Irrigation Scheduling of *Aflaj* of Oman:
Methods and Modernization

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Introduction

In Oman agriculture is almost fully dependent on irrigation owing to the fact that most crop production areas receive only between 100 to 200 mm of rainfall annually (Norman, et al, 1998 a, b). Oman has 4,112 *falaj* of which 3,017 are live *aflaj* ????, producing about 680 x 10^6 m^3 of water per year and 410 x 10^6 m^3 $year^{-1}$ is used (Al-Hatmi and Al-Amri, 2000). *Falaj* ??? *(*singular of *aflaj*) can be defined as, a canal system, which provides water for a community of farmers for domestic and agricultural use. The term *falaj* is derived from an ancient Semitic root, which has the meaning *"to divide"*, hence the water shares in *aflaj* is divided among the owners (Wilkinson,1977). The local nomenclature of the *falaj* implies the system as a whole (Wushiki, 1997). Normally a farming community owns all *falaj* water. *Aflaj* vary in size and the smaller ones owned by a single family while the larger ones belong to hundreds of owners. In every *falaj*, there are some water shares not owned by individuals but allocated to the community. The value of these shares are allocated for *falaj* service, mosques, emergencies, etc (Al-Abri, undated). Many villages and towns in Oman have more than one *falaj* system; for example, the town of *Samail* has 16 different *aflaj* systems.

Typical Omani *falaj* administration consists of a director, *wakil* ????, two assistants, *arifs* ????, one for underground services and the other for above ground services, banker, *qabidh* ????, or *amin aldaftar* ????????, and labor, *bayadir* ????? (Sutton, 1984, and Wilkinson, 1977). The *aflaj* systems are arranged in such a way that domestic use is primary and agricultural use is secondary. In most *aflaj*, water is first allocated for drinking purposes, then for uses in mosques, forts, men's public baths, women's public baths, and lastly to the area for washing dishes and clothes. After domestic uses, *falaj* is used to irrigate the permanent cultivated lands, mostly for date palms followed by the seasonally cultivated lands. This arrangement helps farmers to control drought.

The *Wakil* is in charge of the overall administration of the *falaj*. For example, he is in charge of water distribution, water rent, expenditure of *falaj* budget, solving water conflicts between farmers, emergencies and other decision-making activities. *Arif* ???? can

be in charge of timing irrigation in the field. The *qabidh*'s job is to control the *falaj* income, which comes from special water shares, land or crops located for the *falaj*. He is also in charge of updating the *falaj* transaction book, giving an annual report to the *falaj* owners and does other tasks as directed by the *Wakil*. The administration of the *falaj* system depends on its size. Some *falaj* can have administration system as described above where as others may not have full administration but normally should at least have a *wakil*.

In *falaj* irrigation system, water is distributed by time basis. Only in few cases volume basis is used. There are three types of *aflaj*: 1) *Ghaily* ? ??? , where the source is a base flow of *wadi* (dried rivers). 2) *Daudi* ? G??O, where the source is a mother well, like the *qanat* of Iran. 3) *Ayni* ? ??? , where the source is natural spring.

Traditional methods for *falaj*-water distribution

Falaj-water distribution by Athar

When the construction of *falaj* is finished, farmers establish a committee of experienced people to distribute *falaj* water shares among *falaj* owners. If the government contributed in constructing the *falaj*, it normally owns some shares of water or land. The committees investigate the *falaj* flow rate, water flow fluctuations, soil type, number of owners and their proportional contribution in constructing the *falaj*, etc. In the *athar* basis distribution, the first step is to decide on the irrigation rotation, *dawran* ? ???O. *Dawran* is the irrigation cycle, normally 7 to 14 days. However, it can be as short as 4 days or as long as 20 days. The most important factors when deciding the *dawran* are soil type and flow rate of the *falaj*. For example; *falaj al-Awabi* ? ????? has a *dawran* of 14 days, *falaj Al-Hageer* ?????? in *Wadi bani Kharous*, 7 days, *falaj al-Farsakhi* ??????? in *Samail*, 8 days and *falaj al-Dariz* ?????, in *Ibri* has a *dawran* of 19 days. In all *aflaj* of Oman the *dawran* is divided into many subdivisions of time. After *dawran* is decided, water share is divided between *falaj* owners using unit of share *athar*. Each full day is divided into one or two *badda*. Each day should be equal to 48 *athars*, so if the day is one *badda*, *badda* will be equal to 48 *athars*. If it is two *badda* then, each *badda* will be equal to 24 *athars*. Normally the day is divided to two *badda*, the day *badda* and night *badda*. Wilkinson (1977) reported a *falaj*, which has 3

