

# IRRIGATION WATER MANAGEMENT UNDER SMALL LAND HOLDING IN THE AFLAJ SYSTEM (OMAN);

## A NEW APPROCH TO OVERCOME CHALLENGES OF WATER SCARCITY

Salim Al Mamary<sup>1</sup> and Salim Al Kalabani<sup>2</sup>

### ABSTRACT

In arid countries, water scarcity plays a major role in developing the economics and therefore countries tend to look to agriculture intensification, by the efficient use of water through irrigation technology transfer, to reach high productivity and food sustainability. However, the challenges are high. Drought which causes many *Aflaj* to dry out and reduces the average flow of others has a negative effect on Aflaj small holders' communities. This is because of many factors that influence the small holder's irrigation practises which tend to be inter-connected and complex.

In 2005 the Ministry of Agriculture tried to introduce central control and implement a modern irrigation system to Aflaj communities. However, most farmers rejected the project because they believed that trickle irrigation would not be sufficient to irrigate date palm trees. Farmers also believe that water rights in Aflaj are a difficult task and can not provide equity in distribution with regards to each farmer's rights. Afterward, with agriculture extension efforts the farmers agreed that improvements could be made and the projects were executed. The project was successful in achieving its goals and objectives. The implementation of the project in Amla includes two reservoirs to store the water and two control units connected with automatic valves to control irrigation water. The output of the project was high and input was reduced so social-economic values of the village improved. The project achieves high efficiency in irrigation and reclaimed excess water to expand the cultivated land. The project also reduces water stress and achieves higher production for existing crops and expands cultivation. The first year income calculations show the high feasibility for such a project to be implemented on Aflaj systems. The project also changes the concepts of Aflaj improvement for the farmers. A recent survey shows a high percentage of farmers accepting the change in management to the new techniques of central control and irrigation technology.

### INTRODUCTION

Oman is one of the driest regions in the world – classified from semiarid on the coastline to arid inland regions. The average precipitation received is approximately 100 mm/year which indicates very limited renewable water resources per capita. Moreover, the growing scarcity with limited rainfall is worsening the situation resulting in lower groundwater recharge and reducing surface runoff. This scarcity generates a high competition from different users and locations so that water resources management is under increasing pressure to save and allocate water more efficiently and according to priorities.

*Aflaj* systems are an ancient indigenous engineering technique for irrigation in Oman, created by the ancient Omanis civilisation a long time ago to supply water for irrigation and domestic use and they act as a part of Oman's social life and heritage. Historically, *Aflaj* were the main sources of wealth and the country's economy remains reliant on its revenue. The rural communities of *Aflaj*

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<sup>1</sup> Irrigation expert, Ministry of Agriculture Sultanate of Oman, Almamary@yahoo.com

<sup>2</sup> Head of Irrigation department, Al Dhahira region, Ministry of Agriculture, Sultanate of Oman

system are fully dependent on *Aflaj* and consider them an integral part of their life (Abdel Rahman & Omezzine 1996).

*Aflaj* can be defined as the utilisation of ground water, using slope engineering techniques to bring water to the surface by gravity force so that it can then be canalised and distributed for domestic and irrigation purposes (Al Mamary 2010). The flow of water in *falaj* systems is continuous and the distribution of water is divided in periodic units by the owners of the *falaj* water rights. The irrigation by turn arrangement is applied to all farmers according to their shares within a recognized water rotation program. The *Falaj* water shares are divided on a time basis – not by volume of water. Thus, the volume received by each farmer depends on the flow in the Falaj and normally each farmer must adjust his cropping according to the availability of water.

*Amla* is a village in Al Dhahira region that has suffered from drought for several years; farmers try to keep their permanent crop, the date palm, alive and due to this the running cost was exceeding the monetary output from village. The cultivation was not receiving enough water; accordingly the yield was low and social-economic problems starts to emerge in the village. The government helped the farmers by digging two borehole wells to support the *Falaj* system. However, the yield of the well was low compared to the irrigation requirement using a traditional form of flood irrigation. The complexity of the *Aflaj* water rights and the high number of users were the main challenges to improving and developing this village. This paper presents this complexity and describes how the government overcame these challenges. The paper also shows the success of the development.

