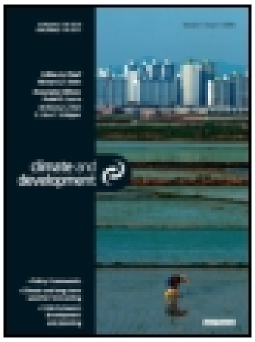

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Harnessing indigenous knowledge for climate change-resilient water management – lessons from an ethnographic case study in Iran

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ABSTRACT

Through an in-depth ethnographic case study, we explore water management practices within the Jiroft County province in Iran and discuss the applicability of indigenous knowledge of regional water management to the resource governance of arid regions across the world. We explore, through qualitative analysis, the relationship between community social structure, indigenous knowledge, water management technologies and practices, and water governance rules under conditions of anthropogenic climate change. From participant observational and interview data (n = 32), we find that historically-dependent community roles establish a social contract for water distribution. Cultural conventions establish linked hierarchies of water ownership, profit-sharing and social responsibility; collectively they construct an equitable system of role-sharing, social benefit distribution, socio-ecological resilience and adaptive capacity in the face of climate change-induced drought. We conclude that the combination of hierarchical land ownership-based water distribution and what we term 'bilateral compensatory mutual assistance' for the lowest-profit agricultural water users, provides a model of spontaneous common pool resource management that bolsters community drought resilience. We use this case to proffer recommendations for adapting other centralized, grey infrastructure and regulatory models of water management from lessons learned from this spontaneous adaptive management case.

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Indigenous knowledge; water management; Iran; climate change adaptation

1. Introduction

It is widely accepted that freshwater ecosystems face multiple and severe threats – they remain amongst the world's most imperiled ecosystems (Jackson et al., 2014). Freshwater ecosystems underpin global food production from both commercial and subsistence fisheries, aquaculture, crop production and pastoral grazing (Abbasi et al., 2016; Dixon et al., 2001; Ghoochani et al., 2018). Both crop and animal food production systems are therefore stressed when agricultural water supplies are scarce (Azadi et al., 2015; Hoekstra et al., 2012; Parraguez-Vergara et al., 2018). Water scarcity mars both indigenous and non-indigenous agricultural communities, although, the former commonly bear the greatest burdens. Many indigenous collectivities rely upon aquatic resources for their livelihoods, and it is these groups that are most vulnerable to the impact of long-term water shortages as a result of changing precipitation patterns under climate change, and from water resource extraction and utilization projects such as reservoirs and dams (Eskandari et al., 2016; Jackson et al., 2014; Stoeckl et al., 2013).

Global water shortages are caused by both exogenous environmental factors, such as temperature change, changes in dust levels, pollution and precipitation patterns (Schewe et al., 2014), and endogenous human activities including poor land and water use policy and planning, and long-term resource mismanagement (Ghanian et al., 2020; von der Porten, 2013). In response, over the past two decades, there has been a shift in water resource management away from a centralized, top-down 'command and control' paradigm towards a political-ecological perspective that links the hydrological cycle at local, regional and global levels with processes of social, political, economic, and cultural power (Swyngedouw & Swyngedouw, 2004). Water then becomes a combined physical and social process commonly referred to as a *hydro-social cycle*. Embedding this thinking within water management requires decentralized processes of social decision-making and appropriate structures and procedures to support public participation in water management under conditions of long-term climate adaptation planning, population growth and changes to agricultural practices (Douthwaite et al., 2009; Jackson, 2018; Mostert, 2003; Nasrabadi & Shamsai, 2014; Sanz et al., 2019; Srdjevic & Srdjevic, 2013; Tan et al., 2010).

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Hydro-social paradigmatic thinking emphasizes the importance of facilitating local initiatives in water management – defined as informal or semi-formal organizations, or collective action by groups. Water management under the hydro-social paradigm has undergone a 'procedural turn' (Schmidt, 2014) – an orientation that has 'favored the design of management institutions that allow for multiple viewpoints, multiple objectives and the capacity to reflexively respond to surprise and uncertainty' (Schmidt, 2014). *Procedural justice* such that 'fair procedures will produce fair outcomes' (Schmidt, 2014), is underpinned by the expectation that decision-making will 'not intrinsically favor the beliefs – the substantive goods – of any particular group' (Schmidt, 2014). Fair water management will therefore foster shared visions, objectives and norms amongst communities of water users and practitioners (Jackson, 2018; Savari et al., 2020), and be attentive to the cultural capacities and long-term ecological potential within local initiatives in a way that is sustainable under conditions of long-term climatic change. Integrating diverse types and sources of knowledge to achieve this aim is of critical importance (Bohensky & Maru, 2011; Mantyka-Pringle et al., 2017; Rathwell et al., 2015; Suresh et al., 2018), and there is a growing interest among scientific, governmental and non-governmental institutions in harnessing both the social capacity of agricultural communities and their respective *indigenous knowledges* (hereafter IK) within contemporary natural resource management (NRM) practices (Von Der Porten, 2012, 2013; Woodward et al., 2012). Bottom-up hydro-social water management is posited as both a means to alleviate environmental injustice faced by these groups, and to substantively improve the adaptive capacity of existing NRM approaches through processes of social learning (Berkes, 2009; Berkes et al., 2000; McDonnell, 2008). In short, there is increasing recognition within academic and policy circles that modern, globally connected consumer societies can learn from peoples that have effectively managed their natural resources sustainably over many centuries, through an understanding of social roles and water management norms, and the application of IK around water conservation practices (Bicker et al., 2003; DeWalt, 1994; Dove, 2006; Rawluk & Saunders, 2019).

2. Indigenous knowledge (IK)

With a shift towards a hydro-social paradigm of water management there is recognition that local needs, aspirations and knowledge in relation to the use and management of water resources are pivotal for effective and sustainable long-term governance (Eskandari-Damaneh et al., 2020; Nguyen & Ross, 2017). There is no single definition of indigenous knowledge (IK), though it is generally understood as the collective skills, understanding and philosophies of societies that have a long history of occupation and observation in interacting with the natural environment (Fraser et al., 2006; Woodward et al., 2012). IK is commonly interwoven with local religious beliefs, customs, folklore, and land-use practices, and it plays an important role not only in sustainable NRM under conditions of rapid and sustained environmental change, but also in sustaining traditional culture and livelihoods (Chao & Hsu, 2011; Juanwen et al., 2012; Maragia, 2005). The issue of indigenous water maangement has gained considerable international research interest. Case studies across as range of communities in the Global North - including Australia, (Ayre & Mackenzie, 2013), the United States (Wilson, 2014) and Canada (Wilson & Inkster, 2018), and the Global South - including notable cases in Ethiopia (Behailu et al., 2016), Eri-trea (Mehari et al., 2005), and Nepal (Gautam et al., 2018) illustrate the role that indigenous knowledge plays in developing sustainable water management strategies that allow fair distribution of water resources contingent upon the participation of Indigenous People in planning processes.

