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Groundwater Irrigation Management and the Existing Challenges from the Farmers' Perspective in Central Iran

Forough Jafary * and Chris Bradley

School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham B15 2TT, UK; C.Bradley@bham.ac.uk
* Correspondence: foroughjafary@yahoo.com; Tel.: +44-7538377869

Received: 24 October 2017; Accepted: 17 January 2018; Published: 23 January 2018

Abstract: The sustainable management of natural resources, and particularly groundwater, presents a major challenge in arid regions to ensure security of water supply and support agricultural production. In many cases, the role of smallholder farmers is often neglected when managing irrigated water and land processes. However, management decisions have a major impact on farmers' livelihoods, and it is essential: first, to recognise the crucial role of regional and local social, political and economic systems; and second, to integrate farmers' perspectives in the governance and management of local groundwater practices. This is particularly important as the ways in which arid region farmers use land and water have wider implications for land degradation and salinization. This paper uses a community-based approach to identify and examine the social, economic and cultural dimensions to groundwater irrigation systems from the perspective of local farmers in central Iran. The paper utilises interviews with local farmers and water agencies in Iran to reflect on their respective roles within the irrigation system and in developing management plans for the sustainable use of groundwater. Through social research, we investigate the reasons why farmers might reject government irrigation management schemes and outline how local problems with land degradation and salinization and reduced water availability have arisen as a result of changing management policies. In conclusion, we identify future challenges and consider appropriate future management strategies.

Keywords: drip irrigation; groundwater; common-pool resource; water rights; local farming

1. Introduction: Groundwater Management Crisis in Iran

Groundwater is the principal source of water used for domestic and agricultural purposes in Iran. However, there are major challenges in managing groundwater sustainability given anticipated increases in the demand for food and potable water, which are leading to increasingly high rates of groundwater abstraction and contributing to widespread reductions in groundwater levels. In Iran, aquifers have been over-abstracted due to changing crop patterns, inefficient irrigation systems and high water wastage associated with traditional Iranian irrigation practices [1]. Currently, one of the major failures in groundwater resource management by national government is the inefficient agricultural water use, as the efficiency of irrigation water delivery is thought to be between 33 and 37 percent [2]. Other failures include uncompleted water projects, problems with water delivery and drainage, as well as inadequate resources for future water development schemes.

The consequences of inappropriate agricultural water management include environmental degradation, salinization, land subsidence and wetland desiccation. Soil salinization is widespread in Iran with an estimated economic loss of >$1 billion (U.S.) [3]. In arid regions, water scarcity has led to increased abstraction of brackish groundwater for agriculture, which can lead to salinization and accelerated land degradation and desertification [4]. As a result, it has been suggested that groundwater conditions in Iran are in a critical state [5–7]. This highlights the need for changes in domestic and agricultural water use practices, and specifically the adoption of more efficient irrigation technologies, which are adapted to local conditions and are economically viable for farmers. However, there have been problems with introducing new groundwater management practices, which have sought to increase irrigation efficiency (e.g., using micro-irrigation methods) and reduce groundwater abstraction rates. Hence, the impact of policies on irrigation modernization is uncertain; particularly the degree to which the introduction of new technologies might help to reduce rates of water use and consumption [8]. Although changing irrigation systems, from furrow to micro-irrigation (i.e., drip method), has reduced water use in some cases [9,10], other studies suggest it has been associated with increased water and energy consumption [11,12].

It is also important that ecosystem sustainability should be given more attention when managing water resources: particularly, the long-term consequences of changing irrigation policies on environmental sustainability. For example, at present, irrigated waters are prevented from recharging the common pool groundwater body due to: (i) the high aridity and evaporation rates; (ii) high rates of water consumption due to intensive cultivation practices; and (iii) the depth of the groundwater table. This raises questions about the current sustainability of groundwater aquifers. In response to these problems, the Iranian government is seeking to introduce new irrigation systems to reduce groundwater abstraction rates and improve water delivery efficiencies for irrigated agriculture, but this requires engagement with local farmers to maximise rates of adoption.

This paper investigates the challenges in introducing new irrigation technologies and management plans for local farming systems through top-down national policies. One potential outcome is that the projects are rejected by local farmers, which compromises any future improvement in irrigation delivery efficiency that was anticipated by the original policy. Hence, in developing such projects, policy makers should consider the socio-economic, biophysical and cultural dimensions of managing natural resources, particularly strategic common-pool resources such as groundwater aquifers. A crucial factor here is the flexibility of technologies to accommodate local irrigation traditions and water allocation rules as evidence suggests that technological solutions are not widely adopted if they are not socially acceptable [13]. Hence, any new technology, or management plan, must address the different dimensions of traditional irrigation and land management systems if it is to minimise social, economic and environmental impacts. In this empirical study, we discuss the main changes in this irrigation transformation, which are: first, the conversion from collective action around tube-wells, which occurred as farmers transferred from the historic Qanat irrigation system, to a new collective ownership/action for drip irrigation promoted by government (Qanats are underground water transmission canals that convey groundwater from upland areas to the lower plains by gravity) (Figure A1); second, the adoption of drip irrigation systems with associated changes in water right allotments (reduction), which create many challenges for farmers.

Water Crisis and Efficiency Management: Reconciling Different Viewpoints

In Iran, policy makers have largely attributed ‘the water crisis’ to climate change and particularly to the increased frequency of drought, which as a ‘natural disaster’ is outside their control and represents only a temporary problem [14]. However, in discussing Iran’s water crisis, Foltz [15] suggested that many Iranian researchers believe that the water crisis is only partially attributed to drought events; and some water experts believe that about half of the problem is due to mismanagement of water resources.

The degradation of groundwater (both quantity and quality) thus reflects a combination of excessive groundwater abstraction (and/or drought, which reduces groundwater recharge), inappropriate groundwater governance and management plans and poor land use management. The lack of agreement between water experts and policy makers on the causes of the water crisis has inhibited the development of comprehensive water management plans. Consequently different solutions have been advanced to improve irrigation efficiency, which is defined differently by local communities and government decision-makers.

Recent work has challenged the concept of efficiency in irrigation practices, and there is a belief that what is usually known as improved irrigation efficiency is a misleading concept [16]. Under the concept of irrigation efficiency, the volume of water saved is considered an 'efficiency gain' (i.e., saved water to be used in environmental enhancement and non-farming activities). This is a paradox as the water saved is not allowed to return to the drainage basin (i.e., to recharge the groundwater body), and hence, true rates of water consumption are unchanged [16]. In an Iranian context, some of the proposed government schemes to improve irrigation efficiency strongly contrast with what local users perceive to be irrigation efficiency, and hence, there is a lack of cooperation between local water users and authorities.