## METHODOLOGY

The approach of this paper is to present the importance of the *Aflaj* system in rural areas and considering how these systems have suffered from drought in recent years. Data collected for this study came from different sources, the primary data being from ministry of Agriculture, with the secondary data collected from ministry of Water Resources. In addition, to some interviews with farmers from two regions AL Dhahira and Al Dakhliya conducted by the authors.

*Amla* is a rural village from Al Dhahira region northern interior of Oman. The village was selected for development of the *Aflaj* system as a demonstrations project for other farmers, to encourage them to use modern techniques in irrigation and cropping. The approach presents the data collected before development and addresses the challenges to executing the projects in such small rural village. Moreover, the project component and design aspects will be presented, in addition to a comparison of the net income obtained in the first year after project implementation. Finally goals and milestones achieved will be presented.

## AFLAJ AND DROUGHT

The *Aflaj* constitute 43% of the total renewable water resources available in the Sultanate of Oman. The date palm tree forms the primary crop irrigated by *Aflaj* water, amounting to 70 percent (Almamary 2002) of the total irrigated area. Other crops such as Lime, Mango and other trees accompanied by intercropping with cereals and vegetables occupy a further 15 percent. Fodder crops occupy 9 percent and 6 percent is made up of cereal and vegetables (Al mamary 2002). These crops are grown by surface irrigation through either a completely earth, or cemented, channels network distributing the water according to each individual's rights.

The first *Aflaj* inventory project was carried out in 1997 (results reported in 2001) and showed that the total number of Falajs found was 4112, of which 3017 were operational. The inventory concludes that the total discontinued or dead Falaj was 1004, and mostly were of the Gaili type with 59% representing the highest percentage from the other types (MRMEWR 2001). This is because this type is a simple diversion and canalization of surface wadi flow, using a shallow aquifer.

Furthermore, the inventory shows that the irrigated areas under Aflaj were estimated as 18536 hectares which represents 30% of the total irrigated area in Oman. In addition to that about 7961 hectares that were under cultivation. However, due to recent drought conditions this area is now cultivated only during excess Falaj flow in a wet season. The total average annual flow from Aflaj is about 552 million cubic meters per year.

Aflaj oases represent the basic income for thousands of farmers in the rural area who are dependent on agriculture for their basic needs. Therefore, changes in the reliability of Aflaj as a consequence of drought and climate change could have serious consequences for the Aflaj oases communities and the country's economic wellbeing.

## **IRRIGATION AND WATER USE EFFICIENCY**

Aflaj represent a long history of traditional irrigation practice which continues to impact on farm water use efficiency. This is because the management and practises are the same even considering recent developments. Aflaj areas are divided according to a smallholder system and utilise earthen canals to distribute the water to manually prepared basins. Many factors contribute to the deterioration of the irrigation efficiency in the Afalaj areas, among which is the 'irrigation by flooding' method. This method contributes greatly to the loss of water through deep infiltration. The use of large basins to irrigate trees results in water waste through evaporation and deep percolation. In addition, weed growth consumes considerable quantities of water. Irrigation is distributed by a complex network of channels; typically the main channel is cemented while others distribution channels are earthen channels which contribute to the high loss of irrigation water. The Ministry of Agriculture estimates losses of water to be about 40 %, mainly from distribution networks and flood irrigation methods.

The water rights in Afalaj are fixed in period but variable in quantity. This is because there is no control on water flow which depends normally on availability of water in the aquifer. Farmers in such a system normally apply the total quantity of his rights to his land, which could be either over or under irrigation requirements. Small extra intervals in each share do not mean much for a farmer however, accumulation of these units means a lot and could be used to irrigate extra land.

Moreover, The falaj continues discharge water day and night giving the farmers inconvenient times for irrigation whereas the fluctuations in falaj water flow from time to time creates difficulties for the farmer trying to invest in new crops. The water rotation cycle sometimes continues over longer than 15 days and this means the trees will be exposed to a severe moisture deficit phase especially in summer conditions which leads to low production levels for permanent crops and prohibit farmers from growing seasonal crops.

## AMLA VILLAGE

*Amla* is a small village located 50 km from the centre of Al Dhahira region and 350 km from the capital of Oman, Muscat.



