ARTICLE IN PRESS

Journal of Arid Environments xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Transforming tradition: The *aflaj* and changing role of traditional knowledge systems for collective water management

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ARTICLE INFO

Keywords:
Collective action
Subterranean tunnel-wells
Qanat
Traditional knowledge
Hydraulic heritage

ABSTRACT

Living in a harsh, desert climate, Omani rural communities have developed locally-appropriate knowledge to deal with water scarcity. Similar to the *qanat*, the *aflaj* taps into the natural water table and uses a gravity system to channel water through underground channels to villages. Traditional techniques of water management, such as the *aflaj*, represents a way of adapting to and coping with difficult climates which have persisted for millennia. However, knowledge systems have often ‘decayed’ with the onset of modernity. These management systems, which developed concurrently with early Omani date palm cultivation, have defined customary and hereditary water rights which are in decline. This article uses Ostrom's Common Pool Resource (CPR) framework, which prioritises the collective management of shared resources to maximise the benefit for all involved and avoid diminishing benefits that are created by the pursuit of individual goals. Using this framework, this article's evaluation of the literature found that traditional *aflaj* management systems have a great capacity to evolve and, therefore, the *aflaj* represents both a dying system, and a potential for climate adaptation. Historically, *aflaj* have been managed by ancient water users associations, which provide social controls and govern usage norms. The findings of this review are that the *aflaj* system's ability to respond to pressures of modernity from competing institutions, including markets, and embedded social capital mechanisms will influence its capacity to mitigate uncertain hydrology and climate. This article suggests ways in which the management of the *aflaj* can adapt to a multiple institutional framework to ‘transform’ collective water management.

1. Introduction

The *aflaj* subterranean tunnel-well system is the most common form of water management in Oman (Dutton, 1989; Zekri and Al-Marshudi, 2008). With precipitation rates of less that 100 mm per annum and a desert cover of 80% (FAO, 2008), the adaptability to harsh climatic conditions has been central to Omani communities' survival (Häser et al., 2010). The *aflaj,* fed by mostly alluvial aquifers, represents one of these adaptations. Oman has several important aquifers which are the alluvial aquifers, the regional Quaternary aquifers, the aquifers of the Hadramawt Group and the Fars Group (FAO Aquastat, 2008). Groundwater is most abundant in the North and South of Oman where the water is most frequently recharged (FAO Aquastat, 2008). However, the changing precipitation rates, and increasing risk of drought means that several previously renewable groundwater sources are now slow to recharge (FAO Aquastat, 2008). As shown in Table 1, there is currently a deficit in the groundwater balance. However, depletion of groundwater varies regionally and therefore some areas may have a greater deficit than others.

This groundwater deficit compounds increasing desertification rates in a country which is already largely desert (Al-Hashmi, 2013). There are predictions that, despite Oman's reliance on subterranean water sources, groundwater will be increasingly saline with predicted increases in temperature, and greater land degradation for the entire Gulf Cooperation Council (GCC) area (Elasha, 2010).

Oman is divided into five regions which are Al Dakhiliyah, Al Batinah, Al Wusta, Ash Sharqiyah and Al Dhahirah, classified as either hyper-arid or arid (Al-Hashmi, 2013). Oman's geography has11 physiographic regions which can be divided into plains, wadis and mountains (Al-Hashmi, 2013). As shown in Table 2, the *aflaj* prevalence differs regionally (the term *aflaj* is plural; the singular is *falaj*). Like the *qanat* system, the *daudi aflaj* system (i.e. *aflaj* with underground channels and ventilation shafts) has existed in some form in Oman since the pre-Islamic era (Lightfoot, 1996; Remini et al., 2014).

This paper uses Ostrom's Common Pool Resource (CPR) framework to analyse the extent to which the institutions governing the *daudi aflaj* can adapt to modernisation. The paper does this by considering the potential of the Ostrom's collective action theory to revitalise the

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http://dx.doi.org/10.1016/j.jaridenv.2017.10.003
Received 7 March 2016; Received in revised form 3 October 2017; Accepted 9 October 2017
0140-1963/ © 2017 Published by Elsevier Ltd.

Please cite this article as: Remmington, G., Journal of Arid Environments (2017), http://dx.doi.org/10.1016/j.jaridenv.2017.10.003

Table 1
Groundwater balance in Oman (MCM/yr source: FAO, 2008).

Rainfall	Groundwater Recharge	Agricultural Use	Domestic and Industrial Use	Total Use	Deficit
9481	1267	1487	158	1645	−378

declining system. Using Ostrom (1990: 30) seminal definition, a CPR is defined as 'a natural or man-made resource system that is significantly large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use'. For example, an aquifer is of such a size that it is very difficult to prevent another person from extracting groundwater for their use – or even over-abstracting this resource. The difficulty of this system is that it becomes hard to manage individual consumption of a resource even when it is to the detriment of other users (for example, through individual tubewells depleting aquifer levels). In the case of the *aflaj*, the CPR is the aquifers which the system uses to produce water.

Within this framework, collective action promotes the sustainable management of the CPR through the organisation of individuals and institutions to manage the resource within a system of norms and social behaviour which govern its use (Ostrom, 1990). With the historical development of the *aflaj*, methods of management, which included 'codes of social behaviour' evolved around the system (Sutton, 1984; Adeel, 2008). This article explores how these codes of behaviour are embedded within traditional knowledge systems which have governed community management of water in Oman. The article further explores how traditional knowledge has further codified systems of equitable and sustainable use in the form of land rights (Buerkert and Schlecht, 2010).