In this paper, we illustrate how perspectives on water values, on the water crisis and on the rationale for groundwater protection and sustainable water resource management differ between local communities and the groundwater regulator, the Iranian Agricultural Jihad Agency. It is important to recognize the different viewpoints and to identify areas of common understanding. In Iran, improved efficiency for farmers' means increasing their accessibility to specific water rights to maintain or increase agricultural production levels. Farmers are likely to reject new schemes that threaten these rights, for example, the installation of drip irrigation systems to improve efficiency and manage groundwater sustainably. Furthermore, socio-economic conditions, livelihoods and technological constraints, all have a local context and must be understood separately as they can greatly affect water management and efficiency [17]. Conversely, government irrigation management schemes seek to protect groundwater bodies from over-abstraction and to ensure continued water availability to support projected water demands. Thus, the main difficulty is how efficiency should be measured by the water regulator and how permission for abstraction should be granted to avoid groundwater depletion and to satisfy the objectives of both farmers and government agencies. Currently, the Iranian Ministry of Energy (MoE) issues new permits for applicants on the basis of a hydrogeological assessment of the aquifer [18]. Legally new abstractions are allowed as part of a business plan, but under the traditional local system, water rights are associated with individuals through their historical allocation. The historic water distribution system (the Qanat) is based on cycles of specific numbers of days and nights (24 h) [19] (pp. 148–152), and this system of water allocation and distribution is still largely practiced by local farmers. The water cycle is divided into different time-slots (water right delivery might be received during the day or night). The water hour right for each person is the basis of assigning the entitlement, although the eligibility criteria for individual applicants is not necessarily transparent [18].

In this situation, controversy and conflict between environmental issues and farming practices can easily arise, usually resulting in conflict between agencies and farmers. In Iran, the government has sought to protect groundwater resources, while farmers' reliance on groundwater abstraction through pumped tube-wells hinders enhanced groundwater protection. The operation and maintenance of the traditional Qanat irrigation systems in Iran are established based on collective action and cooperation among farmers. This encourages farmers to share costs and responsibilities and is the main driving force for farmers to act collectively in maintaining the operation of currently-used pumped tube-wells. The traditional norms, rules and social capital around irrigation systems, e.g., water rights and allocation, have also been transferred from the Qanat system to the modern system of tube-wells to enable successful farming practices to continue. Generally, tube-well owners fund the construction, maintenance and operation of their wells, but not any external costs resulting from extensive groundwater abstraction on the environment or aquatic ecosystems [20]. Similar processes occur in developing countries where economic conditions act as a barrier for improving environmental protection, resulting in the general depletion of natural resources with inevitable environmental consequences [17].

In Iran, local farmers are confronted with a number of irrigation challenges that contribute to their unwillingness to join, or collectively participate, in government schemes to increase irrigation efficiency and manage scarce groundwater resources sustainably. Groundwater over-abstraction is potentially catastrophic as there is insufficient regulation (i.e., the issuing of new water rights/entitlement for applicants) and monitoring of groundwater abstraction rates (most tube-wells lack metering) to ensure the sustainable use of groundwater resources. At the same time, research on farmers' behavioural approaches to groundwater abstraction in arid regions is limited and detailed investigation of irrigators' reflections on concepts of efficiency and productivity are needed. Here, for the first time, we identify the factors that influence local farmers' adoption of drip irrigation within the government "Tooba Scheme" and investigate local definitions of irrigation efficiency. As part of the 'Tooba' scheme to install drip irrigation systems, farmers have to build small reservoirs on their land and consolidate scattered land holdings. The establishment of a reservoir is followed by acceptance of a drip irrigation system, which requires farmers' agreement to consolidate their fields if they are to be eligible for a government loan. For small-scale farmers, construction and maintenance of new irrigation systems is expensive, requiring new collective ownership of the infrastructure to share their cost.

Global and national water problems require local solutions, and local knowledge can enhance local capacity by utilising that knowledge to embrace alternative solutions [21]. Hence, local knowledge and community-managed systems have a crucial role in water management, particularly in Iran, given the importance of traditional and current irrigation management practices. Before discussing this, we first review water management practices and proposed government management schemes to provide a context for the discussion.

2. Materials and Methods

2.1. Case Study Characteristics: Kashan

Kashan city, and the surrounding rural villages (population ~400,000), is the largest city in Northern Isfahan province in central Iran (Figure 1). Given its location in Iran's Central Desert, this region has a dry climate and groundwater is the only source of water for agricultural, urban and industrial uses. At present, agriculture utilises 86 percent of the annual total of abstracted groundwater, while domestic and industrial activities use 7.5 and 1.7 percent, respectively. The remaining 4.8 percent is used to maintain green spaces.

There are two different climates within the region: First is an alpine climate with winter snow cover, where irrigation waters are supplied by springs, ephemeral rivers and Qanat systems. These alpine areas experience infrequent conditions of water scarcity, and farmers are able to cultivate a range of products including fruit trees. The second climate is associated with the plains adjacent to the central Kavir desert: a region of arid climate with a low annual precipitation (140 mm/year) and high temperatures (see Table 1). Here, the soil is sandy and the only water source is groundwater abstraction from deep wells, as most of the Qanats are dry. The main villages in Kashan are associated with areas of cultivation and include: Abu-Zeid Abad, Ali Abad, Rijen and Fakhreh. Farmers in these villages were interviewed and were the main participants in group discussions for this study (Table 2). The main criterion governing selection of the study area and participants was that the study should be in an arid region of Iran where water management practices reflected the rich indigenous knowledge of local irrigators. A further constraint was access to local communities with long experience in groundwater irrigation practices who were willing to cooperate in the study. The participants were mainly male farmers who practiced small-scale farming in Kashan (women are not generally involved in farming) (Table 3).

Traditional crops in Kashan include fruit trees (pomegranate, pistachio and apricot), cereals (wheat, barley, maize, millet and chickpea), vines, melons, cucumber and vegetables. Recent agricultural productivity has been threatened by reduced water availability, and farmers suggest that climate change, particularly a prolonged drought since 2010, has affected the diversity of crop cultivation patterns. In common with other arid and semi-arid regions in Iran, farmers in Kashan are experiencing critical declines in groundwater levels and increased water scarcity [1,22,23] to the extent that the future availability of groundwater is questionable. The majority of farmers have installed individual or collective tube-wells, and farmers have a vital role in the irrigation management process: both in maintaining irrigation practices and agricultural productivity. Farmers ensure the adoption of locally-based irrigation solutions and agree to collective management strategies, including selecting appropriate crop patterns given the conditions of water scarcity. However, the role of farmers has been largely neglected within the management-decision process in Iran.

The increasing frequency of conditions of water scarcity provides a strong incentive for farmers to identify and adopt coping mechanisms and adaptation strategies [24]. Local farmers in Kashan have sought to sustain their livelihoods despite this threat by: (i) extending their sources of income (e.g., husbandry, weaving carpets, working in factories); (ii) keeping livestock to be sold during periods of financial crisis; (iii) taking collective action to reduce labour costs; (iv) sharing the costs of purchasing land and drilling and maintaining tube-wells; (v) renting harvested lands to other farmers for livestock grazing in exchange for reducing labour costs for land clearance; (vi) relying on their social network for food or cash during times of financial crisis; and (vii) engaging in an informal market for water and land rental, as well as dairy products.

These local adaptive management strategies are alternative solutions used by farmers, which are neither governed, nor imposed by government. Where farmers feel that government management plans are poorly conceived, or if there are implications for future profitability, then farmers will follow their own management strategies and reject the range of different schemes proposed by the Iranian government to improve irrigation management efficiency. In the following section, we describe existing irrigation management schemes before examining the reasons that farmers gave for rejecting these schemes.