IK is defined as being in some sense 'local' – it is a relational place-based knowledge that informs communities' day-to-day decision-making, and encompasses language, resource use and management, systems of classification (including biota and biophysical conditions), social interactions, and cultural and spiritual practices (Ford et al., 2016; Mackey & Claudie, 2015; Nalau et al., 2018). Indeed, human interactions with water bodies and aquatic ecosystems are often a source of cultural inspiration that have a religious or spiritual foundation (Jackson et al., 2014). Collectively, IK forms a stock of social, human and cultural capital which embodies complex systems of beliefs, values, methods, tools and knowledge (Roux et al., 2006). IK systems contain detailed representations of the forces that have shaped the diversity and conditions of past and current environments (Ens et al., 2015), and are fundamentally *social-ecological* knowledge systems that enable human use of natural resources within existing limitations and opportunities (Yuan et al., 2014). This means that IK structures the relationship between societies and natural ecosystems as well as the association of communities with themselves (Berkes et al., 2000; Pei & Huai, 2007). IK structures *indigenous institutions*[1], in the sense of systems of rules, norms and management frameworks. IK (commonly) treats humans and nature as inherently inter-related and mutually dependent, and that respect for this dialectic is necessary to maintain long-term ecosystemic and livelihood sustainability (Berkes & Folke, 1998; Colding et al., 2003; de Groot et al., 2010). IK then structures the rules, norms and institutions that regulate human use of ecosystems such that natural resources continue to remain viable into the future (Berkes & Folke, 1998; Leach et al., 1999).

IK has diverse merits in water management, irrigation system management (Parajuli, 2013; Poudel & Sharma, 2012), sustainable construction practices (Gautam et al., 2016) and climate adaptation (Codjoe et al., 2014 Nkomwa et al., 2014). Learning from IK can improve the capacity to develop and implement water management plans in areas of inter-seasonal variation. It can also enhance understanding of river ecology and water-dependent ecosystems, of surface and groundwater interactions, efficient supply of high quality water resources to remote communities, and water accounting practices under stressed conditions (Baul & McDonald, 2014; Baul & McDonald, 2015; Chaudhry et al., 2014; Mantyka-Pringle et al., 2017; Rivera-Ferre et al., 2016; Robinson et al., 2016; Shemsanga et al., 2018). IK in water management practice has been shown to have a number of environmental sustainability benefits (Ayre & Mackenzie, 2013; David & Ploeger, 2019; Jackson et al., 2012), as well as economic and energy efficiency measures (Lall, 1993; Sillitoe, 1998). However, the tripartite challenges of land use pressures to meet food security aims, the centralization of grey infrastructure approaches to water management for industrial and agricultural use, and the water stress pressures of climate change, create constant and growing pressures on water resources. The incorporation of IK-based learning into centralized, grey infrastructure-dominated water management systems, therefore, has tangible sustainable development benefits, and this paper aims to explore this policy and practice gap through lessons gained from the implementation of IK within a critical Iranian case study. We then discuss how the learning from this local initiative can be applied to water management in climate change-induced arid and drought-stricken regions across the world.

Specifically, we examine the following research questions:

(1) What are the patterns of social organization and beneficiaries' relationship pattern with the case study region?
(2) What are the indigenous knowledge systems of water circulation practice and how is division of the resource governed?
(3) What are the practical sharing mechanisms for hydro-social-system maintenance (e.g. the dredging of streams and pools)?
(4) What are the participatory features of local water management? Who is involved and how?
(5) What cultural beliefs underpin residents' perceptions and practices of NRM?

We explore these questions through a participatory and ethnographic case study in the Roozkin village in Jiroft County in Iran.

3. Case study characteristics

The combination of Iran's arid/semi-arid climate and high levels of industrial, agricultural and consumer water use create a 'perfect storm' of water insecurity; thus, hydro-social management is an essential focus of policy-making, system design and socio-environmental research. Mesbahzadeh et al. (2019) argue that considerable evidence for contemporary climate change in the arid regions of Iran, with a resultant water crisis emerging. Water scarcity in Iran has intensified in recent decades under conditions of climate change (Sayari et al., 2013) and population growth (Madani, 2014). The country is subject to severe and intensifying droughts which have caused economic, social and human losses in all sectors (Foltz, 2002; Ghoochani et al., 2017; Hayati et al., 2010). In this empirical study, we employ a critical case study approach (Flyvbjerg, 2006) to one region affected by changes to regional climate, and the interaction between these broader environmental factors and the social organization processes of water management based upon IK practices. The case study is based in Sarduye in the Jiroft county located in Kerman province (population 36,379 based upon recent census data (2016)). The geographic location of the case study region is shown in Figure 1. This part of the province is composed of many small villages. The villages collectively manage agricultural water with the same hydro-social system, as shown in the bottom-right hand corner of Figure 1. All villages within the basin rely upon rivers as the agricultural water resource, and we selected the Roozkin village in this county as an exemplar case within the region. River water is shared among other neighbouring villages, though the qanat[2] water belongs exclusively to Roozkin village. Roozkin village was selected as it has a special boundary management arrangement and is an illustrative example of local place-based initiatives and indigenous knowledge in irrigation water management. The local economy is primarily agricultural (nuts, cherries, apricots, apples, peaches and almonds).