**Figure 1.** Amla village

The total area of cultivated land is 17 hectare mostly with date palm, some citruses, wheat, Alfalfa, garlic and onions. The village land is owned by 200 farmers each of whom has a small piece of land and shares the water rights of two Falaj with other farmers; Al Qray and Al Kohly. The village suffers from drought accompanied by water management problems. The irrigation cycle has extended up to 15 days in view of the very hot, dry conditions. The irrigation efficiency has been low due to the use of open earthed channels for distribution. The leakage, evaporation and deep percolation from such channels can be very high. Therefore, the production of the village was low and farmers suffered from the high running cost of irrigation and labour, combined with low income. Existing cropping was as outlined in table 1.

**Table 1** Cropping patterns at Amla village before project start

Crops	Date Palm	Wheat	Fodder	Others crops
Area (Hectare)	15	0.8	1	0.2
Total				17

Farmers also grow garlic, onions and other vegetable in small areas for their own use. The selection of *Amla* village for improvement and development was based on several criteria. These included:

- The village suffers from drought, both Falaj irrigating the land discontinue for several months each year.
- There are 3 wells with limited flows to support the village in drought seasons.
- The high interest from some farmers in the village for improvement and development.
- The good cooperation among the farmers especially in the management of the irrigation water and election of Falaj director, or *al Wakil*.
- Basic income for many farmers in the village.
- Good location to be a demonstration project for other villages.

## IRRIGATION WATER

Irrigation in a hot dry climate is characterised by high demand and required throughout the year. The water resources in the village are limited; Falaj Al Kohly has an average of 9 L/s and Al

Qray with 5 L/s. Both Falajs are supported by 3 borehole wells each with a yield of 5 L/s. The wells are used during the drought to support the Falaj supply. Both wells are from the same aquifer; therefore only 2 wells can be run – and for 10 hr maximum – due to scarcity of water in the area. Al Qray Falaj has stopped since 1999 and did not return due to its location in downstream from other Falj (Figure 1). It runs only for a short time after rain storms and during wet seasons. Al kohly Falaj is more productive and runs for several months during the year. Unfortunately there is no record or hydrograph for the Falaj however; the average flow in a wet season is about 9L/s.

Winter is the rainfall season as well as being the start of the cultivation season therefore farmers are benefits from low water requirement and rain water stored in aquifer. The high demand for water is in summer from May to October is characterised by high temperature range between 45 °C as a maximum and 20 °C as minimum.