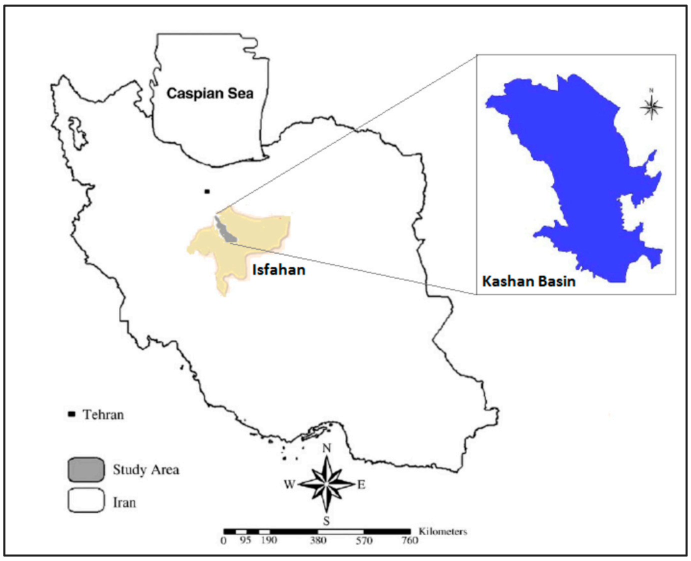

Figure 1. Kashan City in Isfahan province in Central Iran.

Table 1. Characteristics of farming systems in Kashan.

Agriculture Features	Farmlands Size	Crop Pattern	Water Right	Access/Ownership	Irrigation System	Water Uses m^3/ha	Irrigated Land
Kashan City Small-scale Large-scale	1470 km^2 1–5 ha >5 ha	Wheat, barley, alfalfa, pistachio	Is based on each land's size	Private or shared ownership of tube-wells	Furrow, flood, drip system	Total extraction 238 million cubic metre	22,500 ha (Kashan) 18 million ha in Iran

Table 2. An example of surveyed local farmers in Kashan region.

Farm Features / Farmer-Village	Farmland Size	Crop Pattern	Water Right	Access/Ownership	Irrigation System	Water Uses m3/ha	Irrigated Land (ha)
Taghavi, R. Rijen	2 ha	Barley, alfalfa	3 h water right every 5 days	Shared tube-well (5 small-scale farmer)	Furrow, flood	-	2
Saboohi, A. Ali-Abad	5 ha (integrated land)	Wheat, barley, beetroot	10 h water every 8 days	Shared tube-well	Furrow	-	5
Razavi, H. Rijen	32 ha (integrated land)	Pistachio	35 h every 5 days	Private land-purchased water rights	Furrow and drip system	-	32
Golnari, A. Ali-Abad	4 ha	Wheat, barley, pistachio	2 h water every 5 days	Shared tube-well	Furrow and flood	-	4
Nouri, T. Fakhreh	10 ha (Integrated land)	Pistachio, wheat, barely, alfalfa	24 h every 5 days	Shared tube-well	Furrow and drip	-	9
Ganji, A. Rijen	1 ha	Alfalfa, barley	2 h	Small-scale farmer	Flood	-	1

Table 3. Data collection in Kashan Villages (2011–2013) [1].

Methods \ Participants	Local Farmers Ali-Abad	Local Farmers Fakhreh	Local Farmers Rijen	Local Farmers Kashan
Deep Interviews	4	2	3	1
Semi-structured Interviews	3 (total 12 farmers)	2 (6 farmers)	1 (4 farmers)	1 (3 farmers)
Group Discussion	3 (total 38 farmers)	2 (25 farmers)	1 (8 farmers)	

[1] In four different villages and in the Kashan City, separate sessions of deep and semi-structured interviews, as well as group discussions were conducted. In Ali-Abad, 3 sessions of semi-structured interviews with a total of 12 farmers were carried out. In addition, 3 group discussions were organized, which in total, 38 farmers attended. The number of sessions and total participant farmers are summarised in Table 3.

2.1.1. Tooba' Drip Irrigation Scheme

In Kashan, the Iranian government encourages smallholder farmers to participate in large-scale (>10 ha) irrigation schemes, termed 'Tooba', comprising drip irrigation systems, which seek to improve irrigation delivery efficiency. The micro-drip irrigation system (in the 'Tooba' scheme) provides water and fertilizers through a network of narrow plastic tubes, and water is delivered directly to the root zone, or soil surface, to supply plant water requirements. In Iran, the area under micro-irrigation system is ~400,000 ha [25]. This method can prevent groundwater over-exploitation and reduce water wastage [26,27]; however, in arid regions, its implementation presents many challenges, which require detailed environmental monitoring of the irrigation system and engagement with local farmers. For example, Rodriguez Diaz et al. [11] evaluated water transmission from surface irrigation to a pressurized drip system in Guadalquivir (Spain) and reported a 40 percent reduction in water diversion, but with a 200 percent increase in cost. Given the expense, farmers with large land holdings and better access to water resources are in a better position than subsistence farmers to invest in the expensive irrigation equipment required [28]. In addition, studies using agro-economic models to evaluate pressurised systems to improve irrigation efficiency noted increases in water consumption rates, which is known as the rebound effect (e.g., [8]). This effect occurs where modern irrigation systems lead to increases in irrigated land areas, and the saved water is used to increase the extent of agricultural cultivation in situations where there are no limitations on water rights, leading to an increase in overall water consumption [29,30].

2.1.2. Sub-Surface Piped Irrigation System

Recent applications of sub-surface piped water technology for irrigation have included the use of 30 cm diameter polyethylene irrigation pipes installed at depths of ~1 m. These were introduced by the Iranian government in 2012 to reduce water transmission losses and improve irrigation efficiency. Different water distribution systems (such as canals or pipes) are usually tested by farmers, and their reflections on the practical utility of these systems can help local agencies to improve the system or to introduce different methods or devices.

The majority of studies promoting drip irrigation systems have had an experimental focus, whilst information on farmers' perspectives on these systems, and on collective irrigation management practices, has been limited [27,31]. There has also been little critical evaluation of farmers' perceptions of Iranian government schemes: there has been no local evaluation of the 'Tooba' irrigation scheme, nor have participatory and community-based management approaches to irrigation management been assessed.

2.2. Methods

This paper considers the perspectives of different groups of farmers who participated in a qualitative research study including a combination of group discussion, semi-structured interviews and a participatory irrigation simulation exercise (to be described in a subsequent paper). Four periods of field-work were undertaken over three years (2011–2013), each year for a period of between 1 and 2 months. Interviews and group discussions were conducted with experienced farmers and local water management authorities in the region (Tables 3 and 4). The purpose of the interviews were to: provide general background understanding of the irrigation system in Kashan; identify the main problems regarding irrigation efficiency, sustainable groundwater management, and the implementation of irrigation rules and management practices, as well as existing cultures regarding irrigation from the perspective of local farmers. Semi-structured interviews were designed on the basis of key statements extracted from preliminary 'deep interviews'. The former were conducted with 25 individuals, in farmers' houses or on their land (see Appendix B). Further interviews were conducted with officials in relevant local agencies, including the Regional Water Authorities of Kashan, with the responsibility of managing and maintaining the irrigation infrastructure (water canals, reservoirs and large-scale groundwater schemes) and delivering water to farmers. Officials in the Agricultural Jihad Agency were also interviewed: this body oversees the development and management of on-farm irrigation schemes. In total, 4 in-depth and semi-structured interviews were conducted with different management bodies in two sub-district regions of Kashan and Aran-Bidgol (Table 4).