badda in each day. In this *falaj*, each *badda* has 16 *athars* so the full day is also equal to 48 *athars*. Al-Hajri (1998) reported that the number of *badda* per day differs from one reign to another in Oman, where the existence of three *badda*/day is rare. *Athar* is commonly used in *aflaj* of Oman where each *athar* is divided into 24 *qiyas* a ???. Practically, *qiyas* is the smallest unit of water share, which is approximately equal to the time required to irrigate one date palm tree with good *falaj* flow. Other units may have different names or length of time. Al-Marshudi (1995) mentioned that *qama* ???? equals to 1/4 *athar* and *rabiya* ????? equals to 6 *athars*. There are some other units of time like *rabee* (???? which equals to 6 *athars* (1/4 of half-day *badda*) and *riba* ???? equals to 6 *qiyas* (1/4 of *athar*). Smaller units are also used in *aflaj* like *mithqal* ?????? and *habah* ??S . In *falaj al Awabi*, *qiyas is equal to* 8 *mithqal;* each *mithqal* equals to 36 *habah*. Theoretically, an *athar* is equal to 30 minuets, therefore *habah* equals to 0.26 second. Wilkinson (1977) explained a system of dividing water share from the book of *falaj Izki* (in the Interior Region of Oman), in which an *athar* is divided to 24 *qiyas*, and *qiyas* is divided into 24 *daqiqah* ????O, then *daqiqah* is divided into 24 *shariah* ????? and *shariah* into 24 *jalilah* ????? . One *jalilah* will be equal to 5.42 x 10^{-3} seconds. Practically, it is non-measurable; hence, these small units are used only in inheritance. It is noticed that the length of the time-share is inversely proportional to the flow rate and number of *falaj* owners and it is directly proportional to the contribution of the owner in constructing the *falaj*.

When the water is divided between the shareholders, the division never changes but the water and land shares can be sold or rented. When the owner dies, land and water share is distributed among his family according to Islamic regulations. Each farmer will irrigate his farm(s) with same number of *athars* at each *dawran*. The sequence of water shares in the rotation of irrigation does not change if a farmer misses irrigating his land during the rotation (Norman, et al, 1998b). Most of *aflaj* have special number of *athars* to be rented for *falaj* service and maintenance. In these *aflaj*, some water shares are not fixed with land, so can be sold or rented separately by auction, *Maqouda* G???? . The price of *athar*, for rent or sell, varies depending on the availability of water and auction events. For example, *falaj al-Hageer* (small *falaj*) has 15 *athars* for the *falaj* from a total of 336 *athars*, 7 days *dawran*. A large *falaj* may have more water share to be devoted to the *falaj* or common

use, like in *falaj al Awabi dawran* is 15 days (720 *athars*) in which 150 *athars* are allocated for *waqf* ? ?? . The water that allocated for *waqf is* to be rented to raise money to be used for mosques, Islamic schools or for other community benefits.

In many Omani *aflaj*, particularly the larger ones, farmers can be classified in 4 types; i) owners of land and water, ii) owners of land and renting water, iii) owners of water and renting land and iv) renting land and water. The existence of each type depends on many factors such as the sizes of the *falaj* community and the amount of water share that is owned by the government (*bait al-mal* ???? ??) *or* located for the community benefits, *waqf*.

Estimated time intervals

In some *aflaj* systems, the day is divided into estimated intervals. For example, the full day can be divided into seven intervals, between dawn, sunrise, midday, prayer time in the afternoon, sunset, prayer time at night, and midnight. Farmers therefore share the water using these intervals. However, Al Abri (undated) noted that this method is seldom used because it has no clear length of time or standard unit therefore it causes a lot of conflicts among farmers. Al-Saleemi and Abdel Fattah (1997) described the irrigation time division as of September 1996 of *falaj al-Farsakhi, Samail*. In this *falaj* the full day is divided to six intervals called *riba*, ???? and each *riba is* between 2 and 6 hours in length, as shown in Table 1.