The research question that this article sets out to answer is: how can the collective action framework lead to improved management of the *aflaj* in modernity? The paper aims to use Ostrom's collective action framework to examine where traditional knowledge systems can adapt to promote sustainable water management and reinstate the *aflaj* in Oman by promoting collective action, and identifying the difficulties in current *aflaj* management which limit the ability of the management system to adapt.

2. Background

2.1. The origins, diffusion and variants of the qanat

The origin of the Omani *daudi aflaj* is from the Persian system of *qanats* which likely originated in Iran, although the provenance is not fully agreed upon (Fattahi, 2015). Estimates of the date of origin are also contentious, with most estimates in Iran around 700 B.C (Lightfoot, 2000; Martinez-Santos and Martinez-Alfaro, 2012). However, as Kamash (2006) reports, the other theory argues that the *qanat* originated in the Arabian Peninsula between 1000 and 600 B.C. Estimates for Oman suggest that the *aflaj* have been operating for 1500–2000 years (Dutton, 1984; Al-Marshudi, 2007).

Historically these systems developed in arid and semi-arid environments that are characterised by low rainfall and dependent on specific hydrological, topographic, climatic and geological conditions, which are necessary for the system to function (Lightfoot, 2001; Kamash, 2012). As Lightfoot (2001: 6) extensive work on the diffusion of *qanats* states: '*qanats* are very often found originating at the base of hills or mountains, where water from alluvial deposits or bedrock aquifers in these highland regions can be directed onto adjacent valleys or basins, but they are not found up in the highlands'.

As shown in Fig. 1, which depicts a typical Omani *daudi aflaj,* the *qanat* system taps into alluvial aquifers using a vertical tubewell or 'motherwell' (Al-Ghafri et al., 2003; Lightfoot, 2001). Using gravity, water flows into a gently sloping subterranean tunnel which begins at the base of the motherwell to end in a village or fields (Al-Marshudi, 2001;English, 1968). The subterranean channel can extend for tens of kilometres (Al-Marshudi, 2001) and the landscape is punctured by shafts at different intervals which connect to the channel. These ventilation structures are used for both supplying air during maintenance and additional infiltration (Lightfoot, 2001). As a holistic system, water infiltrates into many points of the system as the *qanat* is gravity-fed from the water table (Lightfoot, 1996, 2001; Al-Ghafri et al., 2003).

The diffusion of the *qanat* system has been recorded in many forms across the world, whilst retaining the same fundamental characteristics (Remini et al., 2014). Across the Middle East and North Africa and the Levant (Lightfoot, 1997), this technology has been recorded in Algeria where it is known as *foggara,* and in Morocco, where it is also referred to as *khettara* (Remini et al., 2014; Fattahi, 2015). In Afghanistan, it is called *kariz*, whilst in Yemen, where there are fewer, it is referred to as *Ghail* and *Miyan,* and in Syria Q*anat Romani* (Al-Ghafri et al., 2003; Lightfoot, 1996, 2000; Shams, 2014). It is thought that diffusion of *qanats* across the Middle East spread with the Archaemenid empire, during which time it reached Oman (Martinez-Santos and Martinez-Alfaro, 2012; Shams, 2014; Kamash, 2006, 2012). Later knowledge of the *qanat* system, and subsequent development transmitted to Spain, and onwards to Latin America (Martinez-Santos and Martinez-Alfaro, 2012; Lightfoot, 2000) where they are largely referred to as *galarias*, although other names such as *puquio* and *matrit* also exist (Al-Ghafri et al., 2003). The success of *qanats* to survive into the twenty-first century, as indicated by the number of functional *qanats* in each country, varies significantly. Spanish *gallerias*, such as those found in Madrid, have long-since been replaced by municipal water systems (Martinez-Santos and Martinez-Alfaro, 2012). Even preceding current conflict, similar significant declines of *qanat*-based systems have completely disappeared in Syria, and in Yemen (Remini et al., 2014; Lightfoot, 2001). However, in countries such as Iran, Oman, Afghanistan, Pakistan, China and Azerbaijan, *qanats* still play a significant role as a sustainable water technology (Hamidian et al., 2015). Notably, in many cases, the *qanat* is operational in low-density and rural environments, and less in urban areas (Fattahi, 2015).

Despite core similarities between the *qanat* systems, adaptations in the technology have varied from context to context with variations in depth reflecting hydrological differences, or differences in the distance between the shafts. For example, the average distance between service shafts is 13 m for the Algerian *foggara*, 18 m for the *qanat* and *karez*. Channel length similarly differs from 12 km in Oman to several times that in Iran (Al-Ghafri et al., 2003). The *foggara* is often about 30 m deep, with the deepest recorded at 300 m for the Iranian *qanat* (Remini et al., 2014; Hamidian et al., 2015). Whilst there are notable similarities between the systems, the diffusion of *qanats* has resulted in adaptations to local environments, cultures and contexts (Hamidian et al., 2015). Hamidian et al. (2015) have defined a classification of *qanats* according to five criteria: length and depth; topography; geographical situation; discharge and source.

Table 2
Shows the distribution of *aflaj* and size of region (Aquastat, 2008).

Regions	Al Batinah	Al Dhakliah	Al Dhahera	Al Sharqiah	Musqat	Total
Area (ha)	5594	7895	3527	4326	225	21606
# of *falaj*	1209	501	473	661	173	3017

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