Group discussions were invaluable in encouraging farmers to engage in debate, particularly prior to, and after, implementation of government irrigation schemes. A total of 6 group discussions was conducted to explore challenges in irrigation management and identify farmers' perspectives towards government schemes. These interviews were translated and transcribed into English for analysis. The transcripts were coded using NVivo, to enable the information to be classified to identify themes for further discussion.

Table 4. Key governmental departments interviewed (2011 and 2013).

Roles/Interviewees Official Agencies	Official Role	Number of Interviewees and Types of Interviews
Agricultural Jihad Agency	Chief of rural cooperative	1 semi-structured interview
Water and sewage agency (in two sub-districts of Kashan and Aran-Bidgol)	The head of water agencies	1 in-depth interview and 1 semi-structured interview
Academic experts	University lecturer and PhD students	1 in-depth interview with academics 2 group discussions with PhD students

3. Results

3.1. Challenges for Local Stakeholders with Groundwater Irrigation Management in Kashan

In this section, we summarise the interviews with local farmers and water agencies on their role(s) in Kashan's irrigation systems and outline their perspectives on challenges regarding the sustainable use of groundwater resources. The interviews identified many challenges with current groundwater management and irrigation practices in Kashan, due to a combination of harsh climatic conditions, the long-term overexploitation of groundwater resources, decreasing water quality and the lack of effective controlling and monitoring mechanisms for groundwater abstraction. The introduction of pump irrigation technology has contributed to an increasing inequity in access water supplies between large-scale and small-scale farmers, and the latter have increasingly relied on their historic water allocation and collective management of tube-wells to sustain their farming practises. As a result, farmers and water agencies both consider that the sustainability of groundwater resources in Kashan is threatened. While some of the groundwater management problems can be attributed to national policy, others have arisen through a combination of water scarcity [14], the ineffectiveness (in some areas) of local institutions and as a result of farmers' local decision-making. Thus, a range of factors contribute to the challenges confronting farmers in Kashan and, importantly, analysis of the empirical outcomes of the interviews with local farmers show that perspectives on water values, on the rationale for groundwater protection, the definition of irrigation efficiency and on the sustainability of water resources differ between local communities, farmers and official authorities. Hence, there is a need to tackle different viewpoints and derive commonly-agreed statements of the problem prior to identifying appropriate irrigation management plans.

The empirical findings also suggest that farmers in Kashan face particular challenges that prevent them from taking collective action and agreeing on joint management decisions. This is the process whereby government devolves certain actions to small-scale farmers to encourage land consolidation and installation of drip irrigation systems and also transfers costs to farmers as part of a transition in water governance structures from state-led to community-based management. There is also an unhelpful focus on government schemes promoting technological solutions without considering socio-ecological conditions (i.e., importing technologies that may not be adaptable to local needs). Other factors include land consolidation agreements, as well as changing crop patterns, which might be counter to traditional social and cultural practices in a particular region (see the Discussion).

The interviews with farmers also revealed that historically, Iranian water rights were adjusted to provide a fair and equitable distribution of water to small and scattered land holdings. These small and scattered farmlands are increasingly economically disadvantageous for farmers, and inhibit farmers' participation in 'Tooba' irrigation schemes. However, while farmers are aware of the advantages of land consolidation, which can reduce water wastage and facilitate machinery use, in practice, land integration is difficult for farmers to achieve (see Section 4).

Regarding different perceptions on the efficiency and sustainability of groundwater use among farmers and state agencies, farmers in Ali-Abad (2013) defined the improved irrigation efficiency as:

> "Based on each farmers' water right (refer to the Qanat allocation system), a farmer needs to receive his water at time and if the total water reaches his plot increased by saving (water) from seepage through the transmission canals, then it means efficiency has improved so he can cultivate more lands . . . and his final production level and revenue is higher".

The statement indicates the crucial importance of water right and allocation mechanisms amongst farmers, as this provides fair access and distribution of irrigated water. This also indicates that farmers recognize that significant quantities of water are lost during water transmission, when using poorly-maintained water canals. The main measurement for improved efficiency for local farmers seems to be improved accessibility to their allocated water rights, in order to maintain or increase their production level. Farmers also stated that cement-lined, or sub-surface, tube water canals can provide access to more water, and hence are more advantageous, as they can considerably improve water delivery efficiency. This can significantly affect farmers' decision-making behaviour in selecting suitable technology. When farmers evaluated the policy on reducing water rights to one-third of the current amount under the 'Tooba Scheme', they suggested initial estimates of groundwater abstraction rates need to be re-evaluated because they were incompatible with current needs. As one farmer in Fakhreh village (2013) stated:

> "Farmers cannot cope, government has to evaluate any new policy first with farmers and then set the rules, we cultivate based on our water right and if the policy interferes with this we cannot accept it".

In response to the question of whether the new water allocation rule had been re-assessed recently, the agricultural water agent responded:

> "No, we agree that there is an implementation problem for this scheme to be accepted by farmers, but on the other hand the agency has to deal with groundwater over-abstraction".

Many farmers stated that this state-oriented policy of water right re-allocation can potentially disturb the historic water allocation mechanism. The implementation of more restricted rules on water rights can potentially add extra uncertainty and increase the inequity between farmers in their access to water.

These empirical findings provide a deeper understanding of existing challenges when scarce groundwater resources are the only water source available to support domestic and irrigation practices for local communities. It is important, however, to understand the historical background to current irrigation practices, and particularly their irrigation context. The following section uses information from the interviews with farmers to assess the different factors influencing whether farmers might accept or reject the government irrigation schemes.

3.1.1. Introducing Pumped Technology and Associated Difficulties

Pumped-well technology in Iran was initially thought to have been successful introduced as it was widely adopted by farmers, although over time, it has adversely affected groundwater resources. This raises questions over the sustainability of pump technology, which has been described as 'the source of health, irrigation, power and control' [32]. Farmers initially valued the flexibility of pumped well systems, and the majority of farmers in Iran adopted these systems when they became available, leading to increased agricultural production. In Kashan, farmers indicated that when the government introduced pumped-well technology, they were encouraged to drill tube-wells and were provided with incentives including a cheap tariff on groundwater, subsidized electricity, long-term loans, free manure and aerial applications of pesticide on their farms to encourage uptake.

The introduction of irrigation wells created short-term economic benefits for many farmers, but has led to a number of subsequent problems. One major consequence is that following the introduction of pump technology, groundwater has become the main water source for agriculture: it offers a more resilient water source in drought-prone regions such as Kashan and can sustain local livelihoods and incomes. This illustrates how "groundwater development can improve socio-economic status of poor to a greater extent than traditional surface water" because it needs less initial investment to dig a new well, and it can be drilled inside the farmland [33]. However, as the technology was widely applied and was managed inappropriately, there were only short-term benefits. Extensive groundwater exploitation has resulted in salinization and degradation of soil and water quality. Interviews with representatives of the local water authorities indicated that the main reasons of soil salinization in Kashan included: the local geology, climate (high evapotranspiration, wind-borne salinity), saline groundwater intrusion, traditional irrigation methods and the usage of saline water in agriculture. As the situation has deteriorated over time, farmers' choice of crops has become increasingly limited to salt-tolerant crops, such as pistachio, barley and wheat, which has reduced agricultural incomes.