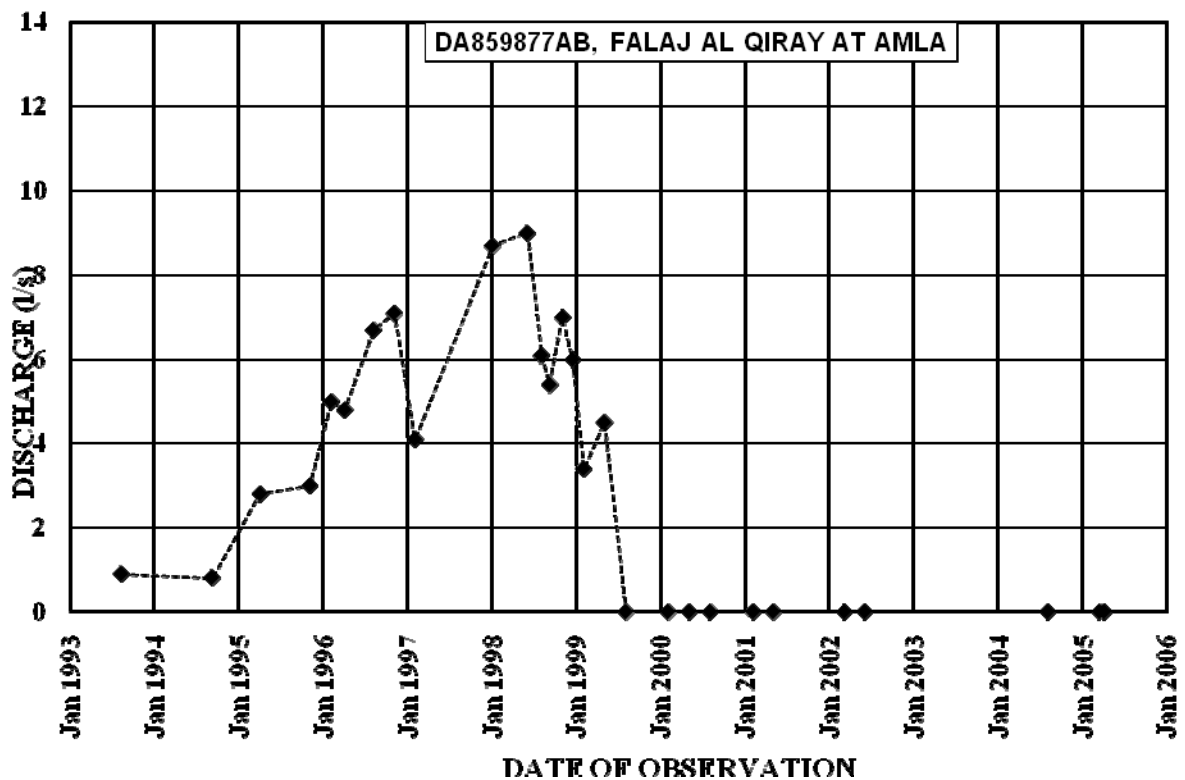
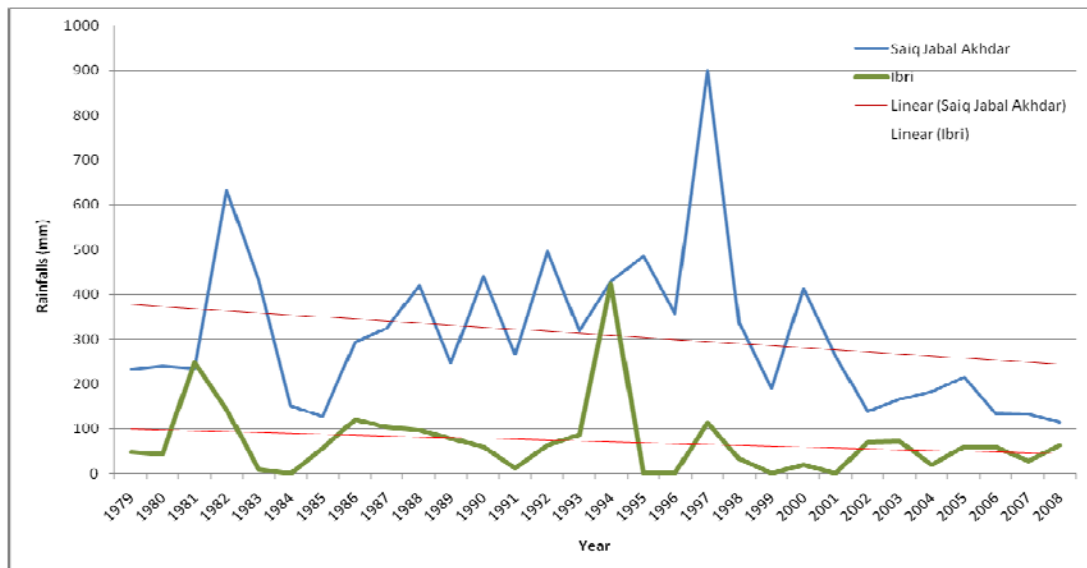


Figure 2. Falaj Al Qray at Amla village hydrograph showing discontinuity of the Falaj

Analysis of rain data shows a negative trend during the last 30 years in the two stations nearest the village (figure 2) and this reflect the scarcity of water in the area and may explain the reduction in two *Afalaj* flows and the complete dryness of the other.

The irrigation by turn is apportioned to the 200 farmers who own land in the village. The distribution is according to their shares; with a recognized water rotation in place. The Falaj water shares are divided on a time basis not on volume of water. Thus, the volume received by each farmer depends on the flow in the Falaj and normally each farmer must adjust the cropping to the availability of water.



**Figure. 3.** Shows total annual rainfall and trend in two meteorological stations (Saiq & Ibrri) nearest to the village

The Falaj system is designed to distribute irrigation water in a manner which is satisfactory for irrigating the main crop, date palm trees, during drought seasons. This crop receives priority in irrigation and occupies the forefront of the cultivated area. In summer the water requirement increases sharply and the Falaj water is totally directed to irrigating this crop. However, in winter extra water can be directed to irrigate seasonal crops which are normally at the far end of the cultivated area. Different types of fodders crops are also cultivated under the date palm trees to satisfy the farmer's needs for livestock, sharing the date palm trees the soil and water

The irrigation turn is completed in 10 days during normal flow of the Aflaj and extends to 16 days in a drought season. The distribution units of Falaj water divided the day into two *Badah*, the local unit equal to 12 hours, and *Badah* is divided to 24 *Athar*; one *Athar* is therefore equal to 30 minutes. This half day *Badah* starts from sun rise to sunset and the night *Badah* operates from sunset to sunrise interchangeably with the next rotation. So each farmer will irrigate in day and night time, assuring equity between themselves.