Distributing water by *badda*

In *Falaj al-Muhaidith* ? ????? , *Ibri*, the *dawran* is divided to 10 days, where each day has two *badda*. In this *falaj* the smallest water share division is *badda*, (half full day).

Table 1. Summer divisions of time for irrigation in falaj al-Farsakhi, Samail

Number	Riba	Time From	To	Total time
1	*Al-BadwahG???*	4:15 pm	9:00 pm	4.75
2	*Al-lail'???*	9:00 pm	3:00 am	6.00
3	*Al-Athaan ????*	3:00 am	7:00 am	4.00
4	*Dhil 6* ??	7:00 am	11:00 am	4.00
5	*Al-Nisf?* µ *???*	11:00 am	2:00 pm	3.00
6	*Al-Aakhir ????*	2:00 pm	4:15 pm	2.25

Tasa

In *Jabal Al-Akhdar* mountain, in North-center of Oman, and some surrounding villages, another method of water distribution is used. Farmers use a water timer called *tasa* ???s or *sahlah* ??? ? . In some cases the *tasa* itself is used as a time unit. However, in other places the *tasa* is divided to the common time unit of *aflaj, athar*. *Sahlah* is a timing device using water and two containers. The upper container, called *tasa,* is placed on a bigger container, which is filled with water. Fig 1 shows the *tasa* which is used in *falaj* Saiq, in *Jabal Al-Akhdar* mountain. *Tasa* has a small hole through which water fills it up slowly until it sinks. Farmers use the time it takes the water to fill the entire container as

Figure 1: Tasa of falaj Saiq

a single unit of water share, *tasa*. The book of *falaj* Saiq describes the water share of the farming community in which *tasa* was used as a unit of water share. Each owner of water share gets multiples or divisions of *tasa*.

Water tank

In some parts of Oman, usually in the mountains, for small *falaj* system, the *falaj* water is stored in a large water tank, *Liggil* ???, constructed by local cement, *sarooj* ????. Water is then distributed by volume according to the size of the owned farm(s). For example, a farmer with a small farm may have one full tank; another one with larger farm will have more water, like two tanks. In such *falaj* system flow rate is very low and land shares are small. An example is *falaj al Air* ???? which is located in *Wadi bani Aouf* in *ar Rustaq*. This *falaj* is small *ayni falaj* with a *dawran* of irrigating every 7 days. Each day of irrigation is owned by one or two farmers. In this *falaj*, farmers store water at nighttime and early day time then they irrigate in the afternoon. In case a conflict occurs, the amount of water that was delivered to someone is checked by measuring the height of water in the storing tank. They put a stick made of date palm branch and mark it by date leaves for the height of water that represent half the stored volume. The full tank represents one day (two *badda*), and each half tank represents one *badda*.

Irrigation Scheduling

The daytime *badda* starts at sunrise and ends at sunset. The nighttime *badda* starts at sunset and ends at sunrise. In scheduling irrigation, farmers start counting *athars* from sunrise as shown in Fig 2. Several traditional methods were