Farmers in Kashan expressed their dissatisfaction with increased farming costs and indicated that they had become more vulnerable as pumping costs have increased and groundwater abstraction rates have been controlled by the state. Irrigation costs have also increased while government subsidies have been removed. This has contributed to an increasingly uneven pattern of water distribution and water accessibility, which presents significant social and economic disadvantages for farmers. Inequity in access to water resources is one of the main social consequences that have arisen through pump technology: farmers in Kashan suggested that richer farmers have sufficient capital to purchase more land and water rights, and hence, their production levels and revenues are higher than poor farmers with limited access to water. Higher revenues also mean that rich farmers can easily pay the increasing labour and electricity costs and can secure loans to adopt modern irrigation facilities.

Although rich farmers work independently, in comparison to poor farmers, farming is not their main occupation. Small-scale farming systems include a large number of shared owners of wells who had previously shared water rights in a Qanat system. Where there are high numbers of shared owners, the benefits to the individual farmer is reduced with lower income and profit. Small-scale farmers, who cannot afford to purchase additional water rights above their historical allocation, also believe that richer farmers have secured better access to water sources through corruption in recent years. However, groundwater abstraction appears less susceptible to corruption in comparison to large-scale surface abstraction schemes.

3.1.2. Problems of Management Transfer

Current management problems in Iranian agriculture and irrigation management systems are associated with a change in the control and maintenance of water supply and distribution systems from individual communities to government authorities known as management transfer. Nationalisation of water and irrigation management practices and organisations commenced during a process of land reform in the 1960s, which has transferred irrigation management from a feudal basis to the state [34]. There have been several consequences for irrigation practices, particularly at a local level. Crucially, in contrast to the previous situation when the landlord was responsible for the distribution and maintenance of the water supply infrastructure, this responsibility has been transferred to the government, which enables the state to control and monitor farmers' abstraction rates. Farmers stated that in the traditional irrigation system, they worked collectively in activities such as irrigation, harvesting, land preparation and cultivation and in cleaning and maintaining Qanat systems and irrigation canals. Farmers tried to transfer these collective activities to the tube-well system management; however, collective management of water and irrigation systems largely ceased following the installation of private tube-wells by large-scale farmers. At present, farmers believe it is not their responsibility to protect and control groundwater abstraction rates from tube-wells, although when they used the Qanat systems, they were responsible for maintaining the water supply system.

In general, farmers have struggled to maintain their traditional water rights and allocation systems when adopting new irrigation technologies. One farmer in Abu-zeid Abad village in Kashan (2012) stated that:

> "Today it's the water that gives value to the land. The value of water is increased because its price has increased . . . We stayed here because of available water".

Farmers also stated that collective ownership of tube-wells (by small-scale farmers) could ensure equitable access to groundwater resources and reduce pumping costs. However, government policies, such as drip irrigation systems, affect existing collective actions and water right regimes in ways that are particularly problematic for poorer farmers. Many small-scale farmers stated that this state-oriented policy disturbs their historical water allocation and the way they collectively manage irrigation practices. They considered it was neither suitable nor effective for them to use drip irrigation systems to support their existing farming patterns, and these farmers could not be persuaded to accept this method.

Small-scale farmers also outlined how a drip irrigation system was inappropriate for Kashan, as with their scattered land holdings and brackish groundwater, it was not feasible to use drip systems to irrigate pistachio trees. There were further problems with the labour-intensive maintenance requirements, high rates of water leakage, the cost of repair and worries about theft of key infrastructure components.

Consequently, the majority of farmers (both medium and small-scale) have tended to reject modern irrigation systems (i.e., drip irrigation methods) as this would require differing practices of collective ownership and action (see the Discussion). As a result, farmers would be unable to predict and accept future risks and would be unable to assume the responsibilities associated with modern irrigation technologies.

Another underlying factor in rejecting drip irrigation was provided by a farmer in Kashan who stated that:

> "This is why we cannot accept drip irrigation system, because then we have to establish a shared water reservoir; but each farmer wants to have his own authority on his 4–5 h of water within traditional water right allocation. The Jihad Agriculture (the agency) wants a farmer to manage his water in reservoir while it is not adapted to our practical water allocation mechanism".

When installing drip irrigation systems in the 'Tooba' Scheme, farmers have to construct small reservoirs to store their water allocation, which is then distributed through drip irrigation to their lands. This disturbs traditional water allocation mechanisms. It is also problematic given the scattered land ownership, and it is difficult to allocate water rights to farmers from the reservoir. Group discussions with farmers indicated that construction of a reservoir and the adoption of a drip irrigation system require farmers' agreement to consolidate their land holdings and become eligible for a government loan. For small-scale farmers, construction of the reservoir and/or drip systems and funding subsequent maintenance is expensive, requiring collective ownership of the infrastructure to share their cost equitably. Farmers pointed out that land consolidation requires extensive effort and agreement between farmers, which cannot be easily arranged.

As part of the contemporary water governance regime in Iran, the government has tried to promote a decentralized management approach to irrigation and to improve stakeholder engagement in irrigation management practices, but this appears to have been largely unsuccessful [35]. For example, in the new irrigation systems, the government has reduced financial support for farmers and has gradually transferred responsibility for irrigation management to farmers. However, adoption of this policy requires capacity building among small-scale farmers who rely on government financial support to implement and maintain their irrigation systems. The government policy of decentralization essentially transfers costs onto poorer farmers, with insufficient financial support and limited education and capacity building.

Farmers identified other factors that discourage their participation in large irrigation schemes, which mainly related to a lack of financial resources to invest in projects, the lack of agreements and cultural differences, inefficiency and poor coordination by rural institutions and unsuitable irrigation projects for farmers (with respect to profitability). However, poverty is the main factor affecting farmers' capacity to adapt to conditions of water shortage [36]. Other factors influencing the successful introduction of new irrigation technologies in Kashan are described below.

4. Discussion

4.1. Factors Influencing Farmers' Adoption of Government Irrigation Schemes

The main government schemes discussed here are the 'Tooba' scheme and associated policies (including the installation of drip irrigation systems, reduced water rights and land integration) and changing cultivation patterns with increasing pistachio cultivation. Different factors influence the acceptance or rejection of government schemes including: biophysical adaptability, economic return, cultural and social adaptability, which are analysed here from empirical research and by reviewing the literature. If a new government irrigation scheme includes all these factors, it is likely that local farmers will accept the project and participate in its adoption.

4.1.1. Biophysical Adaptation

As stated previously, the combination of changing water supply systems and mechanisms for water abstraction has led to significant changes in the Iranian irrigation and water distribution infrastructure. Government policy over the last 30 years has mainly focused on improving irrigation efficiency by introducing different irrigation technologies and encouraging farmers to adopt devices to control abstraction. Empirical evidence (e.g., [37]) suggests that farmers have failed to accept many of these policies, controlling mechanisms, or technologies, as in most cases, they are inappropriate for the local circumstances. The introduction of new technology (e.g., drip irrigation methods) requires social and material adaptability, and the most successful technologies are those that are flexible given the existing social, biophysical and cultural situation [34]. Bijker et al. ([38], p.13), argue that technological choices often require an iterative process of negotiation between members of each group to shape and confirm the best technological option. Implementation of each technological solution may bring different advantages or problems for local users, and it is important that the technology is fully evaluated and can be adapted to different ecological, social and cultural conditions ([34], p.28).