### CHALLENGES FOR DEVELOPMENT OF AFLAJ

The Aflaj are facing several problems and challenges due to the recent progress and development progress. The change in the current life patterns and attitudes has economically influenced the agricultural societies especially falaj communities. The date palm trees which occupy about 70 % of the cultivation in Aflaj communities have displayed a reduction in economic returns due to the change in the life pattern which requires a good variety compare to the existence old style varieties. Additionally, the poor marketing systems and lack of agri-business is worsening the problem. This change negatively affects the Aflaj area resulting in a low income and reduction in value of the lands.

The small land holding is a major challenge in the village. The total land is divided between 200 landholders with each landholding ranging between 100 m<sup>2</sup> to 4000 m<sup>2</sup>. The economical feasibility of small holdings is very low; therefore most of the production goes into family consumption. Through each coming generation each holding is liable for further division into smaller and more dispersed fragments by the inheriting children. As a result more difficulties confront the system so technical and financial obstacles could lead in the end to a deterioration of the production.

Most of the land holders in *Amla* village are the older generation who are very resistant to change. The agriculture extension centre in the village spent great efforts to convince farmers to accept change. The farmers' concern is that the date palm tree requires more water; and trickle irrigation might not provide such quantity. Several meetings and field trips were organised for the farmers to introduce the trickle irrigation and its benefits for production.

Water rights were a major challenge to improve water management; the farmers concern was about the private owners of Falaj water rights such as investors, endowments and charity, and the Falaj water rights which were typically employed to maintain the Falaj. To solve this problem the agreement was that farmers who do not have sufficient water rights and regularly rent water for their farm continue to rent water and pay the Falaj director according to the latest price. The falaj shares will be used to cultivate Falaj owned land and the return will be used for paying maintenance and electricity bills of the new irrigation system, accordingly the system can be maintained. The excess water accumulated from improving irrigation efficiency will be used to irrigate additional cooperative land and the returns will be distributed according to each farmers' percentage of water rights. Solving this problem was the "green light" for commencing project implementation.

The date palm is the basic cultivation at *Amla* village as with other *Aflaj* communities. It occupies 88% of the village cultivation area. Generally these trees are old and inherited over two or three generations. Most of these trees were from one variety, *Naghal* and other similarly low market price varieties. These trees are planted very close together, with less than 5 m between palms which represents a high cultivation density for such trees (7-10m is the optimum space) – therefore, the yield is low. To convince farmers to remove these palms trees was a very difficult task. However after some time and negotiations, the farmers agreed to remove 1500 low quality palms out of 3300 trees, in two stages with free good variety plants to be provided by the Ministry.

### **PROJECT AIMS**

The main purpose of the project was to sustain the existing cultivation with improvement in quality and productivity for drought seasons. In addition, it would increase the water use efficiency and use the extra water in wet seasons and winter to irrigate uncultivated land in the village consequently improving each farmer's income. Therefore, the main aim of the project was to overcome drought conditions and improve village income through introduce of new technology in irrigation.

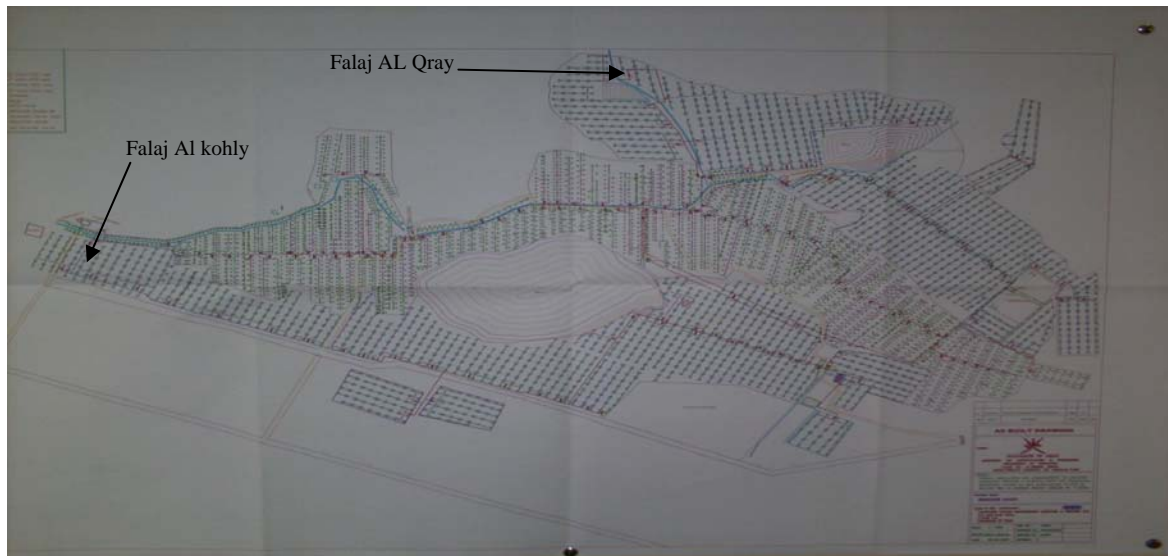
Other specific aims are as follows;