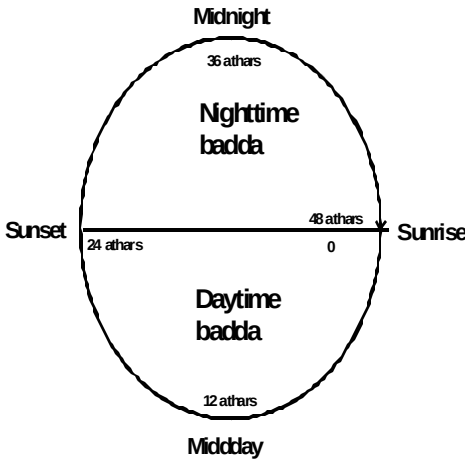

Figure 2: Traditional full day water-share

developed to verify the *athar*-basis water-share for farmers, on the field. The sundial and stars method was the most common way of irrigation scheduling in northern Oman. In this method, farmers use sundial at the daytime and special stars at the nighttime. The process of inspecting the sundial or the stars for water shares is called *mohaynah* ????? or *mahazarah* ?????. Sundials, locally called *lamad* ??? or, *alam* ??. The place for *mohayanah*, where the sundial is located, should be in the head of the *falaj* system, before any divisions in the distribution system. Usually it is located near the main fort of the village where the *sheikh* ?? (the village head) resides. The schedule of *falaj al Hageer* is an example of schedule for traditional irrigation. In this *falaj* the *dawran* is divided to 7 days that is equal to 14 *badda* or 336 *athars*. Each *badda* is divided to 4 quarters, *riba'* (???), so each *riba'* is equal to 6 *athars (rabee is called riba' in al-Hageer)*. Table 2 shows a complete schedule of irrigation for *falaj al Hageer.* The table shows the order of farmer as of January 15, 1996 (Monday) to January 21, 1996, (Sunday). Fifteen *athars* are allocated for the organization, mainly for the *falaj* and mosque service (Wednesday, code 16). The rest of the *athars* are distributed among *falaj* owners. The water share varies from 2 *athars* (code 9) to 48 *athars* (code 18) per farmer. In *al-Hageer* a farmer may have his water in more than one day in the *dawran*. For example, farmer with 24 *athars* has 14 *athars* on every Friday and 10 *athars* on every Sunday (code 7). A farmer may also have water in the same day but in separate *badda*, for example, a farmer on Monday has total of 11 *athars*, 4 *athars* in one *badda* and 7 *athars* in the other *badda* (code 10). Farmers do not have more than 24 *athars* in a single irrigation. So, if a farmer has more than 24 *athars* in one day, he will have a full *badda* and the remained *athars* will be in the other one. An example of this is on Friday. A farmer has 34 *athars*, 24 in one *badda* and 10 in the other one (code 21).

Daytime Scheduling

A typical sundial in northern Oman consists of a stick, 8-cm thick and 2 m long, fixed vertically on a flat rectangular area. Special selected stones, which are carefully spaced, mark the area. The stones that represent early and late daytime *athar*s are spaced farther apart than the stones that represent midday *athars.* A single stone is called *jamood* ????, its plural is *jawameed* ?????. Farmers watch the movement of the stick shadow over the set of

Table 2. Irrigation Schedule of falaj Al-Hageer

Day	Number of separate irrigation	Farmers codes and owned athars							
			Badda 1				Badda 2		
Mon		Codes	11	9	10	8	13	10	12
	7	Athars	8	2	4	10	8	7	9
Tue		Codes	14		15		4	2	1
	5	Athars	9		15		14	3	7
Wed		Codes	18				16		17
	4	Athars	24				8	7	9
Thu		Codes	19		20		18		
	4	Athars	14		10		22		2
Fri		Codes	21		7		21		
	3	Athars	10		14		24		
Sat		Codes	1		2		3		
	3	Athars	11		13		24		
Sun		Codes	4				5	6	7
	4	Athars	24				5	9	10

stones and count *athars* by the time it takes the shadow to move from one stone to another. These stones are marked to represent each *athar* on the daytime *badda*, so 24 stones are placed in one line in the direction of East-West. The marked line is also called *lamad*.

A system like this has more than one line-*lamad* to adjust the location of the stones on the tilt of the earth throughout the

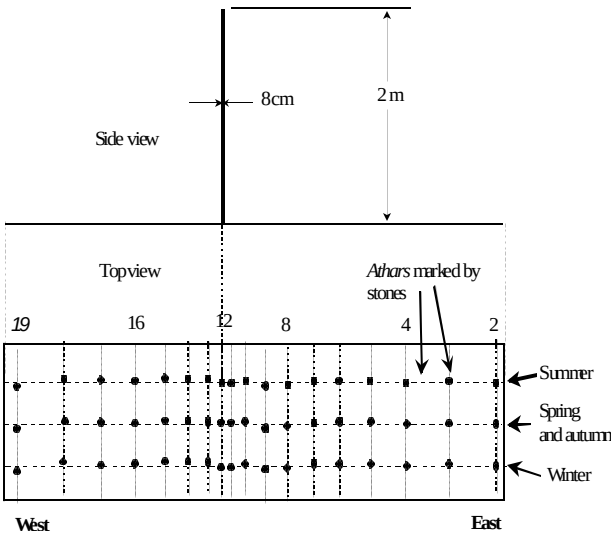

Figure 3: Sketch of the sundial of Falaj Stall

seasons, which affect the position of the shadow. There are three line-*lamads*, one for summer, one for winter and one for spring and autumn. The stones with the same *athars* in the three lines are connected with a line (Al-Ghafri et. al., 2000b). If the village is situated between high mountains; the number of *athars* to be inspected using the sundial will be less than 24, therefore the farmers use the surrounding environment to complete the missing *athars*. This is because the sunshine time on the village will be less than the actual daytime length. Fig. 3 is a sketch of the sundial of *falaj* Stall. Another type of sundial is used in *falaj Al-Dariz*, Ibri. This version is called, *alam*. It consists of a 30 cm metal stick fixed vertically on a big solid flat rock, which is covered by concrete. The rock is marked permanently for *athars* and subdivisions of *athars* with a minimum division of 1/8 *athar*. This type of *lamad* also has 3 lines for summer, spring and autumn and winter.