The climatic and biophysical characteristics of a region will also affect the adoption of a particular irrigation technology. In Kashan, farmers outlined their main reasons for rejecting proposals to reduce water abstraction rates to one-third of their current amount: farmers suggested that given the harsh regional climate, it was difficult to use less irrigation water. Currently, farmers are irrigating continually (for almost 24 h a day), and yet, they are still unable to achieve a good yield, so they question how they might increase production with much less water. For example, when discussing the adaptability of drip irrigation systems to the regional climate, one farmer in Ali-Abad village (2013) said:

> "This region is a desert land and it must be irrigated with flood method and consumes lots of water because the region is hot, and the soil is clay, so within 10 days we should irrigate again".

The other main limitation to adopting the drip irrigation system is that it is only suitable for wells with low salinity groundwater (i.e., with an electrical conductivity (EC) <3000 μS cm^{-1}). Where water has a higher salinity, drip systems typically become blocked with sediment, and the groundwater in most villages in the Kashan plain is above the salinity threshold.

Another farmer in Ali-Abad village (2013) stated that the permitted volumes of water abstraction and the degree to which farmers' must reduce their abstraction hours mirrors the practice in other arid countries and had not been assessed in the context of local water needs and climate. Farmers also suggested that water rights should be gradually reduced by government, as a sudden reduction would present financial problems.

It is evident that although farmers have struggled to maintain traditional water right systems, which could potentially ensure equitable access to groundwater resources, government policies (such as encouraging drip irrigation systems) affect existing water rights in ways that are problematic for poorer farmers. Farmers explained how drip irrigation systems were inappropriate as given their scattered land holdings, they could not use drip systems to irrigate pistachio trees. Farmers also explained that sub-surface piped water irrigation schemes could be more acceptable as the water outlets matched the time slots of the traditional water allocation mechanism. As a result, the water was not exposed to sunlight, and evaporation losses were much less in comparison to open cement-lined canals.

4.1.2. Economic Advantages/Returns

Economic factors act as both incentives (in terms of providing higher agricultural revenue) and as barriers (financial constraints) for farmers' acceptance and adoption of a particular irrigation scheme or technology. Under conditions of water scarcity and reduced farm income [39], any new system that could improve agricultural production by increasing water availability for farmers is an advantage that would help farmers accept technologies such as sub-surface piped irrigation systems. On the other hand, financial constraints can affect a farmer's choice of a particular irrigation scheme, and farmers' financial status should be considered when introducing government schemes. The government is required to provide sufficient financial support or loans for farmers, based on an estimate of the project's cost. However, in Kashan, the area of cultivated land has fallen due to increasing water scarcity, and farming costs have increased (due to the use of electric pumps and the removal of subsidies). This has prevented Iranian farmers from investing in schemes to improve the irrigation infrastructure.

Empirical findings from the interviews indicated that farmers were fully aware of the importance of sustainable abstraction and irrigation practices. However, as a result of their small and fragmented land ownership, farmers lacked the financial resources to address the problem.

One local farmer in Ali-Abad village (2013) indicated:

> "Land integration has many advantages, when we did it the government supported us, my lands which is around 1 hectare were scattered in 5 to 7 different locations, but now they are all gathered into one piece".

Agricultural productivity varies according to the type of farmer (particularly their farm size), the farm location and access to water supplies. Wealthier farmers, who could afford to purchase more water rights, were usually interested in consolidating any fragmented land holdings and increasing the size of their farm to enable adoption of modernized irrigation facilities to increase crop yields and hence income. Poorer farmers, with small- or medium-scale land holdings, had more difficulty in accepting and adopting new irrigation technologies. Farmers were also confronted with economic uncertainty in agricultural production as the state provides insufficient support for capital investment and there is a significant barrier for farmers in adopting new technologies, which might present an economic risk.

The other economic factor influencing acceptance of a particular scheme is crop value, which is the most important element relating to agricultural revenues. As farmers became more educated and wealthier, they moved from low value crops to higher value crops and cash crops as water availability increased with expansion of private tube-wells. This has compelled farmers to use more efficient technologies and develop national or regional markets for their products [20]. However, this is only possible for wealthier farmers: medium or small-scale farmers in Iran have retained traditional crop cultivation practices. The Iranian government has sought to persuade poorer farmers to cultivate crops requiring less water to conserve groundwater resources (although this scheme also requires land integration by farmers).

In this regard, and in response to the water shortage and salinity problem, one farmer in Kashan (2013) added: "We decided to change our cultivation to crops that use less water for irrigation, we came to this conclusion that the best way to irrigate with saline and scarce water is to plant pistachio in Kashan. The quality of groundwater is not good for cultivation of crops such as cucumber, tomato, fruit trees or vegetables; they will not grow and under extreme salinity those dry out quickly".

Regarding the government plan to encourage a change in cultivation patterns to pistachio trees, one major consequence would be the change to local farmers whose livelihood depends on short-term crops such as wheat and barley. It was found that small-scale farmers adopt an economic strategy based on the profitability of individual cultivated crops. The strategic behaviour of one farmer in choosing an appropriate crop pattern, in Rijen village (2013), was described as:

> "Our strategy is to see which crop is profitable for us in a short term, if it has economic return then we plant it otherwise we don't follow governmental crop pattern. Because we have to pay for everything so it must be profitable for ourselves. Officials just express their request blindly but they do not stick to their promises to support us".

If they are to implement the new irrigation systems provided by the government, farmers (particularly the poorer farmers) would require more financial support. However, farmers stated that as their production does not contribute to the national economy, the government has reduced financial support and has instead allocated the budget to large-scale industrial cultivation.

Some farmers expressed concern that by increasingly removing agriculture from this area and introducing industrial activities, they would no longer have a viable livelihood, particularly as they had no experience of working in industry.

The government is also seeking to reduce water rights to one-third of their current volume. This presents significant economic disadvantages for farmers, which is the main barrier to accepting this policy. One farmer indicated that the government would not allow farmers any choice and the scheme would have significant economic disadvantages for small-scale farmers. Hence, small-scale farmers would not adopt this policy as their reduction in water rights would result in a significant reduction in farm income. This would leave them with no choice other than abandoning farming and migrating to a city in search for work. However, whilst protecting groundwater from over-exploitation, significant quantities of water will be used in proposed industrial developments, which overshadows the gain for farmers. In situations where there is insufficient control and regulations over aquifer water levels (in terms of issuing new abstraction permits and the monitoring of groundwater abstraction rates) and where some stakeholders have better access to groundwater resource, any re-allocation of water rights may aggravate competition over water and contribute to environmental degradation.