From a climate and development perspective, Roozkin is significant, due to growing evidence of climatic change at the regional level (Aboubakri et al., 2020; Eskandari Damaneh et al., 2019; Khanjani & Bahrampour, 2013; Mesbahzadeh et al., 2019). Recent data gathered from the nearest synoptic automatic weather station to the study area (Miandeh Jiroft Station: 57°′″ 24′ 00″N, 28° 35′ 00″E, Altitude: 639 m) show decreasing levels of precipitation during the years 2006–2020, with rainfall in the last four years less than the 3-year moving average of the region, as shown in Figure 2. As Figure 3 also shows, there is also an increasing temperature trend in this region during the same period. Accordingly, the reduction of water resources due to reduced rainfall inflows and increased evaporation of surface water is indicative of climate-induced water stress. How to manage ever-scarcer water resources requires hydro-social management – linking changes in resource availability with stakeholder knowledge and experience in handling changes in environmental conditions over time. Local initiatives involving traditional methods of water scarcity-adaptive measures are a strategic research and planning priority for the Iranian Government, and key lessons from local Iranian experience are relevant to other semi-arid and arid environments (Balali et al., 2009; Khalkheili & Zamani, 2009; Mesgaran & Azadi, 2018).

4. Methodology

The empirical research employed ethnographic research methods familiar to this type of indigenous knowledge study (Sillitoe, 1998); through participant observation over a 25-day period and in-depth interviews with local participants ($n = 32$). Researchers used field surveys involving direct observation and participation to outline the culture, lifestyle and organization of social groups (Gupta & Ferguson, 1997; Iphofen, 2013; Reeves et al., 2013). Observation methods allow an understanding of the spatial and temporal context of indigenous knowledge to sustainable water management, and the semi-structured interviews with Roozkin villagers were employed to harness individual perspectives on water management practice. Participants were selected to create a nominally stratified sample across the social roles of villagers. All interviews were face-to-face, as appropriate to social research situations where literacy proves a barrier to community participation (Phellas et al., 2011); and utterances were translated into English. Field guides and interview protocols were designed to explore the practices and reflections of participants on water resource sources, practices, beliefs and cultures and hence to derive an understanding of indigenous knowledge cultures and practices. Qualitative and observational data

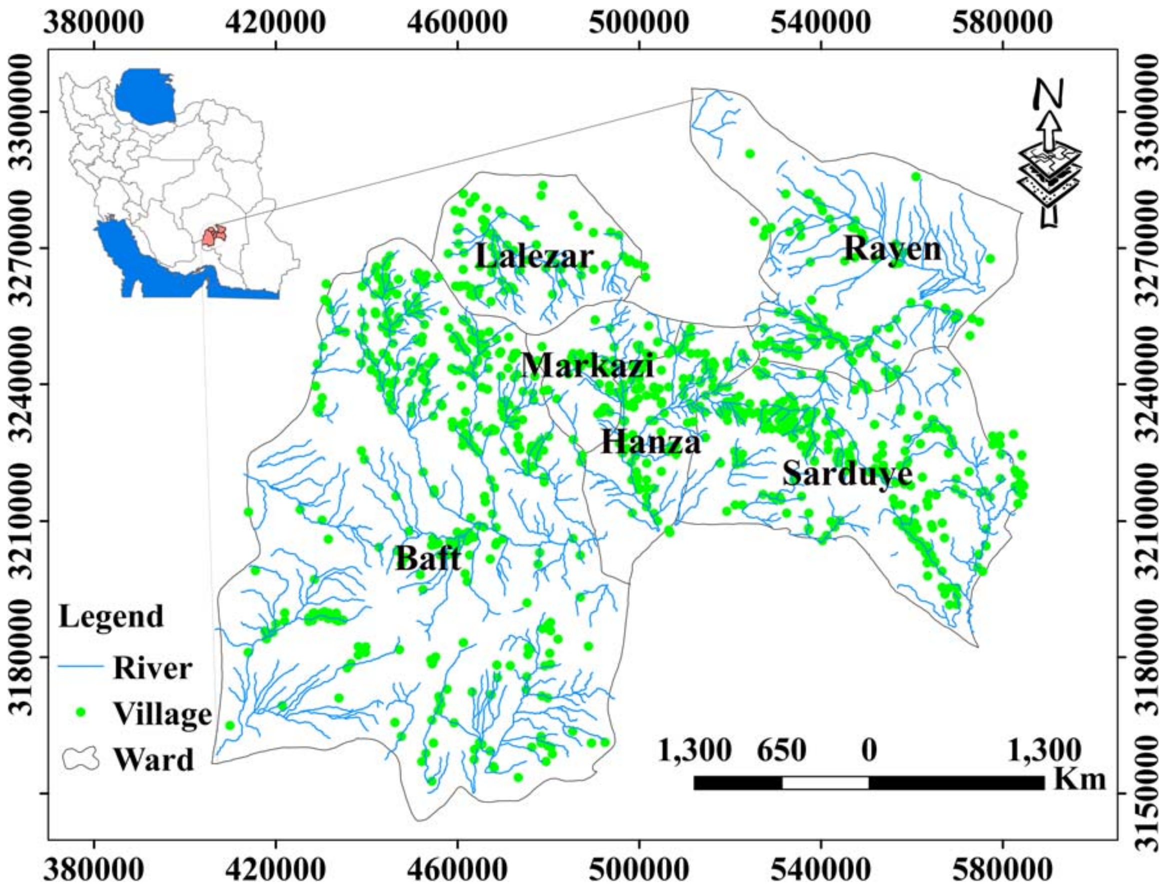

Figure 1. Geographical location of case study.

were subject to a narrative analysis (Mitchell & Egudo, 2003) – a social constructionist approach that emphasizes the stories that participants create and communicate. The analysis involves inquiry into how individuals represent themselves, their social status and collective knowledge, how this reflects upon their own identity and how this is constructed within and amongst the community network. The results are then validated by sharing the analysis with the participants themselves to check for consistency between participant expression in the interviews and the reported findings.

