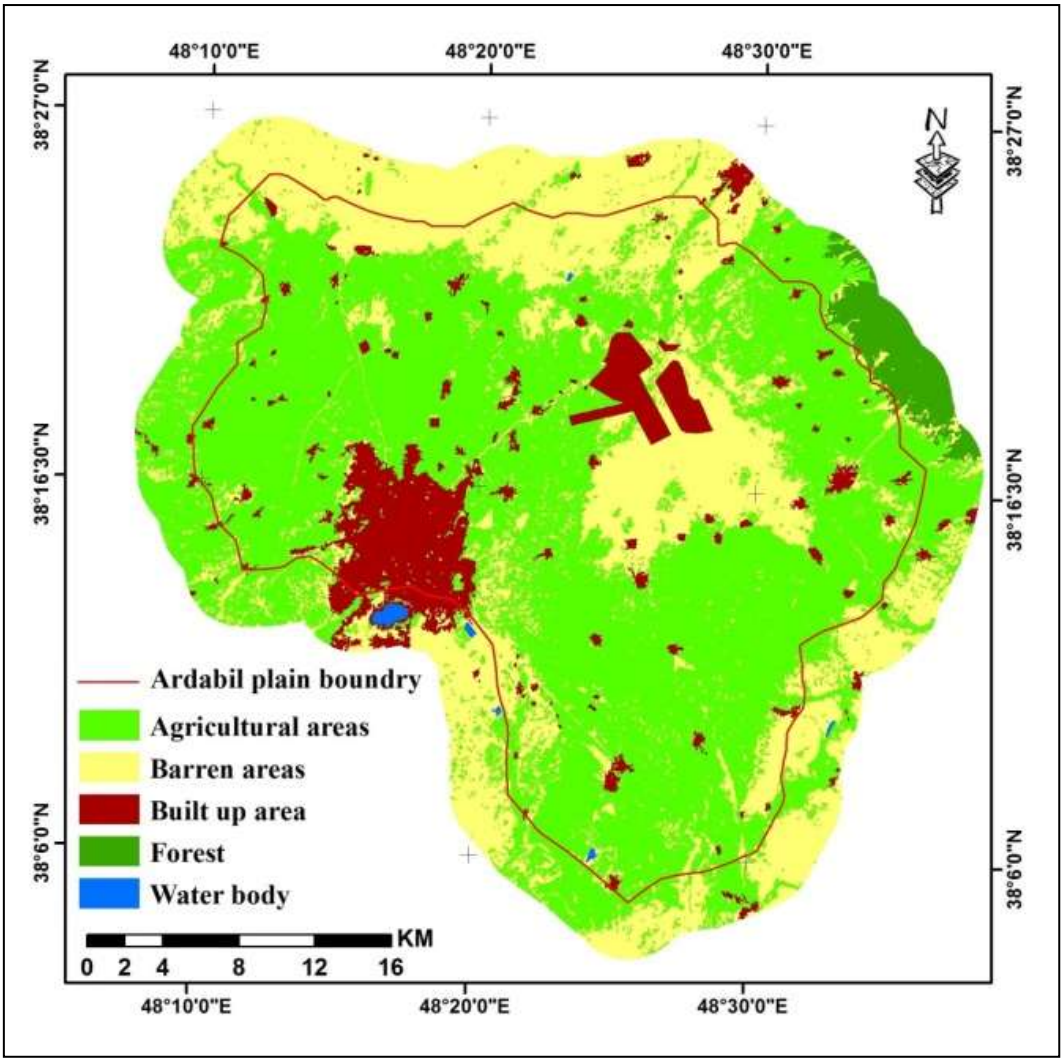

Fig 4. Ardabil Plain Land-use map classification for 2014

Table 1: Second-level variables under first-level core subsystems in a framework for analyzing social-ecological systems(Ostrom 2009)

Social, economic, and political settings (S) ***S1 Economic development. S2 Demographic trends. S3 Political stability.*** ***S4 Government resource policies. S5 Market incentives. S6 Media organization.***			
Resource system (RS)		***Governance system (GS)***	
RS1	Sector (e.g., water, forests, pasture, fish)	GS1	Government organization
RS2	Clarity of system boundaries	GS2	Nongovernment organizations
RS3	Size of resource system*	GS3	Network structure
RS4	Human-constricted facilities	GS4	Property-rights systems
RS5	Productivity of system*	GS5	Operational rules
RS6	Equilibrium properties	GS6	Collective-choice rules*
RS7	Predictability of system dynamics*	GS7	Constitutional rules
RS8	Storage characteristics	GS8	Monitoring and sanctioning processes
RS9	Location		
Resource unit (RU)		***Users (U)***	
RU1	Resource unit mobility*	U1	Number of users*
RU2	Growth or replacement rate	U2	Socioeconomic attributes of users
RU3	Interaction among resource units	U3	History or past experiences
RU4	Economic value	U4	Location
RU5	Number of units	U5	Leadership*
RU6	Distinctive markings	U6	Norms/social capital*
RU7	Spatial and temporal distribution	U7	Knowledge of SES/mental models*
		U8	Importance of resource*
		U9	Technology used
Interactions (I)	→	***outcomes (O)***	
I1	Harvesting levels of diverse users	O1	Social performance measures (e.g., efficiency, equity, accountability, sustainability)
I2	Information sharing among users	O2	Ecological performance measures (e.g., overharvested, resilience, bio-diversity, sustainability)
I3	Deliberation processes	O3	Externalities to other SESs
I4	Conflicts among users		
I5	Investment activities		
I6	Lobbying activities		
I7	Self-organizing activities		
I8	Networking activities		
Related ecosystems (ECO) ***ECO1 Climate patterns. ECO2 Pollution patterns. ECO3 Flows into and out of focal SES.***			