4.1.3. Social and Cultural Adaptability

The historic irrigation rules and social relations around the use of traditional irrigation systems particularly Qanats, in different parts of Iran have developed over centuries and rely upon scientific and participatory management [38]. Thus, these rules have been integrated in each community and cemented through social capital and adaptive rules, which are very difficult to change through government intervention. Individual technologies can greatly affect the social relations between farmers, which make them reluctant to accept technological innovations. The importance of social norms (in the context of this study, water rights and allocation rules) is a key factor in influencing communities in acceptance of new technology or practices [40]. In general, society is reluctant to change traditionally recognized relationships, and new technologies may bring different social interactions to a society [34]. After introducing tube-well technology, the availability of water that provides profit has become the main criteria when valuing water and land.

Introducing pump-well technology has presented many challenges and difficulties for farmers who have adopted it. However, this technology can increase their access to water resources, and farmers have transferred the traditional rules of Qanat to tube-wells. Ultimately, any new technology that does not bring value for farmers, or does not improve their access to water (improve efficiency), or conform with their water allocation mechanisms is unlikely to be adopted. Kamash [34] argues that technology is interconnected with the history, culture and norms in each society, and hence, it is essential to consider social and cultural factors when adopting new technologies. Issues such as water rights and allocation mechanisms, as well as cultivation patterns and landholding systems are historical circumstances that are rooted in farmers' local culture and social norms, which create a sense of social capital between them to cooperate and trust each other and local agencies. Changes in any of these conditions will have consequences.

However, some of the decisions may be made on the basis of misconceptions as suggested by a manager in the Agricultural Jihad Agency when indicating why farmers might reject the drip system:

> "In flood system (under Qanat), because farmers used to see 5–10 cm water on top of soil now they don't accept drip method, they say that tree fails. Maybe under drip system, long rooted trees fail (because of insufficient water seepage through soil layers), it is based on farmers' experience but scientifically drip system is approved, and for their new crops they can adopt this system".

The other crucial factor that has been identified in Kashan is that the technologies and policy schemes are not localised [17] and the rules are not adaptable to a particular climate or to the socio-economic conditions of the region. For example, when questioned about changing cultivation patterns, one farmer in Ali-Abad (2013) suggested that farmers would regret changing the cultivation pattern to mono-cropping within a few years. He stated that:

> "I am not against pistachio cultivation but I'm saying that farmers get regret in 10 years. Now farmers say that cultivating tree is easier but if all cultivate pistachio, farmers would not bother to plant any wheat. Because the main livelihood is bread, if we do not have anything we can just eat bread but pistachio is an economic crop and cannot feed us. Under that situation, government may import more wheat... I think government is trying to make this region economic or industrial . . . "

The change in cultivation patterns threatens traditional livelihoods, which emphasis the integration of agriculture and husbandry activities. Traditionally agriculture and animal husbandry are interlinked [38], creating a resilient system for vulnerable farmers, and any minor impacts have a significant impact on other activities. One farmer explained that: "for example, if someone wants to have husbandry he must have alfalfa or barley production beside it". Farmers indicated that husbandry has reduced because the price of fodder has increased (with an unstable market for barley) and it is not profitable to continue husbandry. The majority of farmers found it unprofitable if they do not keep farming and husbandry together, and it seems that husbandry can help traditional farmers pay their agricultural costs. Thus, retaining the existing diverse cultivation pattern is a more strategic and resilient option for farmers rather than changing to industrial crops such as pistachio. Crop selection by farmers is thus undertaken on the basis of water availability and climate, as well as cultural traditions and economic need [41]. Changing cultivation patterns are one strategy that farmers use when one crop has a low yield; however, the crop they choose must be adapted to saline water and periodic water deficit. Government attempts to introduce new crops into the region are based on observations of a few large-scale farmers' experience in pilot studies, but these crop patterns usually differ from the majority of farmers' circumstances, as they practice small-scale farming and have significant financial constraints.

5. Conclusions

A lack of critical evaluation of management projects and governance systems in Iran has resulted in ineffective management strategies and outcomes, which are designed in a top-down manner. There is also a lack of analytical studies on the role of local farmers' behaviour in managing land and groundwater resources in arid regions of the world, and also in the specific characteristics of groundwater as an invisible common-pool resource for irrigation purposes. Government projects seeking to address water scarcity problems have been mainly technologically-oriented and lack sensitivity to the local social, cultural and biophysical context. This paper has reviewed the main challenges in groundwater irrigation management and practices in Kashan, Iran, from the perspective of local farmers. The main challenges confronting farmers include: management transfer, inappropriate technological solutions and incompatibility of proposed irrigation schemes with the biophysical, social-cultural and economic status of the region.

In the local irrigation system in Kashan, the rules used for irrigation management follow traditional mechanisms of water allocation and distribution, in which equity and timing play a major role in water delivery and division. Farmers conform to these rules and water right allocation because of the legacy of the Qanat system, and they believe that their irrigation practices satisfy their own perceptions of efficiency. This empirical study shows that farmers in Kashan collectively cooperate in regulating water distribution, in which each farmer receives his exact water right on time and in an equitable manner. For example, historical water rights were adjusted to provide a fair distribution of water to small and scattered pieces of lands, which is now problematic given the difficulties of land consolidation to implement 'Tooba' drip irrigation scheme. From the simulation mapping exercise and deep interviews, farmers collectively indicated that the agreements for land integration for installation of the 'Tooba' scheme require extensive effort between farmers, which is not possible within a short period of time. Farmers also consider groundwater resources to be threatened, but believe that their historical water allocation and irrigation rules provided each farmer with their own water rights, thus sustaining farming practices. If government approaches do not consider these mechanisms and collective rules, they will not be successful in managing groundwater resources.

The results indicate the importance of articulating local knowledge and identifying local solutions when making management decisions. The common-agreed policies and management options should be developed under suitable institutional settings, which empower farmers by engaging them in management processes as key stakeholders. By considering local irrigation culture and social economic factors when shaping water management regimes and identifying obstacles inhibiting farmers' participation in government schemes, it is possible to develop a more integrated approach to irrigation management. This highlights the need for more local adaptive management solutions in response to reduced governmental financial support. These solutions will become more necessary given climatic uncertainties (e.g., increased temperature and reduced precipitation) and the socio-political situation.

Regarding improved irrigation efficiency, groundwater over-abstraction and the occurrence of externalities are the consequence of dysfunctional basin management, and farmers are not solely responsible. Farmers are the main stakeholders who suffer from the impacts of water scarcity and are the main group who will be affected by water reallocation. In this basin, better efficiency in irrigation systems does not necessarily benefit farmers significantly. Therefore, it is essential for further empirical studies to investigate the local impacts of micro-irrigation systems' application; otherwise, land expansion (following land consolidation), new crop patterns and re-allocation of water rights may adversely impact water use and consumption rate. Interviews with farmers suggested that the irrigation technologies used to improve efficiency need to match the definitions used by farmers. Farmers want to increase water accessibility to their lands and to maintain agricultural production, and this is particularly the case for small-scale farmers. There are also challenges related to governance issues, which have resulted in a reduction in water rights and also shifting agricultural costs and responsibilities onto farmers. This has only raised dissatisfaction and destroyed trust and cooperation with local governmental agencies. The lack of capacity building programmes to empower farmers' decision-making abilities has also increased the social and financial constraints facing poorer farmers. Transferring management to communities will only be successful with increased participation of resource users in management-decision processes, but it will be impossible unless the government establishes a new relationship with the owners of the resource. The policy of decentralization seems to shift agricultural costs onto poorer farmers, as well as the cost of installation and maintenance of the recently introduced technologies, without sufficient financial support, education and establishment of capacity building among local farmers through the local institutions.

