Collaborative Research To Assess the Degradation of Groundwater Resources in Al-Mujaylis, Tihama Coastal Plain, Yemen

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Abstract

Al-Mujaylis, locates within Tihama coastal plain along Red Sea, was initiated to investigate the effect of the changes in agriculture practices and political decisions on groundwater deterioration. The methodology used is a collaborative research based on participatory rural appraisal (PRA). It was found that the area suffer from many problems such as groundwater drawdown as a consequence of rainfall shortage and a decrease in the amount of groundwater recharge. Because of the changes in agriculture practices in the upstream of Wadi Zabid and Wadi Rima', the traditional spate water distribution rights no longer achieve justice between farmers along the wadies.

Key words: Al-Mujaylis, Wadi Zabid and Wadi Rima', Tihama coastal plain, Groundwater, Participatory rural appraisal, Water rights.

1. Introduction

The coastal plains in Yemen suffer from many problems such as desertification and sand dunes movement, seawater intrusions and a sinking groundwater table, among others. These problems are a result of drought and floodwater shortage, changing irrigation practices, as well as the unequal rights of water distributions between the water users upstream and downstream of the wadis in addition to an increasing number of dams in the mountainous areas often built without adequate water management strategies.

Two wadis in the area, Wadi Zabid and Wadi Rima' have seen large scale irrigation projects affecting the flow of spate water. These areas have seen less rainfall over the past decades, and constructions in the upstream areas have resulted in less water in the wadis. This does not only cause trouble amongst the farmers in the wadis themselves, but also for the areas further downstream which face water shortage as a result. Al-Qubatee (2009) has studied the negative impacts of the construction of upstream dams on the downstream areas, which include drought, dried-up wells and water being lost from the dams' reservoirs through evaporation.

One such area is Al-Mujaylis. According to the previous studies Al-Mujaylis, IFAD (2003) and GP-CooCoN (2011), the village suffers from the problems of the coastal plains: desertification and sand dunes movements, and an increase in the depth of shallow groundwater. This has led to increased migration from the area.

The objectives of this study are to know the exact problems in the area, to map the causes and solutions to those problems, to determine if the problems connect to the legal and political decisions and to reach to a recommendations to solve or mitigate those problems in the study area.

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The materials and methods that used in this study are 1) Review of literature about the study area. 2). Collaborative research by using participatory rural appraisal (PRA), using different PRA activities, individual and group interview, discussion groups with different PRA techniques such as direct observation, transect walk, problems and solutions tree, resources map, time line and daily calendar, people ranked the problems according to which, from their point of view, are the toughest and have the biggest effect on them. The study covers the central parts of Al-Mujaylis village (Al-Mujaylis hamlet and its surrounding areas) in addition some parts in Wadi Zabid and Wadi Rima'. 3) Data analysis, semi-structured interviews were analyzed by a set of categories based on the objectives and emergent themes. In addition, respondents defined and ranked the problems and solutions by themselves.

The study area:

Al-Mujaylis village is located in the Tihama coastal plain by the Red Sea, between the end of Wadi Rima' and Wadi Zabid. It consists of ten hamlets, the total population of the village is about 2642 (1328 male, 1314 female), according to the last census in Yemen (Census, 2004). The topographic map are illustrated in Figure 1.1.

Wadi Zabid originates from the area around Ibb and Dhammar (Yarim) in the southern highlands. The wadi flows westward until it enters the Tihama coastal plain and discharges into the Red Sea. Total length of the wadi is about 140km (about 50km from the foothills to the Red Sea gradually sloping from an elevation of 270m above sea level in the East, to sea level in the West (shown in the topographic map in Figure 1.1). The planted area in the wadi is estimated of 17 thousand ha. The annul flow of the wadi is about 135 million m^3. The catchment area of the flow is an estimated 4450 km^2 with an annual average of precipitation of 550 mm (IDP, 2007). The annual precipitation varies from 100 mm in the West to 550 mm in the East.

The geologic setting of the study areas Al-Mujaylis and Wadi Zabid and Rima' which represented by thick alluvial deposit with some exposure of highly fractured tertiary volcanic rocks (as in the geologic map of Robertson Group, 1991, in Figure 1.2. This indicate the possible recharge of the study area by the floodwater flow from Wadi Zabid and Rima' in the rainy seasons. In addition to the recharge by water returned back from the intensive irrigation practices in Wadi Zabid and Wadi Rima in the dry and rainy seasons. This recharge may be affected by the constructed weirs in Wadi Zabid and Rima'. Five weirs were constructed in Wadi Zabid and one weir in Wadi Rima' after the year of 1979.

The management of surface water in Yemen has a long tradition and involves a well-established system of rules (see for example Varisco 1983; Lichtenthäler 2000; Cohen, 1979, 524). There are several different water distribution rules in the wadies (Al-Shaybani, 2003) and (FAO, 2010). There is a general rule *Al-a'la fi-l-a'la* giving upper riparian dwellers the primary right to abstract water according to their need. When they have taken what is needed they let the water pass to lower riparian dwellers (Lichtenthäler 2000, 145).

The current system for distribution of irrigation water in Wadi Zabid was defined by Moslem scholar, Sheikh Al-Jabarti, more than 600 years ago. This rule gives the priority of spate water rights to the people upstream, according to the traditional "al 'ala fa al 'ala" principle. Furthermore the rule divides the upstream waters of Wadi Zabid (the area along 20km from the foothills, at weir 1 in the East of the wadi to weir 5 at the West) among three "groups."

In the dry season there are base flows from Jan. 1st. to Mar. 28th and from Oct. 19th to Dec. 30th (161 days). The rainy season, when the floods come, lasts from March

29. to October 18. (204 days). The spate water is divided among the three groups as follows: The upper part, or group 1, by weir 1 and 2 get the water from Oct. 19th to Aug. 2nd (288 days). This water is used to irrigate 4,805 ha. (27% of irrigated area). The middle part, or group 2, by weir 3 and 4 get the water from August 3. to September 13. (42 days), and irrigate 10,175 ha (60% of the irrigated area). The lower part, or group 3, by weir 5 have the water from Sept. 14th to Oct. 18th (35 day), and irrigate 1450 ha. (8% of the area irrigated) (Tipton& Kalambach, 1974), and (IIP, 2005). What exceeds the needs of these groups will go to the downstream areas or reach the Red Sea, 50 km from the foothills.