5. Findings

5.1. Social organization of agricultural production and beneficiaries' relationship pattern

The purpose of this section is to reveal the social structure within the agricultural community and identify the pattern of relationships between them. Roozkin has a unique social-organizational structure based upon villagers' respective social roles. Figure 4 shows the basic social structure of the 'Arbab-Raayat' hierarchy of this village, illustrating the different social

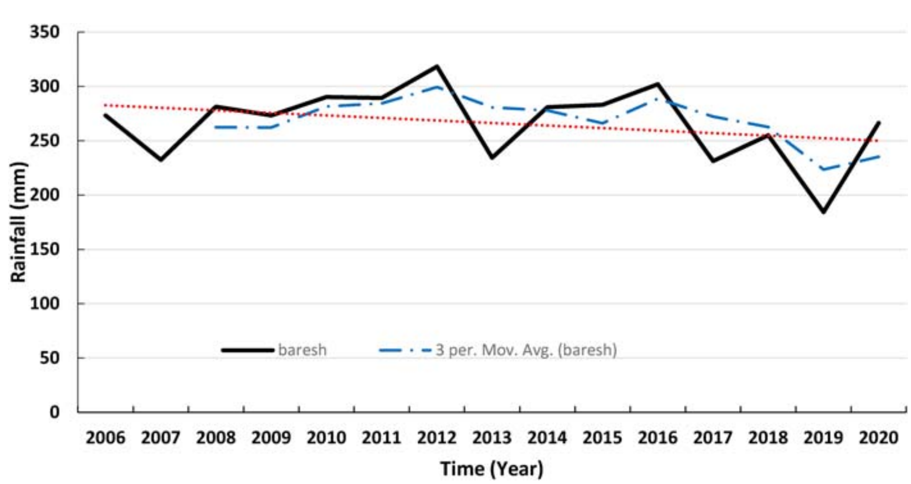

Figure 2. The precipitation in the study area in the period 2006 to 2020.

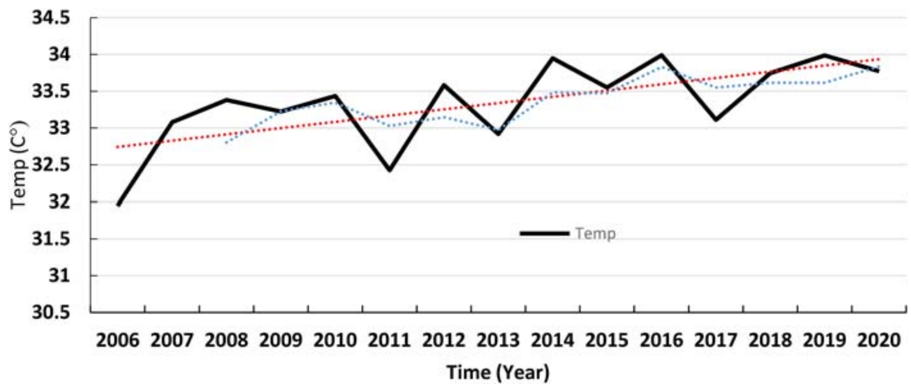

Figure 3. The temprature in the study area in the period 2006 to 2020.

roles from the top-down i.e. 'Khan',[3] 'Mobasher',[4] 'Kadkhoda',[5] 'Arbab',[6] and 'Zaeim'.[7] After Iranian land reform in 1964 this system continued in Sarduyeh with some modification. In the recent framework, 'Khan' and 'Mobasher' disappeared (the white section in Figure 4). In this framework, the Kadkhoda is, as one participant articulated:

> A person who has more agricultural land than other people in the village and this is usually hereditary.

Based on interviews with respondents, it was found that the Kadkhoda is responsible for supervising certain tasks such as the qanats, streams, pool dredging, and resolving the struggles between Arbabs and Zaeims that are lower down the social hierarchy. It is noted that the social position of the Kadkhoda didn't disappear following national land reform but the strength of his (an exclusively male role) ties with lower ranks diminished. Regarding the repetition of the Arbab's name among the discourses of the respondents, we asked them to define the Arbab for us, almost all respondents provided a definition as follows:

> Arbab was a person who possessed some farm-lands and gardens in one or more villages. They settled in Sarduyeh during summer and in Jiroft plain in winter.

The Arbab's social role is thus seasonally affected, as out-migration from the community during the winter months is reflective of the need to diversify income livelihood strategy in line with growing seasons, given their relatively lower social and land-owning status within the hierarchy.

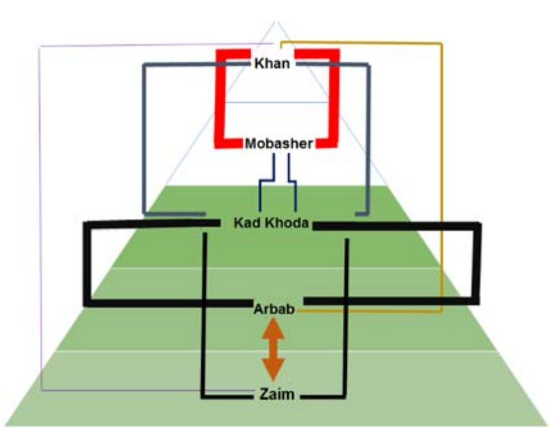

Figure 4. The relationship between social roles in Arbab-Raayat hierarchy in Roozkin village.

The Zaeim is referred to as a person who is more active than the Arbab in the village and has kinship ties with others in his own group. Generally, the eldest son was the Zaeim of his family. The Zaeim was nominated by other villagers (usually brothers and sisters in a family) for irrigation, picking fruit, pruning, fertilizing, and other agricultural operations of Sarduyeh municipality in exchange for a wage (defined as a cut of total production). Regarding his remuneration, one of the respondents stated that:

> The amount of product to be given to this person was defined by local customs and mutual consent. It usually amounts to one third of harvested products.

Families attempted to employ reliable, compassionate relatives for this job. Usually the nominated individual would have a low income. Bearing in mind the above-mentioned criteria, each family can choose its Zaeim from other groups. It is notable that group classifications are not permanent, rather the contract between Zaeim and Arbab is extended or repealed on an annual basis – thus social consent to maintaining the system of resource sharing rules is important to the process of maintaining social status and remuneration from agricultural resources.

Traditionally, residents paid due attention to water resource management and devised a permanent division for it, in which the share apportioned to government, bureaucracies, and local people was precisely specified. In Iran the government is responsible for water management and sale of irrigation water to citizens within a systematic regional water management plan. Therefore, it is this external allocation of water that is redistributed amongst the community, and interactions between Roozkin and surrounding villages take place within this broader national-scale institutional framework.

5.2. Division of water resources by land ownership

The distribution systems for water among farmers are deeply significant to the structures of social organization. The water circulation is measured temporally. In the Roozkin village water sharing and circulation is based upon a 12-day cycle, and within this, the water rights of farmers differ on the basis of their respective land share. This system of time-limited water circulation is locally known as *Demn*. Water circulation between the end and beginning of the next 12-day period is also called *Demn*. Regarding the timing of *Demn*, one respondent stated:

> In each year, Demn starts on 5th May for water. Farmers in many villages store aqueducts' water inside the pool.