From this argument, it can be concluded that the government is not the final arbitrator for groundwater irrigation management and sustainability. Managing groundwater resources requires collaborative efforts between local farmer communities and responsive governmental organizations. While the role of government's financial supports in developing countries is crucial, farmers also need to have their own self-regulated strategies and alternative management solutions. The role of government should be eliminated and most responsibilities be transferred to the local institutions and farmers' communities. However, it is essential that the government still provide financial support and infrastructures for poor systems, as well as trying to establish effective institutions to engage farmers in management decisions and empower local capacity to undertake parts of governmental roles and responsibilities

This paper has also reflected on some of the main factors influencing farmers' decisions to select a particular irrigation scheme or technology. These include the adaptability of the irrigation management solution to biophysical, economic, social and cultural conditions within a local irrigation context. To introduce new irrigation schemes or new technologies, the system needs to be tested and evaluated through pilot studies, and after confirming the project's suitability, it could be implemented at a wider scale. The adaptability of the irrigation technology to the arid climate, the traditional culture and social norms of water allocation mechanisms must be carefully considered, in order to work with, rather than against farmers' prevailing values and behaviours. An in-depth understanding of these challenges and the main factors in the implementation of a successful irrigation management scheme in the region can facilitate introducing a more suitable irrigation technology and improve collective agreement for the adoption of governmental policy schemes.

According to the study's findings, there is the potential for farmers at a local level in Kashan to participate in irrigation management projects. Farmers are willing to improve collective action, and they accept strategies that are adaptable to their irrigation practices to improve irrigation efficiency. The study suggests the crucial role of local informal meetings as the main support for integrating locals' knowledge and perspectives into management decisions, which promotes social capital and empowers farmers' decision-making abilities. Under an appropriate framework approved and encouraged by political will and communities' capabilities for engaging in management decisions, the implementation of wider participatory irrigation management would be possible. Given the high uncertainty and low controllability of groundwater as a 'common-pool resource', there is a strong argument for more community-based and adaptive approaches to water and irrigation management. It is necessary to articulate local knowledge and local solutions in management-decisions in the region: by considering the role of local irrigation culture and social economic factors in shaping current water management regimes.

Acknowledgments: Forough Jafary is grateful to her supervisors in the U.K. and her professor at Tehran University (Iran). Special thanks to all participant farmers in Kashan city who deeply assisted in conducting this study. We are also grateful for the helpful comments from the reviewers and the guest editor on this paper.

Author Contributions: The work is extracted from Forough Jafary's doctorate thesis; this includes empirical field works and literature review studies. Chris Bradley contributed significantly in editing and clarification of the context, as well as the transparency and relevance of the literature and the arguments.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

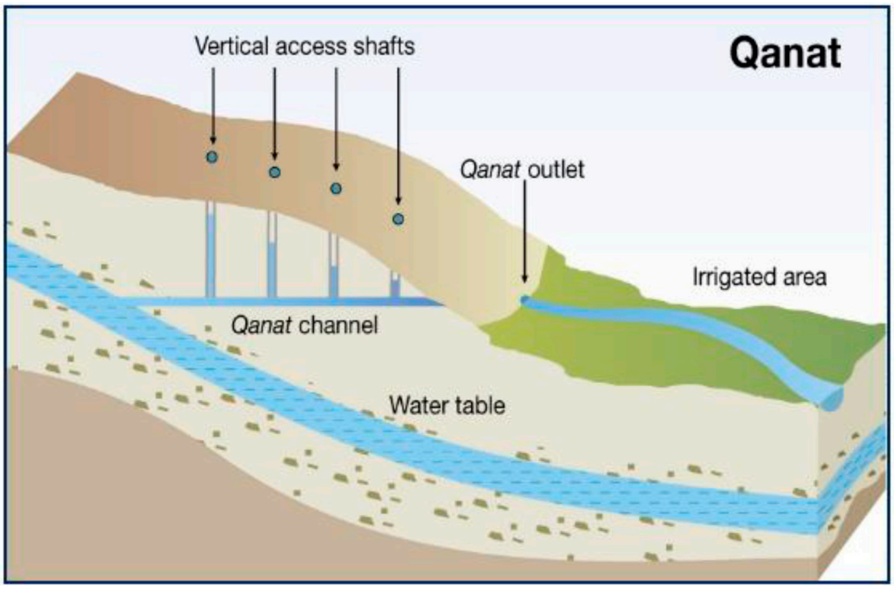

Figure A1. Source: The International Centre on Qanats (ICQHS), Yazd, Iran.

Appendix B

Interview Guide- Sample Questions: Local Farmers in Kashan and associated Villages

Personal Information:

Serial no:
Sector:
Rural:
Date of Interview:
Interviewee: Gender: Age: Mobile Number:
Name of Farm:
Location of Farm:
Farm establishment date:

General Questions on Occupations, Ownership Status, Cultivation Pattern, Irrigation Methods:

What are your responsibilities/roles in agricultural activities?
Are you the main land owner? How large is your farmland area?
If you are sharing your land how many farmers you are working with?

What is your cultivation pattern in different seasons?

What is your irrigation method?

Questions from local Farmers on Water Value and Traditional Irrigation Practices:

How modern allocation schemes affected farmers' traditional perspectives and behaviours towards agricultural water consumption?

How inappropriate governance in the past affected farmers attitudes towards new governmental water scheme projects?

What are farmer's perspectives towards reducing agricultural water consumption?

How different governance structures affect individuals' incentives and capabilities to cope with collective-action problems involved in system operation and maintenance?

Social and Cultural Questions: Kashan

What is your current agricultural water condition? Do you see any reasons to reduce/increase your water abstraction?

How modern system of water allocation has affected your agricultural activities and your income?

What is the main factor for rejecting new irrigation scheme?

Which factors would increase/affect your trust in agricultural water schemes?

Irrigation and agricultural Issues:

Would you apply 'Tooba scheme' for your farmland? Which factors affect your decision to accept or reject it?

Do you know farmers who have applied 'Tooba schemes' for their garden? How would they evaluate it?

Do you think of changing your cultivation pattern to halophyte crops? (Less water consumption plants?) What do you think about this method?

Questions relate to access to groundwater and social inequity

1. Are there any informal arrangements organised by small-scale farmers for accessing to groundwater? Why do they need this, and what is their approach?

2. Do you think access to groundwater is equal between small-scale and large-scale farmers? How land integration can improve farmers' access to water and improve irrigation efficiency?

3. How much land ownership status (small or large scale, assignees or tenant) has affected social inequity in terms of accessing groundwater and irrigation distribution systems?

4. How farmers have secured their access to water resources? Which obstacles exist against their water security?

Interview Guide: Governmental Organizations in Kashan

General Questions: Water and Climate Changes in the Region

Which organizations are involved in addressing key issues and problems related to impacts of Climate change/water resources problems?

What are the policy or strategy documents to guide their work?

What are the strengths and weaknesses of the institutions?

How people have access to information on current and future water problems?

What livelihood or economic sectors are the most vulnerable to climate change impacts? (i.e., to the water shortage problems).

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