Nighttime Scheduling

At night, farmers use stars in scheduling irrigation. Special set of stars is located for irrigation. These stars are well known by the *wakil* or *arif* of the *falaj*. Farmers use the time between the rises of a particular star(s) to the rise of the following star(s) from this set. It is categorized into principal stars and dividers, *qawasim* ?????. Normally, time-share allowed between any of the principal stars is between 1 and 3 *athars*. Table 3 shows the star system of *fajal Stall*. Dividers divide the time between two principals ranging from 2 to 6 subintervals. However, divider stars are not very important in irrigation scheduling. The total number of the principals stars, which are used in each *fajal* is between 20 to 25 stars. This set is fixed for a particular system of *aflaj*. Among *aflaj* of Oman, different nomenclature and dividers between the scheduling stars are used. About half of the total number of the full set is used on every night, depending on the day in the year. In traditional sundial-stars timing the most difficult time to verify *athars* is the transition between the daytime *badda* and nighttime *badda*. The hardship is caused by the fact that the timing depends on the observation of the movement of the sun or stars, it is therefore difficult to decide the start and end of the each *badda* during the sunrise and sunset. The star system for *aflaj* irrigation is very complex and the time set between stars varies from one village to another. Table 4 illustrates the variation of water right, by *athars*, between same stars in 5 different villages in the northern Oman. In cloudy weather for instance when the east is

covered by cloud, farmers use setting of other stars in the west, which synchronize with the irrigation set of stars.

Falaj Water Distributing Equitability

Solution for the change of Athars' length

In the traditional sundial and star method, because of the variation of the length of day and night throughout the year, farmers may have more or less water per *athar*. In northern Oman, where most of the *aflaj* exit, *athar* can be varied in length between 1/3 – 2/3 of an *athar*, according to the change in the day and night lengths around the year.

Table 3. Irrigation Star System of Falaj Stall

Number	Name of star(s)	Number of athars
1	*al-Thuraiya*????	2
2	*Al-Dubran* ?????	3
3	*Al-Yameen* ????	3
4	*al-Shair* ?????	3.5
5	*al-Ganb* ???	2.5
6	*Al-Thraa'* ? p ?	3
7	*Al-Farfarah*?????	2
8	*Al-Mawatheeb* ??????	2
9	*Bu-Gabban* ????	2
10	*al-Ghafar* ???	2
11	*Al-Zabanat* ??????	2
12	*Kuwi* ??	2
13	*Al-Munsif* ? ???	2
14	*al-Tayer* ?? ?	1.5
15	*Al-Ghurab* ????	2.5
16	*al-Adam* ?O	2
17	*al-Sarah Al-Oula* ????G???	2
18	*al-Sarah Alwusta* t ????G???	2
19	*Al-Sarah Al-Akhirah*????G?? ?	2
20	*Al-Kawkabain* ??????	2
21	*al-Fateh* ??	2

Due to using non-precise devices like sundial and stars the variation is much higher. For example, *athar*'s length is varied in *falaj al-Hageer* from less than the half of the theoretical length of the *athar* to more than double. Al-Shaqsi (1996) reported a big variation in *athars* length in *falaj al Kasfah* of *ar Rustaq*. In winter, farmers

irrigating at nighttime will receive more water than farmers irrigating in daytime and the reverse is true in summer. At night farmers use stars for scheduling irrigation, however they