The Roozkin's lands are divided into six *Dang* formed on a base unit of *Habe* (the 6 Dang in the village are formed from 96 Habe). The Habe is the main division unit of the property and hence equates also to apportioned water in the village. The Habe is equal to 3 h of water usage and it is stable across a daily time scale, i.e. every 24 h of the day, it consists of 8 Habe and the allocated time is related to that Habe regardless of the time of day. If there is only one owner of all 6 Dang in a village, then all water will go to him. However, if there are multiple owners, then according to Habe (the property ownership) the water rights will be apportioned into smaller Dang. This is based upon the principle that each 1 Dang consists of 16 Habe of village property and equates to 48 h water use.

In Roozkin village each half of Dang consists of 8 Habe and 24 h' water use is calculated. Each 4 *Habe* is called *Tapsouch*, equating to 12 h. The next smaller unit after *Tapsouch* is *Qiah* that is ¼ *Habe* and water division is done in this way too. The smallest unit of water division and also land division is called *Shahi*, in this way the agricultural division unit is in its smallest number that each 3 *Shahi* is ¼ *Habe* or *Qiah*, 1 *Shahi* is 7 min and in the local dialect this is called '*Dahan-tar-kon*'.

5.3. Water orbit and sharing mechanisms for dredging streams and pools

The mechanism of water division across the social hierarchy is not only linked to social status and land ownership but also to shared labour practices. The type of agricultural product grown, and the need for dredging of streams and pools are particularly important in defining the water orbit, i.e. frequency of irrigation.

In describing the water orbit of different products one respondent stated:

> Irrigation of various agricultural crops (for example: Wheat, Barley, Lentil, Chickpea and so on) starts prior to April, but different fruit gardens' irrigation is done at different times. For example, apricot, cherry, pear, and apple garden irrigation starts in early May and it is repeated every six days.

Since early May, Qanats are replete with water and trees don't need much water, and so systematic irrigation is not applied. As the season progresses and stored water is depleted, the water division system is put into practice. Since mid-May, the *Demn* system is implemented for water resource management and farmers store Qanat's water inside the pool. In response to the question of how pools are designed in the countryside, one respondent stated:

> Farmers in this area, due to the lack of rainfall and in accordance with the available materials in the area, have designed pools that can collect water from the aqueducts within to irrigate the fruit gardens and other products.

The period of time that water is stored inside the pool is specified by the Arbab's *Habe*. For example, if a farmer owns one *Tapsouch*, it means he can store water in his pool only for 12 h in a 12-day cycle (*Demn*). Prior to *Demn* system implementation, farmers dredge waterways and pools at the lower side of the Qanat so as to reduce water waste on the way from the pool to the farm.

We argue that the common pool resource sharing mechanism is institutionalized between farmers for this process. This mechanism obliges each owner to participate in a dredging process proportionate to his share of farm-land and *Habe*. Initially, the whole-pool length is divided based on *Sten* – the length of a spade-handle equal to 1.5 m (needless to say, pool volume varies based on qanat's water flow rate). Then, the number of *Sten* is divided within 6 *Dangs* or 96 *Habe*. If a pool is 6 *Sten* long, each Arbab of 1 *Dang* is then obliged to dredge 1 *Sten*. Since pools are wider at the point ending to the Qanat's outlet, final *Stens* are dredged collectively. The volume specified for each person to be dredged is termed *Gerve*. *Gerving* time is usually done before *Demn* is specified. If one violates *Gerve* rules, the punishment is to then subsequently be deprived of water. This happens rarely, in part because the risk of rule-breaking means total exclusion from the water resource. This proportional punitive system incentivizes all villagers to commit to maintaining and obeying local water management customs.

5.4. Indigenous knowledge and participatory water management

The systems of hierarchical social organization, indigenous knowledge in storage, dredging, irrigation and agricultural labour division collectively form a participatory, hydro-social water management system. Within this are questions of fair access to water, and corresponding water rights. In practice, fair access is based upon local engineering solutions to water distribution. In particular, earthen ponds are traditional structures constructed for dividing water so as to guarantee fair water access rights. They are built at the lower side of the Qanat and are based on its water flow rate. Traditionally, they were constructed out of clay but are now more commonly made of stone and cement. The structure enables Qanat water management when there is low or high rainfall. The pool is usually overlooking farm-lands so that water can flow toward and cover them. The pool's height differs based upon the Qanat's water flow rate, though this will usually not exceed 1.5 m and its thickness must enable 24-hour water storage without being degraded or destroyed by the water flow. The outlet is made from locally cut durable mountain stone called *Mazo* in the local dialect.[8] The usually green stone is exfoliated, and a hole is made at the middle of the stone. The size of the hole depends on the qanat's water flow rate and the volume of the pool. *Mazo* which is situated at the pool's outlet is plugged with a wooden stick and some pieces of cloth at *Demn* time. Some soil is also poured over it so that water will not leak through the hole. The wooden stick is called *Lapoo* by local people. As the *Lapoo* is pulled out, the poured soil is easily washed away under water pressure from the pool. If soft soil is not used, the *Mazo* hole may be clogged and the farmer will not be able to utilize the pool's water at an appropriate time. Every year that *Gerozani* (a local term meaning 'dredging') is done, its extra load will be left on the walls to fortify them and increase their height. At the pool's centre, over the Mazo stone, a type of runway is devised. When the pool is full, extra water will overflow from this runway in order to reduce pressure on the pool's wall. The design of this structure is both a local engineering initiative for safe water storage and distribution, but also a mechanism to control fair access under conditions of water resource variability.

5.5. Local customs and water management

Of particular relevance within an indigenous knowledge-based system of water management are the local customs that shape social practices. In response to the question of how the *Gerozani* (dredging) is monitored, one of the respondents stated:

> During Gerozani of streams and pools, the Kadkhoda supervises the process of dredging. He must confirm that it was done correctly. If he discerns that dredging was not done correctly, villagers are obliged to repeat the process. If villagers are not able to do so, the Kadkhoda will recruit some workers from other villages and pay their wage according to local customs.

Similarly, another participant stated that:

> The streams are divided according to the amount of people's lands and everyone is responsible for cleaning up their own parts before starting the irrigation. They believed that the stream should be clean like a Palm (human hand) otherwise water is wasted.