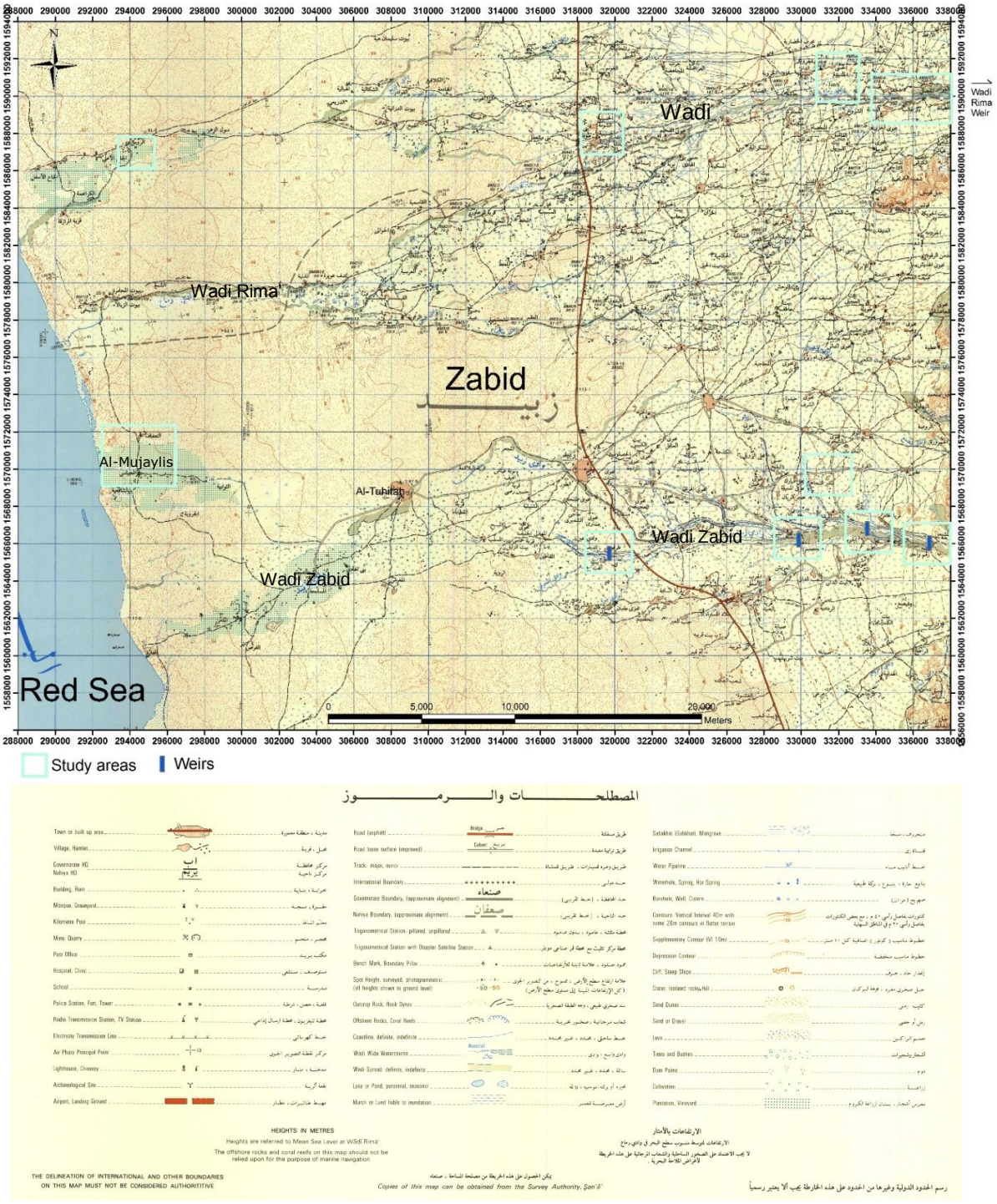

Figure 1.1: topographic map shows the location of the study areas and the diversion structures, part of Zabid sheet no. D38-39 (1:100,000), SA, 1986.