Table 2: Attributes of the Ardabil plain SES

Resource system (RS)			***Governance system (GS)***	
RS1	Sector: groundwater		GS1	Ministry of Energy- ministry of agriculture
RS2	Weak physical boundaries		GS6	No
RS3	Large		GS8a	Filling unauthorized wells (sanctioning)
RS4	Well and Qanat		GS8b	Installing smart meters (Monitoring)
RS5	Moderate			
RS7	Low			
RS8	High			
RS9	High cost of exclusion			
Resource unit: water			***Users (U)***	
RU1	Low Mobility		U1	Large group of users includes farmers (Ua), urban population (Ub) and industrialists (Uc)
RU2	Moderate renewability		U3	Strong in village, weak in plain
RU4	High		U5	Weak
			U6	Strong social capital
			U7	Norms of equity and reciprocity
			U8	High resource dependence
			U9	Advanced technology
Interactions (I)			**Outcomes (O)**	
I1	High harvesting		O1	Sustained collective action
I4	Conflicts		O2	Groundwater depletion

Table 3: Opportunity and limitation in forming collective action

Theoretical variable	SES code	Opportunity		limitation		Description
		Village	Plain	Village	Plain	
Clarity of system boundaries	RS2	–	–	Weak	Weak	Precise demarcation of the resource is difficult both at village scale and plain scale
Size of resource system*	RS3	Little	–	–	Large	The number of users at plain scale is large, therefore unitary management at plain scale is difficult, but it is practical at village scale
Human-constricted facilities	RS4	Well and Qanat	–	–	Well and Qanat	Social management and monitoring of wells is easier and more effective at village scale.
Productivity of system*	RS5	–	–	Moderate	Moderate	Replenishment requires medium effort and takes a lot of time at both scales
Predictability of system dynamics*	RS7			Low	Low	Anticipation of the dynamics of groundwater by users is difficult at both scales
Storage characteristics	RS8	High	High			The groundwater in the Ardabil plain is a great water reserve .
Location	RS9	Low Cost Of Exclusion	–	–	High cost of exclusion	The expense of control at village scale is more affordable and more effective compared to plain scale .
Resource unit mobility*	RU1	Little Mobility	Little Mobility	-	-	Is high at both scales and creates limitations
Growth or replacement rate	RU2			Moderate	Moderate	Is medium at both scales and creates limitations
Economic value	RU4	High	High	–	–	The importance and dependence of the users on the resource is high at both scales
Government organization	GS1	-	Yes	–	No	There are management institutions at plain scale, but there is no governmental or non-governmental institution at village scale
Property-rights systems	GS4	Yes			No	In villages that have Qanat, people use water commonly and equally, and so is also the case with public wells
Collective-choice rules*	GS6	Present	-	–	No	There are traditional rules about Qanat and other resources at village level
Constitutional rules	GS7	Yes	Yes	-	–	There are rules, which include penalties, about using the resources at both levels
Monitoring and sanctioning	GS8	Low cost	-	–	High cost	Monitoring and sanctioning are more effective at village scale
Number of users*	U1	Little group of user	-	–	Big group of user	The number of users at plain scale is large, therefore a unitary management at plain scale is difficult, but it is practical at village scale
Socioeconomic attributes of users	U2	Trust, social unity and cooperation			Conflict	There is a high sense of trust and cooperation in the villages because of family relationships, but there is a sense of competition between the villages
History or past experiences	U3	Strong	-	–	Weak	There is a high experience of regular usage at village level, but it has not been formed at plain scale
Leadership*	U5	Strong	–		No leadership	There is a strong leadership in the village, but it is not yet established at plain scale
Norms/social capital*	U6	Strong	–		Weak	The villages have a strong social capital, but it is still weak at plain scale
Knowledge of SES/mental models*	U7	Strong	Strong	–	–	The understanding of the situation is high at both scales
Importance of resource*	U8	High	High	–	–	The value of and dependence on the resource is high at both scales
Technology used	U9	High	High	–	–	The technology used at both scales is high