The dredging of village Qanats is performed annually. Without maintenance the Qanat roof may collapse in winter due to snowfall and then the water flow will be blocked. If there is a well-digger in the village, he will undertake maintenance. Villagers call this well-digger *Kahkin*. The *Kadkhoda* collects payments from all *Arbabs* to pay the *Kahkin's* wage. Each *Arbab* pays a specific amount proportionate to his properties. It is customary to pay the *Kahkin's* wage once the qanats' dredging ends. If there is no *Kahkin* in the village, he will be borrowed from other villages and he will earn his wage upon completion of the task. The *Kahkin* works under the supervision of *Arbabs* and is obliged to dredge all qanats and carry away debris so that once more it doesn't destroy or block the pool and qanat. If torrent floods threaten the qanat, a detouring blockage will be made by use of local instruments such as wood and *jaz* (a local term denoting dense and round plants such as Astragalus, Artemisia, etc.) and the *Kahkin* is in charge of pouring extra loam on the *jaz* to ameliorate flood risk. This extra loam extracted from the Qanat, along with wood and *jaz*, act as a firm blockage which protects the Qanats and pools against being washed away.

Another local custom is the banning of tree-planting around the Qanat channel. Farmers believe that plant roots will penetrate to the underground water table and subsequently deviate the Qanat's water flow and augment the annual dredging process. As one participant stated:

> If someone wants to use the water in the Qanats' channel and plant trees near it, Kadkhoda will stop him, because this will destroy the channel and also if there is a need to change the size of the channel due to the increase in the diameter of the Qanat, it will not be possible.

However, around the Qanat's outlet i.e. several metres away, short or shallow rooted trees such as thorny olive and poplar are permitted to be planted. If the Qanat's channels are arranged so that the mother well is located in one village, but its outlet is in other village, those who live in the village hosting the mother well are not allowed to plant any trees within its boundaries. If dispute over this issue arises between two villages, the *Kadkhoda* specifies a 70m distance limit around the Qanat's channel. Hence, if a farmer's land is situated within this limit, he will be only allowed to plant agricultural crops, not trees, and will be denied permission to dig a well or Qanat there.

In villages where there is either one river with various tributaries, a river that passes through several villages, a water resource that is supplied by snow-melt, or originates from different springs in different villages, then a special customary system is formed in this area for water consumption. In this system, a detouring pass from the river goes to the gardens. This detouring pass is locally called *Bon Au Doun* (made of wood) as one respondent stated:

> Using stone and concrete for construction is prohibited because it will rob downside villages from their water right due to the impenetrability of concrete structures.

The water flowing in this bypass must be 'more than a brook'. The size of the *Bon Au Doun* differs based upon its distance from the source. *Bon Au Doun* located between the near villages *Khafku* and *Khardun* must be designed to divide water equally. However, the *Bon Au Doun* of *Bagh Hanti* village, which is located further from downside villages, can potentially deviate total river water. This is because consumed water in upside villages is drained and returns to the riverbed. So, villages near to the river enjoy more water access rights than downside ones. However, because the applied structure for detouring water is wooden (and hence porous), some water always remains within the river. Therefore, the water rights of other villages will be observed. If concrete material is used in constructing the *Bon Au Doun*, then this creates social tension between villages. Each village is can set just one *Bon Au Doun*. *Arbabs*, who have livestock, have to send their cattle to the pasture and are not allowed to use the pool or qanat's outlet water. That's because herds enter the pool and destroy the Qanat's outlet. If this happens, the *Arbab* will have to pay more in dredging costs.

IK-based agricultural management also incorporates local customs for fruit-picking. During walnut harvesting, owners of smaller lands can't begin harvesting sooner than the optimal season because, *Pak-chins*[9] will encroach onto bigger gardens. The harvest also can't start at different times in different parts of the village. This is done so that group security of all gardens can be guaranteed.[10] This action is 'bottom-up' in the sense that help is coordinated by the farmers themselves rather than a centralized authority. However, cooperation is socially mandatory, and ecological knowledge plays an important role in the picking of fruit. This IK of harvesting helps the community to identify socially optimal harvest times. Locals believe when the green shell of walnut is cracked, it is its harvest time and it will easily come off the branch. If its shell is not cracked and it is not picked up in time, its kernel will turn black. Community members, therefore, share labour time to break the walnuts and remove the kernels due to the perceived time-sensitive nature of the harvesting process.

Another common custom in the villages of Sarduyeh municipality is cooperation during planting and harvesting agricultural crops (including wheat). Notably, villagers are quick to help one another during harvest time. If an *Arbab's* garden fruits ripen early, he asks other villagers for help and one person from each family obliges. In turn, the *Arbab* is also committed to help them harvesting their products. This action could be described as *bilateral compensatory mutual assistance* – a type of cooperation through collective action that increases compliance with common pool resource management, collaboration and social altruism within the village to maintain a stock of social capital amongst the agricultural workers under conditions of uncertain harvesting. We see, therefore, that the customs around both engineered structures and their materials, land and water ownership, river-based irrigation measures, grazing herd and management practices, and labour-division during harvest collectively constitute a holistic IK-based water and agricultural management system that maintains the sustainability of the resource within the whole watershed basin.

5.6. Cultural beliefs amongst Roozkin village farmers

Close contact with ecological systems has inscribed specific beliefs and attitudes within the social practices of the villages within this region. Some specific features can be summarized as follows. For example, people in the area commonly believe that cutting a green tree is the same as the killing of a child. This is rooted in the religious beliefs of the people of the region to the extent that planting a tree is, in essence, a form of worship. The tree is symbolic of life, the seasonal-biological changes such as budding and fruiting act as social markers for times of the year, and for different social customs. In the very first year that fruits are picked, they are not sold but donated to the poor or to those who have no fruit trees of their own. Within local custom this is believed to enhance future crop yields and to protect their trees against harm. In late summer, as walnut and other fruits are harvested, each farmer bestows some fruit to those who come over to their garden. Roozkin gardeners leave some fruit on the trees as so-called *Pak-chins* which will incur God's blessing. When there is drought, people gather together and get to say a 'Rain Prayer'. They will also slaughter sheep in religious sacrifice so that God will enrich their future harvest and raise the qanats' water. As one respondent explained:

> In order to increase the flow of qanats and increase in products and for God's sake we should slaughter a sheep.

All *Arbabs* attend this type of thanksgiving ceremony at the end of autumn once the harvest is collected. Also, one landowner stated:

> The cloud which comes from the Qibla[11] side is believed to be a rain cloud and will bring us merciful rain.