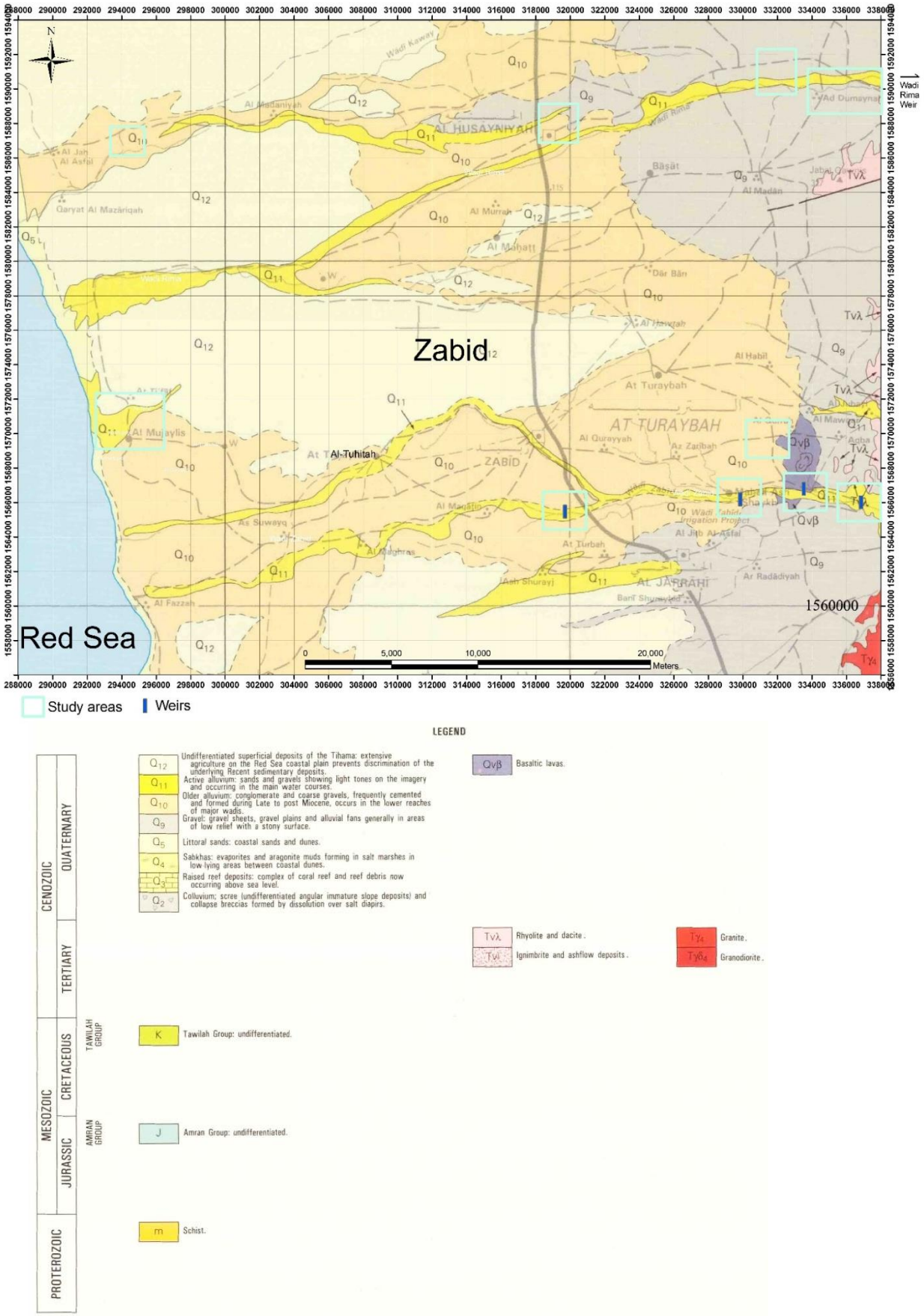

Figure 1.2: geologic map of the study areas, part of Hodydah sheet no. 14F (1:250,000), Robertson Group, 1991.

Wadi Rima' originates from the mountain plains, Dhamar and Raymah. The location of Wadi Rima is shown in the topographic map in Figure 1.1. According to the study done by LRD (1977), Wadi Rima's catchment is about 2900 km^2, most of which (2500km2) lies in broken and generally inaccessible country. The main part of the area which lies below the hill front of Wadi Rima' comprises an extensive alluvial fan and plain with few impediments to cultivation except toward the coast where there is extensive dune field and areas of salinity and alkalinity. The mean annual rainfall is probably no more than 350 mm at the hill front, and nearer 100 mm at the coast. Evaporation exceeds 2500 mm/yr. The mean annual discharge from Wadi Rima' is about 80 million m^3, an estimated 54 million m^3 is diverted onto irrigated fields, and 25 million m^3 passes direct to groundwater (allowing for 1 million m^3 evaporating). This is supplemented by an additional 6 million m^3 percolating through the wadi-irrigated fields including the increment from direct rainfall.

In the 1970s, the government focused on improving the agriculture and public services, and many studies were carried out which resulted in the construction of many diversion structures and canals in many wadies on the Tihama coastal plain. One of these diversion structures (weir) was constructed at the foothill of the mountain area of Wadi Rima' in 1983.

"The system consists of one a diversion structure, main supply canal, a division structure, an inverted syphon and two canal system on left and right sides of the wadi. The main supply canal, after about 5 km is divided into the North and South Bank Supply Canals, of 5 and 10 m^3/s respectively. An inverted syphon, containing two steel pipes 1.2 m diameter, conveys the flow across Wadi Rima'. Eight primary canals off- take from the South supply canal and five from the North Supply Canal." (TDA, 1988).

2. Results and discussion

2.1 The problems in Al-Mujaylis area

These problems varied from more local problems such as poverty, vegetation problems, sinking groundwater levels and sand dune movement, to the more regional problems such as rainfall shortage and problems of groundwater recharge. The problems were ranked as following: poverty, rainfall shortage, Prosopis Juliflora, decreased groundwater recharge, drought and sinking groundwater table, desertification, socio-economic situation and migration.

2.1.1 Poverty

All people agreed that the problems of water resources in their areas first and foremost are because of poverty. While it is true that the groundwater levels are sinking, they are still not very deep (around 9 m to 12 m), but they cannot afford the cost of rotary drilling down to 40 m to 50 m in addition to the pumping machine, and the engine.

2.1.2 Rainfall shortage

The second problem that people agreed on was rainfall shortage. In the past, the rainfall was heavy and had more frequency than nowadays. The spates, which used to reach the area are caused by rainfall directly, and have decreased significantly in the past thirty years due to lack of rainfall. Besides the actual shortage in rainfall compared to previous years, the shortage in spate water around the area (due to interception by weirs and dams) decreased the recharge amounts for the groundwater aquifers, causing groundwater level drawdown, and might give the impression of droughts compared to previous years.

2.1.3 Fast and heavy spread of Prosopis Juliflora trees

The third problem that people face is the increasing numbers of the Prosopis Juliflora trees in their areas. This kind of tree spreads quickly and heavily and has deep roots which suck the water from a large surrounding area,affecting other nearby plants such as palms trees. Therefore, the trees will remain green even when neighbouring palm trees are dead. It was noticed the Prosopis Juliflora had spread over a large area in Al-Mujaylis. The photos in figure 2.1, show the clinic center (photo A) and dry and dead palm trees (photo B), both surrounded by Prosopis Juliflora.

Figure 2.1: Photo A: The clinical center surrounded by Prosopis Juliflora. Photo B: Dead palm trees surrounded by Prosopis Juliflora.

2.1.4 Decreased groundwater recharge

Groundwater is the main source of water for drinking, domestic and agricultural purposes (livestock and irrigation). There are three types of wells in Al-Mujaylis: dug wells with depths ranging between 8 m - 15 m, borehole wells and borehole dug wells with depths ranging between 40 m – 70 m. We were told that the two wadis do not have branches to ther area. Wadi Zabid and Wadi Rima' flow South and North of Al-Mujaylis village respectively and discharge into the Red Sea. The nearest branch of Wadi Zabid is Al-Nasary canal, and the nearest place of Wadi Rima' is Al-Tur.

A few people mentioned that some interventions and changes in agricultural practices upstream of the wadis might affect the amount of water flowing downstream, which would in turn recharge their area. For example the construction of diversion weirs and dams in the mountains upstream of the wadis, as well as the changes in agriculture practices such as crop pattern change and increased agricultural areas irrigated by flood irrigation.

Al-Mujaylis is part of the Tihama coastal plain which is characterized by thick alluvial deposits and is the best aquifer in the country (DHV, 1988). The thickness of the quaternary upper part of the alluvial deposits in Tihama is 50 m – 200 m while it reaches 3500 m for the lower sequence (shallow marine deposits) of Tertiary (Miocene) age. In the middle part of Wadi Zabid and Wadi Rima', beside the alluvial deposits, there is some highly fractured tertiary volcanic rocks exposure (as seen in the geologic map of Robertson Group, 1991, Figure 1.2.