Table 4. Variations of athars in different star systems of aflaj

Athars	Stars	Falaj Al-Hamra	Samail	Al-Hageer	Stall	Al-Awab
	Kuwi ??	3	2	2	2	2
	Al-Ghurab ????	2	2	2.5	2.5	2.5
	Al-Adam ?O?	2	2	2.5	2	2
	Al-Kawkabain ??????	3	2	2	2	2
	Al-Thuraiya ???? ?	2	2	2	2	2
	Al-Ganb ????	2	2	2.5	2.5	2.5

estimate the length of time between stars. Some two stars may have two *athars* of the length; however, the actual time will be less or more than one hour. Ancient farmers tried to solve this problem by having another rotation within the *dawran*. It was a day-night rotation. In this rotation farmers keep shifting the irrigation in daytime or nighttime; as well changing their order in the same *badda*. As an example, in *falaj al Hageer*, farmers with shares less than 24 *athars* will have their water at night *badda* or day *badda* only. For instance, during summer if a farmer irrigates at nighttime and loses some water, he will gain more in the following *dawran*, when irrigating during the daytime. In Fig. 4, farmers D and E are irrigating in one *badda* and farmers F and G in the other one. In this rotation farmers at same *badda* rotate the order between them each *dawran*, and both groups (D-E and F-G), rotate the irrigation at daytime or nighttime, (Al-

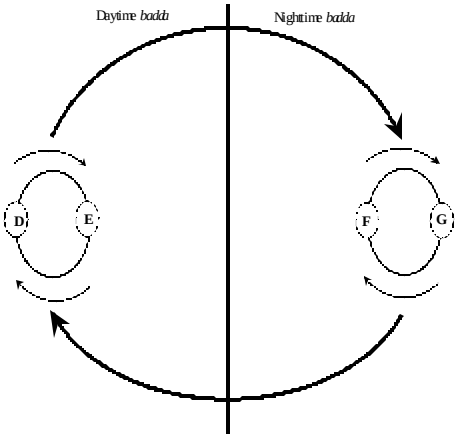

Figure 4: Rotation of farmers

Ghafri, et al, 2000a).In central Oman some *aflaj* adapted different method to automatically make the farmers receive their water alternately night and day. They designed the *dawran* with an odd number of *badas*, like nine and half days, 19 *baddas*, rather than nine days, 18 *baddas,* (Wilkinson, 1977).

Reaction of farmers on flow rate fluctuations

Farmers act against the change of *falaj* flow rate by dividing the *falaj* into smaller streams, re-adjusting the *dawran* or store the *falaj* water in a big tank before irrigating. In large *aflaj* systems, the water stream of the main channel is divided into several sub-streams depending on the size of the *falaj* and its flow rate. Farmers can irrigate from one stream or more at once. In dry years, farmers cut the number of sub-streams depending on the reduction in the main flow rate. The process of equally dividing the main flow of the *falaj* is called locally *moghayza* (???? The place where this process is done is called *shari'ah* ????? . This process can be summarized in the following equation;

The number of *athars* a farmer will receive: $T = t \cdot N \cdot n^{-1}$

t = Standard number of *athars* owned by a farmer.

N = Number of equal streams of the *falaj*.

n = Number of streams which farmer use simultaneously.

In this division the farmer who irrigates using the main flow will receive the same amount of water if he irrigates from one or more sub-canals. The amount of flow in each sub-canal is set to be equal. An example of this is shown in Fig. 5. The photo shows the flow division of *falaj Birkat al-Mouz*. By joining A1 and A2 a stream A is formed. In this division A:B = 2:1; so if a farmer has an x *athars* from the main stream and he irrigates from stream B only he will get 3x *athars*, but if he irrigates from stream A, he will get 2/3x *athars*. Big *aflaj* may be divided to 8 streams as of *falaj Daris* in *Nizwa*. *Aflaj* with stable flow usually are divided permanently to major sub-streams. Each stream will be devoted to a specific land area.