This belief has its antecedents in Iran's complex atmospheric geography. Iran is located within an arid belt, but close to tropical ocean systems. The patterns of the rainwater systems originating from the Indian Ocean and the Persian Gulf are vital to the region. Summer rainfall is very effective in boosting agriculture and re-supplying water behind dams, and its containment can evolve in the pattern of cultivation and livelihood of the residents of the region. As in many indigenous cultures, worship practices and offerings are designed to stimulate a perceived supernatural influence over unpredictable climatic systems. The villagers' wellbeing and economic prosperity is deeply intertwined with the amount of water available for agriculture within the arid region, so social practices of water management are geared towards trying to maximize the total stock of available water through worship and sacrifice. Such actions are designed to minimize the structural vulnerability that villagers face in relation to arid conditions, unpredictable weather systems and the inherent threat of long-term climatic variability affecting the region.

6. Discussion

This study examines local-based initiatives and indigenous knowledge of water resource management in the Jiroft County. Local traditions play a key role in the management of irrigation, water storage, and sustainable agriculture in the region. Local people, despite their ongoing economic marginalization under conditions of environmental stress from growing drought conditions, have rich social capacities to achieve sustainable management of local and regional water resources, which in turn, strengthen their adaptive capacity in the face of water scarcity. Emphasizing the complexity of social structures within the settlements of the region and resilience to other climate-related disasters such as floods, the inhabitants have long been securing and protecting local water management and sharing initiatives whilst still respecting and accepting culturally defined, water-related traditions, ownership models and hierarchies amongst the local people.

Inhabitants of the Jiroft County region collectively focus upon the importance of harmony between human economic and social capital – commonly termed *ecosystem services*. By creating local traditions in the conservation of water resources such as reduced well drilling at certain intervals from the boundaries of the Qanats, and the unique laws of lower river delineation (for example using water based on each *Habe*), they have been able to split the water supply system through small-scale units like *Shahi* and *Ghayah* with local people. In spite of recent population growth, water resources remain well managed as a common pool resource because water access rights remain fairly divided between properties, and between villages. We can therefore interpret this system of indigenous water management as an adapted spontaneous common-pool resource management framework (Ostrom, 1990). That is, that the water management systems differentiate rules between stock capital of stored water in pools and flow capital of the Qanat. This shows similarity to other indigenous knowledge-based water management systems, such as those in cases in Eritrea (Mehari et al., 2005), Australia (Keremane et al., 2006), or Ecuador (Adolina, 2012), that use geographically distributed and hierarchically defined systems of rules for water ownership based upon proximity to upstream and downstream river use. The systems in place in Roozkin have clearly defined boundaries, governed hierarchically based upon a culturally embedded system of land ownership that is used to separate water rights according to quantity and time of access to the water resource. By having a system of culturally ascribed rights in place, collective payments for maintenance operations (such as well digging or dredging) there is congruence between the water appropriation and provision rules based upon local conditions and ownership structures. The hierarchical system provides effective monitoring of the total water stock (and accountability between water appropriators and those that monitor water usage) and sanctions for those that do not respect the rules (i.e. exclusion of access to the resource).

Indigenous knowledge of the division and management of water as a precious resource in different parts of the world has considerable value for adapting centralized, top-down systems of water management under conditions of climate stress. People in the studied region have mechanisms and social capacities for collecting, managing and storing rural water resources. It is notable that villages such as Roozkin perform effective water management at considerably lower cost than the large centrally planned initiatives common to other parts of the country, and to other countries that prioritize grey-infrastructure systems. The reasons for this are twofold. First, Roozkin relies upon a hierarchically defined water ownership model that links together levels of social management responsibility with defined water orbit – such that those with greater levels of power and responsibility within the social hierarchy have greater access and thus greater economic benefit. However, those with the greatest share are also responsible for managing the resource governance structure: resolving conflicts within the village and ensuring rule-adherence so that the common pool resource is maintained. Second, the village adopts codified norms of social cooperation, social capital resource-sharing, and environmentally flexible practices that are profit-generating to the point that surpluses of agricultural goods are used to finance the poorest famers within the village. Moreover, the poorest and those just on the margin of profit are often exempted from paying contributions for water management projects. For example, when the qanat is dredged, the majority of *Zaeims* of the region are often chosen from the lowest-income people in order to help them to become financially self-sufficient. In terms of climate adaptation planning, the sharing of both the financial and common pool resource risks across these social hierarchies improves the social resilience of the affected community because systems of water-sharing and labour-division become increasingly egalitarian under conditions of growing resource scarcity.

The water management system has potentially negative socio-cultural impacts such as the development of socially homogeneous groups and the maintenance of a familial elite. With broader changes in land use policy and planning in Iran and the loss of traditional livelihoods in regions like Jiroft, intra-group stakeholder conflicts are a constant risk, and this is exacerbated by the entrance of new technology implemented from 'outside' e.g. government involvement in centralized water distribution control, modern irrigation and grey infrastructure drainage networks. By analysing the social organization that emerged from *Demn* irrigation system, it can be concluded that indigenous knowledge has led to continued social survival under difficult environmental conditions through the collective action and involvement of local people as water management stakeholders in problem resolution. The people of these areas have been able to make sustainable livelihoods for centuries using techniques and constructs such as *Lapoo*, *Mazo*, *Qanat* and the water pool; we argue therefore that the *political* threat of centralized water management is significant – it reduces the community's capacity to negotiate internally to manage their scarce resource effectively – and this is a greater threat to the sustainability of their livelihoods than just climate-related water scarcity alone.

7. Conclusions

Our findings support the argument that a hydro-social paradigmatic shift towards adaptive water resource planning is beneficial in terms of socio-environmental development and cost efficiency when compared to newer 'hard infrastructure' solutions that favour centralized, grey infrastructure, policy-driven and technocratic water management mechanisms (Jalal Mirnezami et al., 2018; Nabavi, 2018). In fact, the concepts of ownership experience, cost recovery, enforcement, equity, integrity, and unity, which are highly pronounced in centralized systems, can also be found in the traditional water management of the studied region. Based upon our observational and interview findings, the issue of ownership is one of the main factors that influences success or failure of such schemes. Sense of ownership is a challenge for centralized water management systems. Often the users are not integrated to protect and run their own water supply system. Nevertheless, when it comes to centralized water management, it quickly becomes incompatible with local customs and practices – communities become passive observers or consumers, rather than active stakeholders, thus breaking the hydro-social cycle. Centralized systems are often subject to ineffective operation and maintenance; poor community representation and motivation, and user communities feel that water service production and maintenance become dependent upon external agents. Traditional water resource management, by contrast, has the capacity to establish shared sense of ownership, equitable distribution, consistent system operation and maintenance and cost recovery. The communities are already involved in the implementation and maintenance of their systems by providing cattle, contributing labour, and other possible options in the area. Therefore, users have common-but-differentiated responsibilities dependent upon their proportionate water consumption.