This draws a picture of the possible recharge of the study area by the floodwater flow from Wadi Zabid and Rima' in the rainy seasons, as well as the recharge by water returned from the intensive irrigation practices in Wadi Zabid and Wadi Rima' in the dry and rainy seasons. The recharge may decrease as result of the constructed weirs in Wadi Zabid in 1979 (five weirs) and the single constructed weir built in 1983 in the

upstream area of Wadi Rima'. Possible evidence for this is that the groundwater table has changed from 0.5 m to be 12 m, but the water is fresher than in the past, both according to the people interviewed and the recent electric conductivity (EC) which is between 800 µs|cm to 1800 µs|cm (NWRA, 2006). Other evidence that the water salinity was higher in the past is that people only farmed date palms as the trees tolerate harsh weather and high levels of water salinity reach to 6000 µs|cm. Beside that it is mentioned by the LRD study that the soil is saline-sodic soil (LRD, 1977), suggesting the water is now below this soil.

2.1.5 Drought and Falling Groundwater Levels

As a consequence of the above mentioned problems, the area is facing drought and groundwater level drawdown. The older men and women said that fifty to sixty years ago, water was found at depths of less than 0.5 m. At that time, if you dug a shallow pit by hand or when the wind blew away palm leaves covering the ground, one would find water. Therefore, people used their hands or animals such as cows to plow or dig small holes in their field or house to access the water. Farming practices differed as well, and palm seeds were sowed and would grow directly without requiring more labour. The productivity of the palms trees was at its maximum rate of 40 kg to 50 kg from one tree in a season. Livestock were present in abundance at that time as well as some wild animals such as deer.

The groundwater levels dropped to 5 m – 8 m between 1985 to 1990, and reached 9 m in 2000. Nowadays, the groundwater table is at a depth of 12 m in Al-Mujaylis hamlet and the surrounding areas. This level increases or decreases with a few meters towards East and West respectively. As the level of the water drops, people increase the diameter of the wells to install pumping machines a few meters down in the well to enhance the pumping pressure.

In the past, people used a bucket to lift the water from the shallow wells. Then they changed to small pumping machines (oil machines) to get the water from a depth of 5 m, and after that they changed to Hindi diesel pumping machines to lift the water from depths of 8 m. Nowadays, people have to drill tube wells or to deepen their wells and install modern water pumping machines (pump machines with engines) to get the water from depths of 12 m to 30 m. Photos A, B, C, and D in figure 2.2 shows the different water lifting techniques which reflect the changes in groundwater levels. Most people cannot afford the cost of rotary rig drilling, and the dug well drilling is not possible because of the high thickness of alluvial deposits which are dangerous to dig as they may collapse. They sometimes use local techniques to deepen the wells by using iron cases (8 m length) which are pushed inside the dug wells by hammers, and the deposits are pumped out of the case by suck pumps. This method does not always succeed because the casing sometimes hits big stones and cannot penetrate the earth further.

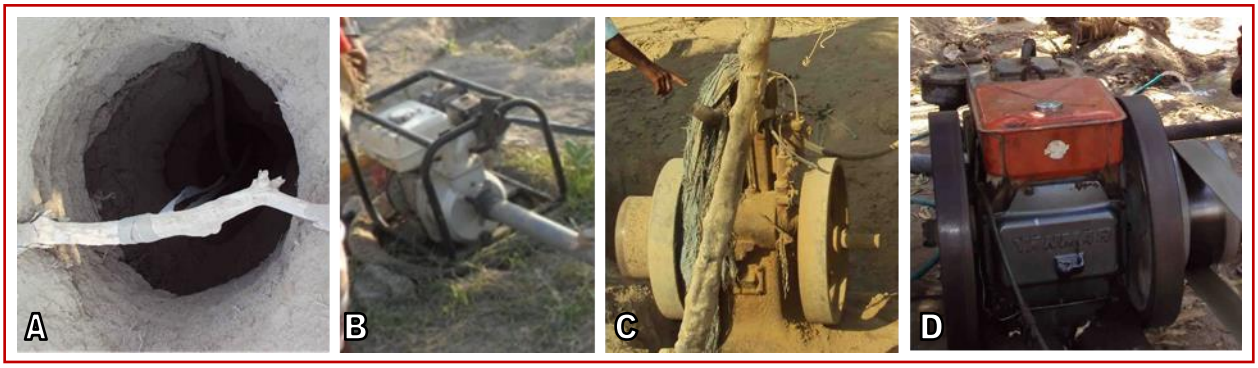

Figure 2.2: The changes in the water left techniques as a result of continuous groundwater drawdown. A: bucket, B: small oil pump, C: Hindi diesel pumping, D: pump machine with engine

2.1.6 Sand dune movement and increased desertification

Sand dune movement presents a big problem in Al-Mujaylis. The sand dunes started to cover some palm tree farms between 1985 and 1990. Most people interviewed, agreed that the sand dunes cover 50% to 70% of the areas. The desertification started from the south of Al-Mujaylis toward the North. The hamlets Al-Shafeiah and Al-Groubah are completely invaded by sand dunes. The sand dunes are now moving towards the central parts of Al-Mujaylis village, toward Al-Zakham and Al-Mujaylis hamlet and represent a catastrophe. Figure 2.3 shows some sites from the area. Photo A shows the palm trees in Al-Zakham hamlet completely covered by sand dunes reaching 10 m in height. Photo B shows the other green palm farms which will be covered by sand dunes. Photo C, shows the beginning of desertification at some sites in Al-Mujaylis hamlet. Photo D shows the areas in Al-Tefaf hamlet (North of Al-Mujaylis village) which still have not been invaded by sand dunes.