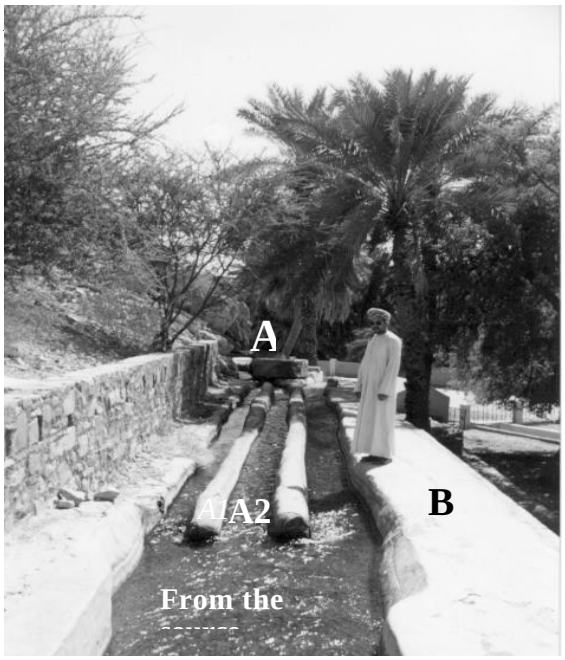

Figure 5: Flow division in Falaj Birkat al-Mouz. Photos: June 1996

The *dawran* is not fixed for all the *falaj* but each major stream may have its own *dawran*. Like in *falaj al-Dariz,* Ibri, the main stream is permanently divided to two streams. In one of these streams the *dawran* is days, in the other one the *dawran* is days. The reason for this difference is that the land which is irrigated by the stream of the shorter *dawran* has a lighter soil than the other one which has long *dawran*. In this example therefore each stream is treated as a separate *falaj* system. In the time of drought, the *falaj* will be joined in one stream only and will be altered between the two in 19 days. During the drought of the late 1980s this solution was adapted, and it was noticed that the farms that were located in the stream of a former short *dawran* suffered more than the other farms. In *falaj al-Ghayzayn* ?????? , north of Oman, *falaj* is divided into two streams in normal years. Farmers use both streams at the same time. The *dawran* of this *falaj* is 7 days. In time of drought, farmers irrigate from one stream only at any one time. In this case, they divert the water every 7 days to one of the two canals; hence the *dawran* is doubled from 7 days to 14 days. In very low flow rate the *dawran* is extended to 28 days (Birks, 1977). Wilkinson (1977) reported that the *dawran* is altered annually in some *aflaj* to meet the changing requirements of summer and winter irrigation. He gave an example of three *daudi-aflaj*: i) *falaj Dariz,* ii) *falaj* of *Ibri* and iii) *falaj* of *Buraimi*. The *dawran* in these *aflaj* changes from ten to twelve days, four to five days, and ten to fourteen days, respectively (Wilkinson probably considered only one of the streams of *falaj al-Dariz*). In *falaj al-Farsakhi,* at *Samail,* farmers adapted simpler method to insure justice distribution of water share. The *falaj* water rights are

divided to 8 full days; one day for the *Maqoudah* (???? , allocated for the *falaj* benefits and the other 7 days for individual owners. In the 7 days each day is divided between groups of owners, from 4-8 owners in each group. Each group is always irrigating at same day, however, the order of irrigation of each group changes in every *dawran (Al*-Saleemi and Abdel Fattah, 1997). It is a common practice in small *aflaj* systems that farmers store the *falaj* water in a big tank for long time and controls the flow rate for irrigation depending on time desired to irrigate. In some *aflaj,* the village has one or more big tanks made of concrete to store *falaj* water during the time of low flow rate. The time for storing the water is included in the share time that farmers have. It is noticed in this system that they store water only when the water flow of the *falaj* become unmanageable. This method reduces the time required for irrigation and increases the efficiency. During this process, if a farmer couldn't finish using all the stored water in the tank before the start of irrigation of the next farmer, his remained water will be allocated to this succeeding farmer.

The problem of using different unties for water share in *aflaj*

Due to the developed passive attitude of farmers toward the *falaj*, technical knowledge of *aflaj* is only possessed by older generation. The new generations have no interest to learn about it. In many systems farmers do not know even the time of the construction or the location of the water source. The terminology and names of star system for irrigation and units for water share is too complicated, unorganized and its knowledge is disappearing. It is therefore necessary to standardize the water share units for future development of *aflaj* by applying new irrigation technologies on the existing systems. Currently, there is no standard unit of time of water distribution for all *aflaj* of Oman. As the traditional way of irrigation scheduling differs from one *falaj* system to another, the standardization of timeshare is likely to be tricky. Even though in most of the *falaj,* farmers use *athars* as a standard unit, the way of inspecting the length of each *athar* varies among *aflaj*. In order to shift into using modern watch we have to change all the existing units of time to standard time, hours, minutes and seconds. Converting all traditional units to the standard time can do this, as shown in Table 5.