- Improve irrigation water management in the Falaj area
- Increase water use efficiency.
- Set up a complete an integrated irrigation system to collect and use the extra water to increase the cultivated land.
- Improvement of the date palm quality and productivity
- Reduce the labor works and other inputs.
- Set up the project as a demonstration for other Aflaj communities
- Improve farmers income

### **PROJECT DESIGN AND COMPONENTS**

The project design considers water scarcity during dry seasons and reduction of water use in the future. Therefore the design is based on the original cultivated land as priority for irrigation without extension into permanent crops, palms and limes. The design also considers the low flow of *Falaj* and wells, therefore two storage tanks were constructed to conserve the excess water. The storage capacity of each tank was 300 m<sup>3</sup> equipped with automated control units. The design networks are according to figure 4.





**Figure 4.** showing irrigation design for Amla village.

The main components of the project are as follow;

1. Two central control units in each tank; each unit composed of two basic units, a pumping unit and an automated irrigation control unit (Figure 5).



**Figure 5.** The control units of the project

2. The main line with a loop system to reduce the risk of system failure due to main line breakdown.
3. A 'bubbler' irrigation network to irrigate palm trees and ensure adequacy of water and farmers' satisfaction. The total area with this system was 15 hectares. This was the basic cultivation area of the village.
4. A sprinkler irrigation system to cover the farmers' need of fodders, wheat and barley crops. The total area introduced was 26 hectare to be irrigated from excess water during winter and wet seasons.
5. Drip irrigation system for vegetables crops with an area of 1 hectare.





**Figure 6.** bubbler irrigation system introduced to the farmers



*Figure 7 Drip and sprinkler system for irrigating vegetables, fodder crops and wheat*

### **PROJECT IMPROVEMENT IN THE VILLAGE**

To improve village income the project implements the following;

1. Improvement of existing palms cultivation through removal of 350 palms trees to increase spaces between trees and decrease overall density of palms.
2. Improve the quality of date production by planting 1500 (better varieties) of date palm trees to replace the existing poorer varieties and improve market price for dates.
3. Replanting citrus trees as a substitute for the old cultivation and to increase income.
4. Open new roads at the center of the village to facilitate the machinery movement.
5. Double the cultivated area from 17 to 38 hectares through the use of a modern irrigation system.



**Figure 8.** Village improvements

## **PROJECT ACHIEVEMENT**

The project achieves many milestones as follows;

1. Irrigation Water Management
  - The management changed from rotation basis to demand management. The irrigation cycle reduced from 10 days to one and a half days, based on crops requirements.
  - Irrigation water use efficiency improved up to 90% with a modern irrigation system compared to the traditional channels irrigation system which has 40 % efficiency.
  - All water losses saved and used to increase cultivation area and improve village income.
2. Social achievement.
  - More cooperation among the farmers to ensure high productivity for the village.
  - The project reduces the labor requirement from 50 to 1 whose job is to check system performance only.
  - There is no night shift in irrigation therefore farmers enjoy staying with their families.
  - The palm trees diseases decreased due to decreased wetted area in the village.
  - Maintaining the cleanliness of agricultural fields and lower prevalence of grass / weeds.
3. The economic achievement
  - The project almost doubled the date palms productivity after improvements due to reduced water shortage on the crop and a reduced irrigation cycle.
  - The project reclaimed 21 hectare of land to the village using the same water resources hence increasing village income.
  - Improved productivity of per unit area of hectare for Alfalfa crop (288 tons/year) and wheat 2.85 tons per hectare.