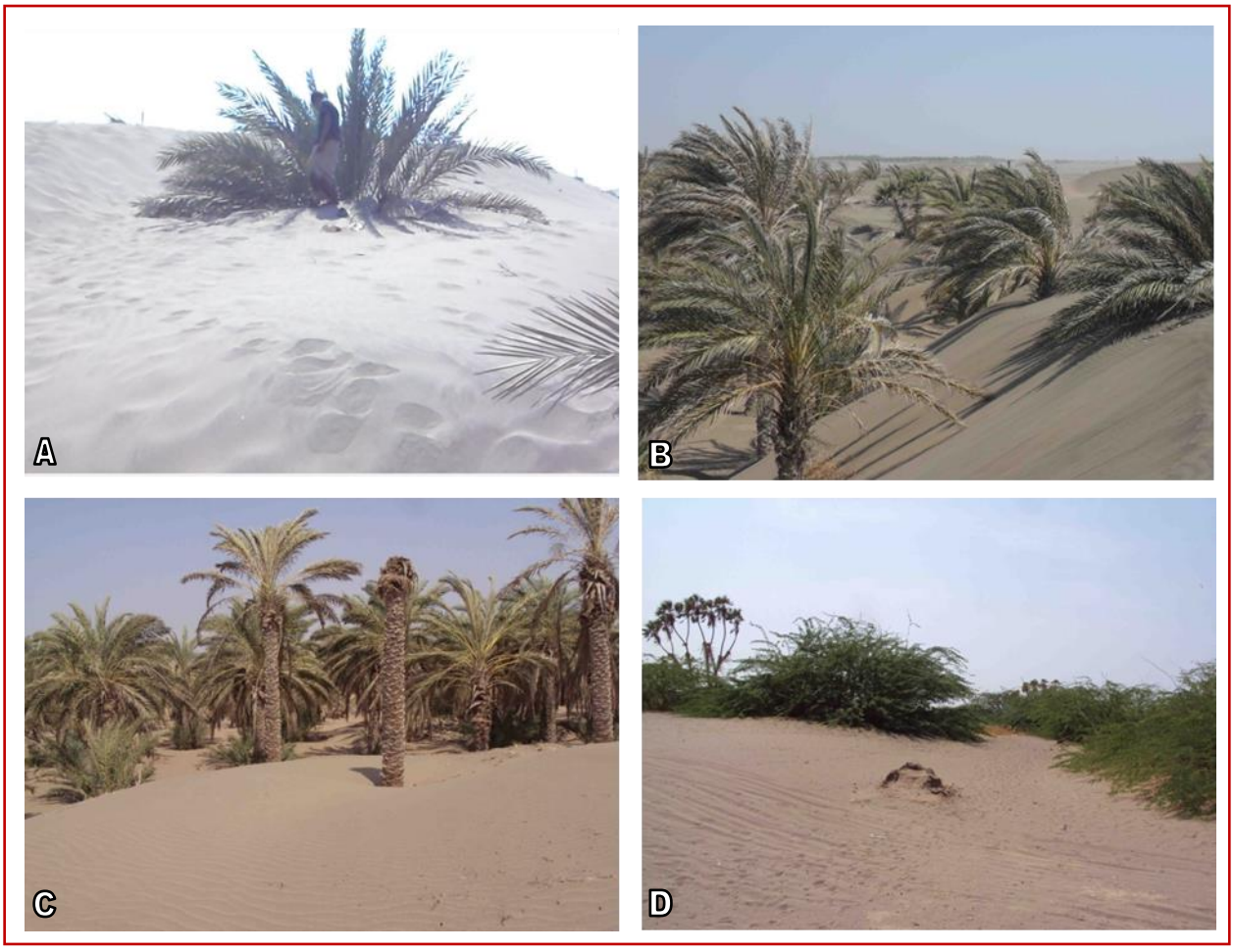

Figure 2.3: photo A: the palm trees in Al-Zakham hamlet completely covered by sand dunes. Photo B: green palm farms in the process of being covered by sand dunes. Photo C: the desertification moving towards Al-Mujaylis hamlet, photo D: areas in Al-Tefaf hamlet still not invaded by sand dunes.

People try to prevent this disaster by building walls of palm leaves and increasing the height of existing walls, but the sand dunes pass through. Figure 2.4 shows some of these attempts. People said that the sand dunes come from the Red Sea coast. This may be because of the seasonal wind which moves from Southwest toward Northeast.

Figure 2.4: Some palm leaf belts made by people to stop the sand dunes' movements, without success.

2.1.7 Scio-economic situation

According to a key informant, 85% of the people in the Al-Mujaylis area, are living in extreme economic poverty and the other 15% living in moderate economic poverty. The houses in Al-Mujaylis hamlet are straw houses or concrete brick houses. There is a drinking water project there but there is a weakness in the construction of the pipe network.

Regarding social infrastructure there are two schools. Al-Shate school in Al-Mujaylis hamlet, a primary and secondary school, was built by the Social Fund for Development in 2009 and Al-Fateh school in Al-Tefaf hamlet, a primary school, was built in 2010 by the Public works Project (PWP). There is also a small medical center but it was surrounded by the Prosopis Juliflora trees and is no longer operational. The land is owned by the people living on it. The value of the land went up after the coast road, which passes West of Al-Mujellies and links Hodeida governorate with Taiz governorate, was constructed and paved.

Agriculture has been the main source of income for people in Al-Mujaylis but as a result of the deteriorating environmental situation in the region, many have had to look for other work. The lack of rain, falling water tables, drought, sand dune movements and the spread of Prosopis Juliflora has impacted heavily on agricultural activity. Some people have left the area in search of a better source of income or turned either to fishing, working as daily workers, bus drivers or motorcycle driver.

People in the Al-Mujaylis area only farm date palms and some fodder for their animals. In the past, palm tree farming generated a good income. Production of dates cost 2500 YR per palm tree a year (for watering, weed control, pruning, control of pests and diseases, pollination, and so forth until it reached the harvesting stage). The trees would each produce 30 kg of fruit which were sold in total for 5000 YR.

Nowadays, the production cost of palm tree agriculture has increased due to harsh natural conditions, and the yield of the palm trees has gone down to only 5 kg per palm tree per year. Besides this, there are the political and economic conditions which cause difficulties, such as the absence of a marketing policy for palm products,

price instability, competition with imported foreign products, and the absence of government support for farmers through loans, marketing or technical support.
As the groundwater continues to fall, people need to deepen their wells to 40 m - 50 m by rotary drilling to reach to the water. The respondents estimated the cost of rotary drilling with casing to about 1 million YR in addition to the cost of pumping machine, engine, and pipes, which are estimated to cost 250,000 350,000 and 200,000YR respectively. One well could irrigate 3000 date palms if it was supported by high efficiency irrigation techniques. The lifespan (depreciation) of a china generator is about two years. With good fruit production and marketing, all cost will be covered after one year. As one respondent said: if the government support framers through white loans (loans without interest rates), the farmers will be able to farm their lands and realise profits.
Although the change of profession to fishing requires substantial structural costs, the daylily fisher generates more income than a palm cultivator during the months suitable for fishing. While the cost of a boat, motor, and fishing gear in addition to operating expenses (fuel, workers, etc.) amounting to 2 million YR or more, people tend to work as daily fishers, with 50% of the net sales going to the owner of the boat and the other 50% for themselves. The average daily income of a family working in fishing is about 5000 YR per day. However, in the windy season (three months every year) fishing is difficult and there is no anchorage for large yachts which are the boats the fishermen use. They also suffer from contract given to large, foreign companies, fishing off Yemen's shore.