Developing countries such as Iran have populations with diverse religious, cultural, social class and educational background. Despite their heterogeneity and high population, external agents that assist in development are few compared with the number of service seekers. However, communities have their own traditional administrative systems where members respect and protect their communal resources. Typically, people are loyal to their own customary laws, and therefore, are commonly distrustful of externally applied governance systems. Bringing a community from traditional to centralized systems of management is therefore costly and difficult (Cleaver, 2017), as it takes considerable time, finance and social license-building amongst community groups and external organizations. This is fundamentally an ineffective solution to chronic water supply problems under conditions of climate change that require urgent remedial action to ensure long-term resource sustainability. Therefore, working with, rather than against indigenous knowledge and traditional social hierarchies is necessary to create adaptive water management systems that will facilitate service-coverage in rural development.

Though true on the village-scale, many urgent water management challenges cannot be met by existing traditional systems alone – scaling up the water management practices of local initiatives to larger regions, involving industrial (e.g. petrochemical) and agribusiness sectors require innovation in irrigation technology and water management under increasingly arid conditions. However, we argue that it behoves policy-makers to better identify and integrate traditional science and knowledge with modern irrigation and water distribution technology. Efforts to build collaborative partnerships are necessary but not sufficient conditions and may be forestalled if governments fail to acknowledge the claims of Indigenous Peoples to have a meaningful say in water management. In this respect, Ross et al. (2016) and McGregor (2014) argue that a lack of recognition of indigenous knowledge is one of the obstacles to the participation of local people in NRM. Berkes (2012) also contends that the prioritization of techno-centric approaches may result in the rejection of IK by water managers. Local knowledge is often considered by government agents to be superstitious, irrelevant or simply a hindrance to the goal of modernizing resource management policy. Moreover, urban government officials often have no, or very limited, understanding about local rules and customs within rural communities. They therefore often assume that local knowledge is, at best, outdated. We would argue, based on the research presented here, that the lack of formal recognition of the value of IK is both detrimental to the ecosystem services of water-scarce regions and to the rights and procedural justice afforded to Indigenous People.

Indigenous Peoples commonly recognize a need to gain technical knowledge and thus contribute to water management led by techno-centric authorities, but they also want to see two-way knowledge-sharing, where water management authorities also learn about local traditions (Stevenson, 2006). This runs counter to common science communication practice which posit *knowledge-sharing* as one-way *knowledge-transfer* from techno-scientific authorities to local 'lay' actors. As a vehicle for bringing parties together, sharing knowledge, building understanding towards convergence of goals and enabling deliberation in the co-management of water (Collins & Ison, 2010), *agreement-making* appears to be a mechanism that local peoples trust and from which positive outcomes can emerge; for example new norms of water use and decision-making criteria. Thus, a two-way knowledge exchange and partnership working between local people and techno-scientific authorities can be implemented through formal mechanisms of water regulation and management. By offering a structure for focusing on the procedural rules that allow meaningful deliberation to take place (Schmidt, 2014), such agreements should offer parties at all levels of the water management sector – policy, administrative, research, management and practitioners – the opportunity to negotiate a socially legitimate and environmentally sustainable solution. By learning from the experiences of combined top-down and collective action for water sharing at the local scale, a broader collective agreement could serve as a framework for ensuring the inclusion of Indigenous People.

Finally, although we recognize that there is no one-size-fits-all solution to the incorporation of IK in water management, we argue that broader adoption of elements of the Jiroft county model could help to structure good water management and environmental sustainability through effective common pool resource management. The beneficial elements are as follows. Firstly, no individual can take more than their fair share of water, through twin processes. The first is 'top-down' based upon institutional norms of social obedience to a hierarchical system of water management, and the second is 'bottom-up': through collective action to ensure economic self-sufficiency and profitability through self-organized labour division between farmers. The IK around water management practices also furthers social sustainability aims by reducing conflict risks that would emerge under common pool resource depletion under conditions of scarcity. As water resources become less predictable under land use and climate change conditions over time (Berkes & Turner, 2006), the social systems of water management through IK in this case, provide greater resilience and reduce the risk of social shocks from resource depletion (both within and between villages) (Shava et al., 2010) when compared to remote, centralized systems of water control based upon grey infrastructure, private enterprise and utility regulation. In essence, the establishment of water ownership through twin hierarchies of water orbit and management responsibility, a system of established social norms to rule adherence, and *bilateral compensatory mutual assistance* through surplus labour and agricultural stock sharing, provide a management system that would improve the adaptive capacity of small rural agricultural communities across arid regions of the world.

Notes

1. Indigenous institutions are 'those institutions that have emerged in a particular situation or that are practiced or constituted by people who have had a degree continuity of living in, and using resource of an area' (Aggarwal, 2008; Shisanya, 2017).
2. Whereby a qanat is a type of underground aqueduct – a gently sloping underground channel to transport water from a well or aquifer to the surface that brings water from a deep well with a series of vertical access shafts.
3. Khan, (nickname), means 'boss'.
4. Mobasher, (nickname), means 'authorized people'.
5. Kadkhoda, (nickname), means the 'leader' or 'head' of a village.
6. Arbab, (nickname), means 'master' and 'landlord'.
7. Zaeim, (nickname), means 'labor'.
8. Photographs of the water pool, Mazo stone and Lapoo are shown in online supplementary material 1.
9. Roozkin gardeners leave some fruit on the trees so that so-called Pak-chins can somehow enjoy God's blessing.
10. Photos of the village gardens can be found in online supplementary material 1.

11. The Qibla, also transliterated as Qiblah, Kiblah, Kıble or Kibla, is the direction that should be faced when a Muslim prays during Salah. It is fixed as the direction of the Kaaba in Mecca.

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