The total income of the village in the first year after improvement (2006) as follows:

**Table 2** shows the total income in the first year after improvement project at Amla village

<b>Crop</b>	<b>Area of cultivation (ha)</b>	<b>Cost production of ( USD)</b>	<b>Gross income ( USD)</b>	<b>Return (profits) ( USD)</b>
<b>Date palm</b>	<b>15.2</b>	<b>229622</b>	<b>128554</b>	<b>105591</b>
<b>Fodders</b>	<b>1.4</b>	<b>1638</b>	<b>11788</b>	<b>10146</b>
<b>Alfalfa</b>	<b>8.5</b>	<b>11073</b>	<b>272367</b>	<b>261293</b>
<b>Wheat</b>	<b>12.6</b>	<b>2356</b>	<b>44409</b>	<b>20849</b>
<b>Total</b>	<b>37.7</b>	<b>244689</b>	<b>244726</b>	<b>397879</b>

The total cost of the project was \$US 597,325 completely supported by the government as a demonstration project for farmers in Al Dhahira area. Table 2 shows the net income in the first year of the project, an amount of \$397,879 which reflects the good feasibility for such projects. The total cost of the project will be returned within two seasons. The project also showed improved sustainability against drought in 2007 and palms tree produced a higher yield compared to previous years.

The main aim of the government has been achieved and the message received by most Aflaj farmers is that such an improvement in traditional irrigation system management is successful and has a great effect in improving production and farmers' income. A recent survey in AL Dhahira region shows that 84.2 % of farmers accept the change in Aflaj system while 10.5 % have doubts and only 5.3 do not agree with the change. Conversely, in AL Dhakalih region only 56.3 % accept the change with 18.8 % having doubts and 25% reject the improved Aflaj system. Therefore, the project has a major effect in changing the ideas and concepts of small holders to accept the improvement in traditional Aflaj management and the introduction of new techniques in management and control of irrigation water.

## CONCLUSION

Reliable supplies of irrigation water are essential to sustain Aflaj villages around Oman. Unfortunately, climate change and drought affect these systems causing reduction in flow or even dryness. The drought has caused water crises in many places and makes it difficult to allocate additional sources of water therefore, the focus now is on improvement of water demand management. For Aflaj this includes a highly efficient water transport system and high water distribution efficiency. Amla village project is a demonstration project of applying high technique in central control and distribution system. Implementation of such techniques improves water use efficiency and saves the little water available to the village.

This project helped the farmers to overcome the scarcity of water and return production back to a sustainable level. The project succeeded in attracting farmers' cooperation over water rights and shared excess water, to develop new land for irrigation. The project implements central control of the water according to availability. One main automated unit on each reservoir is used to manage the water and distribute it between crops. The system treats the farmland area as one unit and applies water according to a calculated water requirement. The system achieves 90 % efficiency and use the reclaimed water to expand irrigated land. The reclaimed land is supplied with a modern irrigation system and the total area reclaimed according to the latest *Falaj* history of average flow.

There is a desire to keep the old management practices in Aflaj areas as it is historic and traditional but, this is not a valid argument because most of those Aflaj suffer from drought and show a reduction in their flow or complete dryness in the others. Because of flow reduction exacerbated by employing such old management methods, smallholders, who are the majority in Aflaj communities, lose their basic income as water losses are high, so available of water is limited and does not match crops water requirement. However, with new improved irrigation management and technology, efficiency could reach 90% and all water savings can be used to irrigate additional crops thus achieving higher productivity and income.

The project uses modern irrigation systems such as bubbler irrigation for permanent trees, sprinkler irrigation for fodder and wheat crops and drip irrigation for vegetables. Although, there are several challenges and obstacles to executing the project, the cooperation of farmers with the Ministry was very successful especially with sharing water rights among the farmers which was the traditional problem. The social-economic achievement of the project was high; it reduced irrigation labourers from 50 to one person. The production of date palms almost doubled due to reduced water stress on

trees. The return of the project in first year was more than expected and covered 66% of the overall project cost; accordingly the feasibility of such projects is very high.

This successful project with its new technology and techniques could be employed and transferred to other Aflaj communities thus helping them to overcome water scarcity and improve their economic situation as well.

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