2.1.8 Migration

The results of the survey show significant migration from the region to major cities or to the neighboring countries, especially the Kingdom of Saudi Arabia and other Arab Gulf countries. Migration started in the 70s and has increased in the recent years. Respondents said that in the 70s around 10% migrated from the area, while according to LRD (1977) around 40% of the working male population left Al-Mujaylis at this time for employment abroad. Recently, around 60% of the total population in Al-Mujaylis have emigrated according to our respondents.

Many of the international emigrants are among the poor who could not adapt to the difficult conditions in the region, but the poorest people stayed in the area or emigrated to neighboring directorates or cities. This is because of the high cost of emigration to neighboring countries. Illegal migration cost about 200,000 YR and legal migration is far more expensive and comes with numerous restrictions. Therefore, many migrants from the area are illegal.

Most migrants are young men from different families, and it rarely occurs that all family members migrate. The main reasons for migrating were to look for a better and easier source of income, especially after the deterioration of the environment and economic situation in the region. Most of the migrants are now in a stable situation which they deem better than that of the past, and which they prefer because of the availability of education, health services, and infrastructure. The agricultural land owned by immigrants is deserted and in some cases it is being covered by sand. A few of them have sold their land, but there is still a link between immigrants and relatives in Al-Mujaylis through communication and sending remittances.

The immigrants do work that does not require experience or certificates, for example guarding buildings, washing cars, driving busses, and daily wage work. Despite the limited income of these occupations, they feel that their situation is better than before. It is worth mentioning that the immigrants have the desire to return to their country or area of origin if all the problems related to water, sand encroachment and support for farmers are solved.

Those who continued to live in the region were those able to adapt to the situation. They have the possibility to dig new wells or deepen existing wells and buy pumps for drought resistance. Some of them have given up farming and started fishing, and some of them have relatives who are immigrants elsewhere and send the money needed to overcome the harsh conditions and cover their living costs.

2.2 The role of institutions in Al-Mujaylis village

The latest intervention by the government in the area, according to the respondents, is a project titled Tihama Environment Protection Project (TEPP), part of this project in Al-Mujaylis village named by respondent as “Poverty Alleviation and Land Resources Deterioration Reduction?”. According to the Interim Evaluation Report (IFAD 2003) and IFAD, 2010), this project is designed to support poor people in Tihama, consistent with the Interim Poverty Reduction Strategy Paper and the government’s objective of improving the rural population’s standards of living. About 47 villages located between the sand plain and flood plain of Wadi Siham and Wadi Zabid are beneficiaries to this project.

The project’s specific objectives are, amongst others, to prevent further encroachment of sand dunes on to farming land and to increase water use efficiency. The project cost was USD 11.7 million with an IFAD loan of USD 9.8 million, the Yemeni Government contributing USD 1.8 million and the UNDP contributing USD 86 000. The project was implemented by the Tihama Development Authority (TDA). In Al-Mujaylis village, five wells were drilled under this project and installed with pumps, engines, and tanks (except one well which is without pump and engine) to help form a green belt to stop the sand dunes movements, but most people said that this project was not a success.

The people claimed that the reason the project failed was first of all that some of these wells were constructed in the areas where there is no drinking water projects to address the far more pressing need of the population. Also, in some places such as Al-Tefaf hamlet, the sand dunes have still not reached the area. Therefore, one well is utilized for the drinking water project after they get permission from TDA. Secondly, an association has been established for the project, but there is no continuous budget for operation and maintenance. The government covered the cost of diesel, laborers to take care of the trees (irrigate them) and guards for one to two years, but after that the support ended. Thirdly, there is no modern irrigation system for the green belts, so it requires more labour and for this there is not enough money. The other wells are still protected by guards and temporarily used for drinking water, but all trees of the green belt have died.

In Al-Mujaylis hamlet, there is a water project constructed by General Authority for Rural Water Supply Projects (GARWSP), the TDA, and the Local Council, but the pipe network is weak. Currently the network is very small and the water only comes every four days (3 - 4 hours a day) and the pressure is very low. There is a monthly fee for operation and maintenance. Regarding social infrastructure, it was mentioned in the socio-economic situation page 11.

2.3 The role of powerful people in the area

Most people responded that the role of powerful people like parliament representatives, association representatives, sheikhs, and imams in the area is weak, but that everyone acts to maximize their personal benefit. On the other hand, a few people responded that powerful people play a role in solving problems that may arise among the inhabitants and follow up applications to the government institutions to seek projects to the area even if there is no response from these authorities.

Regarding associations in the study area, there is an association responsible for the Poverty Alleviation and Land Deterioration Reduction Project. Most people said that this association failed because there was no financial support for the operation of the project. Because most people are poor they themselves cannot support the associations. One respondent took a different view and said the association did not have any role and was founded only to be “a decoration” to convince donors to implement projects there.

Powerful people were asked about their role and the solutions for all of the above mentioned problems. The response was that each institution should take their responsibility to enhance the situation. Government related institutions should cooperate and find the weak points in the laws (formal laws or tradition laws) and suggest changes or new laws to be discussed and approved by the parliament.

2.4 The role of women regarding water issues:

The study also included women to learn about their opinions and roles in relation to water issues. Most of the interviewed men said that women are responsible only for household work, to bring water from the nearest wells with help from their children, in the cases when the house is not connected the drinking water project or when this project is not functioning. The women do not have a role in any water associations.

Women contribute to the income of the family by producing handicrafts (making ropes for mats and making baskets) and sewing. These products are however sold at very low prices and in some families women spend many hours only to receive a tiny income to help their family. Photos in figure 2.5 shows women in Al-Mujaylis working with handicrafts.

The interviewed women had the same opinion regarding water resources problems and the suggested solutions. Poverty, Persopis Juliflora trees, desertification and sand dunes movements, drought, shortage in rainfall were all problems mentioned by the women. Another problem the women brought up concerned education. There is no separate school for the girls in the area and there are no government employees, especially teachers there. Eight women from the area have graduated from high school, but they have not found employment.

Figure 2.5: A: Group interview with women in Al-Mujaylis. B: Women making baskets.