Table 5. Some traditional water share units and their equivalent time lengths

No	Traditional water share units	Equivalent time length (hr:min:s)
1	*Badda* ??	12:00:00
2	*Rabia*???	03:00:00
3	*Rabi*???	03:00:00
4	*Athar* ??	00:30:00
5	*Qama*???	00:07:30
6	*Qiyas* ???	00:01:15
7	*Mithqal* ????	00:00:09.375
8	*Daqeeqah*????	00:00:03.125
9	*Habbah* ??	00:00:00.26

Ghoroobi and *Zawali* timing

As a rule, in the traditional scheduling method, the daytime *badda* starts at sunrise and ends at sunset, where the nighttime *badda* starts at sunset and ends at sunrise. After the modern watch became available to farmers in the last century, they gradually started to check the time using these watches, and they came to fully depend on these watches in some systems, by adapting first the *Ghoroobi* ????? timing and then the *Zawali* ????? timing. When the modern watch was introduced to Oman, the timing system was known as *Ghoroobi* or sunset timing. In this timing system, the farmers set the watch to 12:00 at sunset everyday. The watch is adjusted everyday according to the change of the occurrence of the sunset. In the conventional meridian timing, called *Zawali* in Oman, the day starts at 6:00 AM. In the *Zawali* method, daytime and nighttime are fixed to have equal length (12 hours each), regardless the seasonal change. Figure 6 illustrates the difference between using traditional sundial and stars, *Ghoroobi* watch and *Zawali* watch.

In Table 6, 16 *aflaj* systems are listed with information on the type of the *falaj*, estimated size of the *falaj*, length of *dawran* and the method of irrigation scheduling. In all the four *ghaily* type *aflaj*, farmers use modern watch. In two of them *Ghoroobi* timing is used and in the other two *Zawali* timing is employed. In the *daudi aflaj*, it looks that farmers prefer and stick to the sundial and stars system. We can also recognize from the table that only the small sized *aflaj*

use tank and scale method; distributing the water on volume basis. It is too difficult to ask the farmers to shift from the traditional way of irrigation scheduling to the use of modern watch.

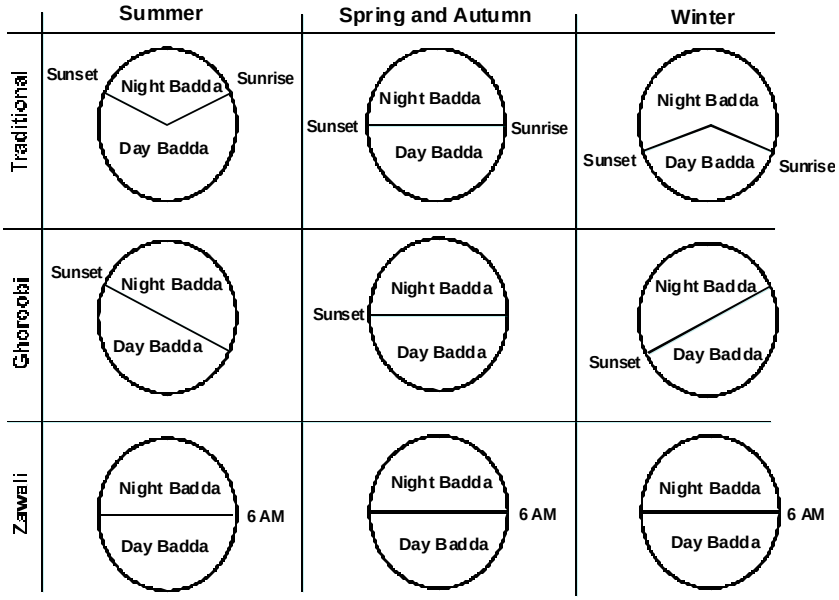

Figure 6: Different methods of irrigation timing in aflaj

Summary

Farmers go through several steps to transfer from using traditional irrigation scheduling to modern watch. The old generation opposes new improvements. Thus, it is necessary to convince *sheiks*, *wakils* and older people of the *aflaj* to convert to using meridian time. It is therefore recommended that all the existing traditional water-share units should be converted to standard time. This necessitates the documentation of all water share of *aflaj*, before further steps and big changes take place in the management or the social system of *aflaj*. Every *falaj* should have a book containing the name of water right holder, amount of water he owns (number of *athars*, volume, etc), and time to start and finish irrigation. It is also necessary to update this database with future changes that may happen to the water system.

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