2.5 The suggested solutions by the community

People in Al-Mujaylis ranked the solutions to their problems as shown in the solution trees. According to them the solutions were the following:

1. To support farmers with modern irrigation systems as there are no modern irrigation techniques in the area. Also, to give loans without interest rates so they are able to drill rotary wells and farm their lands. In relation to this, people said that the role of Cooperative and Agriculture Credit Bank (CAC Bank) which in the past was limited to large-scale farmers and powerful people, now has changed from a cooperative bank to a commercial bank making it even more difficult for them to use.
2. To combat the Persopis Juliflora trees and desertification.
3. To choose suitable locations for the new construction of water harvesting structures (dams) at the end of wadis to benefit from water which otherwise would flow to the sea. Regarding the previous dams and diversion structures, people said that the government should solve the problems associated with those structures so that all people are served by the management of the water.

4. To implement the water law fairly by regulating well drilling and implementing the legal distance between these wells.

2.6 The links between downstream and upstream areas in Wadi Zabid and Wadi Rima'

In Wadi Zabid, the project to improve the irrigation infrastructure in the 1970s changed the control and flow of water in the valley resulting in what many feel is a disruption of the traditional water rights. While there is a general understanding that the current situation harbors potential difficulties, the changes people are experiencing are perceived differently. On the one hand there is the view that the problem is related to the climate and beyond the control of the individual farmers, on the other hand there is the view that some form of control is needed to stop people from violating the system and others' rights.

2.6.1 Changes induced by changing in agriculture practices in the upstream

In the past and until the beginning of the 70s, spate water was the major source for irrigation in Wadi Zabid and Wadi Rima'. The spate water was more or less predictable and benefitted almost all the farmers in the wadis. Then, forty years ago, there was a change in the spate flow primarily because of lack of rain, and a change in the cropping pattern in the region. Where grain was cultivated in the past, now farmers turned to crops yielding significantly more economically, and requiring large amounts of water for irrigation, such as bananas and mangos. Photos in figure 2.6 shows the crop pattern change.

In the upstream areas this led to farmers taking more of the spate water to cover the water needs of their crops at the expense of farmers downstream, in accordance with the Al-a'la fi-l-a'la rule which has been the norm within spate water distribution since ancient times.

The increase in agricultural area and investment upstream also impacted heavily on the water available to farmers downstream. Expanded investments in large mango farms, and the building of dams and canals affected the water distribution rights in the wadi as people upstream were controlling the spate water and restricting the access to farmers downstream.

Figure 2.6: Crop pattern change in wadi Zabid: the photo on the left is of banana farms near weir 3 where there is sufficient spate water; the other photo is near weir 5 is cereals farms where spate water decreased.

2.6.2 Conflicts and cooperation between people upstream and downstream

The people in the upper part of Wadi Zabid and Wadi Rima' are not aware of what happens far downstream. They have many problems among themselves, even within the same canal group, and between the three canal groups in the upper part of wadi Zabid. In the past, before the weirs were constructed and before the banana farming, the people upstream got water by soil diversion structures. These soil structures would, as mentioned, break when there was a flood and the water passed downstream. After the concrete weirs were constructed the pressure from the water could be withstood, and there was no such flood reaching the downstream areas of the wadi. Furthermore, between 2004 and 2006 the body of weir 1 and weir 3 (shown in figure 2.7) were raised by one meter because of sediments which had accumulated in front of it. People downstream were unhappy with this, but on the other hand people on both sides of the weirs suffer from the sediment accumulation in front of the weir.

Figure 2.7: Photos shows the raised body of weir 1 and the current sediment accumulation.

2.6.3 Water conflicts court cases and implementation of court decisions

In the Al-Mujaylis area there are no conflicts between the people over spate water because no branch of the wadis reaches the area anymore. Only two cases were mentioned during the survey which related to land ownership. First, one case that lead to the killing of one inhabitant of Al-Mujaylis. The other case was between the government and one of Al-Tefaf inhabitant. It was related to the land which was taken by the government for the construction of the coast road between Hodeida and Taiz. According to the landowner the government issued a law which stated that all land covered by sand dunes would fall into government ownership; this case is now in the court for the decision.

In the upper part of Wadi Zabid there are daily conflicts over the spate water and many violations of the Al-Jabarti ruling on water distribution rights, both by farmers upstream in the wadi and between the people in the same canal and between groups. Many of these problems were solved by WUAs or the TDA-SA (Tihama Development Authority – Southern Area). One case of strong conflict, still unsolved, is between Al-Mawi on the right side of Wadi Zabid and both Al-Ebri and Al-Jarhazi on the left side.

2.6.4 The roles of WUAs upstream

In the upper part of Wadi Zabid 16 water user associations (WUAs) exist. These associations enhance the distribution of water among the different canals, and decrease the sheikhs' interventions in addition to solving the conflicts between farmers according to some people. The disadvantage is that the role of TDA-SA within maintenance has decreased after the WUAs were created.

2.7 The effect of political decisions

2.7.1 Fruit import ban

A ban on fruit import was issued in 1985 by the government and has, according to the farmers, had a negative effect on Al-Mujaylis village, where the crop pattern is date palm. The effect has been positive in the areas upstream in Wadi Zabid and Rima' where the crop pattern is banana. It was said that despite the fruit import ban, dates are still imported from neighboring countries and this pushes the price of local dates down, while increasing the profitability of water consuming crops such as banana which is exported to neighboring countries. In addition to that, there are also some associations which support the import of dates cost free, on some Islamic occasions like Ramadan.

Furthermore, the absence of marketing for the local dates compared with banana crops and the absence of agriculture farming strategies make the situation worse. In Al-Tuhitah directorate, there is a government date factory which buys the dates from the farmers and manufactures them to be sold in the market. However, the people suffer from the corruption at this factory which lets the factory's staff buy the dates at (100 to 150YR), a price lower than it supposed to (200YR), and for deferred payment.

2.7.2 Diesel subsidy

Most farmers agreed that the decrease in the subsidy on diesel price affected them badly, especially small farmers. On the other hand a few of them said that it is now better than the past when the diesel disappeared from the markets to the black market, but they still hope the diesel price will return to the previous level. A few farmers said that if there is no way to subsidize the diesel price, the government

should support farmers by for example giving them loans without interest rate, farming machines or pumps, farming strategies to stop the crop price going down like stopping fruit import, and by helping farmers export their crops.

The people and farmers did not agree that raising the diesel price would make them conserve more water. Most of them claimed there were many other ways to make people do this, such as raising awareness, supporting farmers by modern irrigation techniques or use a reward and punishment system. They also pointed out that many farms would suffer losses if they irrigated more than required. However, one farmer said that the increase in diesel prices actually forced farmers to plant bananas, as it was the only crop which generated enough money for the diesel. Diesel also affects the small-scale fishermen who use small diesel boats. In addition to that, as mentioned, the government's decision to grant foreign companies fishing licences in these waters has affected the fishermen badly.

2.7.3 The construction of the dams

In the 70s the government encouraged the construction of dams as one method of water conservation, without adequate environmental studies. So many problems appears associated with that dams. People in Al-Mujaylis did not realize what effect the dams and weirs had on the area downstream because their area is locate faraway near the Red Sea coast between the two wadis and there is no direct branch of these wadis to their areas. In the upper part of Wadi Zabid near the weirs, people complain about the dams that are constructed in the catchment areas of Wadi Zabid, in Ibb and Dhamar governorate. Many of them said that these dams, together with wells with motor pumps, reduced the amount of water that flows to Wadi Zabid and to their areas. Many of these dams were constructed for a few powerful people in these mountainous areas in order to irrigate their qat crop. The TDA has raised these problems before the Ministry of Agriculture.

2.7.4 The implementation of the law and court decision

The weak implementation of the laws and of court decisions, with the absence of the principle of reward and punishment, encourages water rights violators to continue their practices and has led to an increase in such cases. Therefore, people in the upstream areas have daily conflicts over spate water. Regarding the other government laws such as the water law, one respondent complained that laws were being implemented in Tihama, but not in other governorates, which suffer from critical water resources problems like Sana'a and Sadah.

Conclusion

People in Al-Mujaylis hamlet do not irrigate their land from spate water now, nor did they do so in the past. They depend on the groundwater which used to be very shallow. The water table was at a depth of between 0.5 m to 1 m, 50 to 60 years ago. Nowadays, the water table has sunk to 12 m in Al-Mujaylis hamlet and the surrounding areas. The quality of the groundwater has however improved and is better than in the past.

People in Al-Mujaylis hamlet responded that they do not have spate water rights because there is not any branch of Wadi Zabid and Wadi Rima' in their areas However, few of them realized that there is an effect on the amount of groundwater recharge in their areas from the spate water shortage in Wadi Zabid and Wadi Rima', due to the shortage in rainfall and the construction of dams and diversions structures.

People in Al-Mujaylis area depend on agriculture for their income; they farm only date palms and some fodder for their animals. In the past, palm farming generated a good income, but nowadays it does not cover the cost of farming because the groundwater lies deeper and they have to spend more money to deepen their wells and buy modern water lifting technology. Furthermore, the fruit import ban, which was issued in 1985 has not been implemented for date import which is still heavy from neighbor countries. In addition to this, the change in diesel price also affects them and there is no support for the farmers in the area: There are no activities for Groundwater and Soil Conservation Project (GSCP) or for Irrigation Improvement Project (NIP) or any organizations, and the CAC Bank has now changed from an agriculture cooperative bank to a trading bank.

As a result of this study, however there is no direct branch of Wadi Zabid and Wadi Rima' to Al-Mujaylis village and other coastal areas like Al-Gah, the environmental degradation is connected historically (negatively or positively) to the political decisions related to the water and agriculture practices. These decisions were started after the 70th. Fruit ban import, diesel subsidy, the irrigation improvements projects by construction of many dams and diversion structures, allowing importing the drilling machine and pumping equipment, weak in implementing the law and court decisions, absence the principle of reward and punishment (to avoid corruptions, mediations, and power people interventions), and shortage in implementation the water law and decrease the centralization.

The traditional water rights and rules of spate water distribution in Wadi Zabid and Wadi Rima' with the recent changes in the agriculture practices do not achieve the equity between upstream, middle stream, downstream and further downstream areas.

Many people in the area are satisfied with the current traditional water rights in Wadi Zabid set down by sheikh Al-Jabarti, because they do not want any violent conflicts, but they are against changes in practices which affected the rule. There are primarily five changes: Firstly, an increase in banana crop farming instead of cereal crops upstream in Wadi Zabid which requires more water as well as irrigation every 15 days with twelve to eighteen crops a year. Secondly, the diversion structures represent a strong control of the water compared to the old earthen dikes, and so does the raising of weirs which decreased the floodwater that goes downstream. Thirdly, repeated violations of the existing rule by some farmers coupled with the week implementation of the law and court decisions. Fourthly, the construction of dams in the mountain areas of Wadi Zabid which decrease the amount of water that reaches to middle stream and downstream of the wadis. Fifthly the weak of related institutions in regulate, control, supervise, enforcement of the water distribution rules. The same is true in Wadi Rima' where upstream water harvesting and irrigation seen as unfair, harms those farming downstream.

Recommendations

In Al-Mujaylis, it is suggested to implement the solutions that ranked by people which are to ssupport the farmers by modern irrigation techniques, marketing their crops or find another cache crops, and cope with desertification and Persopis Juliflora trees. Regarding to what people suggested to help them to deepen their well or to drill deep wells, instead of that it is strongly recommended however to develop effective water

resource management and protection of Tihama coastal aquifers, to ensure the save amount of spate water that reach around the area and recharge the groundwater. That will happen through the solutions that farmers suggested in Wadi Zabid and Wadi Rima' which are:

- As any traditional spate water rights, many people still satisfy with the current rules, so they are recommended to eliminate or mitigate all changes that affected to these rule.
- People suggested to enhance the water rights in the upstream areas such as farmers upstream use the spate for irrigation only once, thereafter letting it pass to the next farm and so on until it reaches the last beneficiary; who that is will depend on the amount of spate. The second spate would then begin from the farmer after the last one to receive the previous spate, and so on.
- Forming a committee consisting of mixture of user organization and local government recommended to be established to study the situation and find best enhancement to the current water distribution rules.
- Distributive justice and law enforcement, and regulating well drilling.
- Supporting farmers with modern irrigation systems.
- Stop the building of harvesting dams in the catchment areas of the wadis and regulate the construction of dams and management of the water in constructed dams. As well as choosing more suitable locations for water constructions.
- Reduce the area planted with bananas by cultivating alternative crops which require less water.
- Raise awareness about the water scarcity and the importance of water conservation.
- Maintaining the status quo, but making sure that the regulations already in place are adhered to, and the law implemented.

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List of figures

Abbreviations and Acronyms

Ala'ala fala'ala	Irrigation spate water rights in Yemen giving the priority to upstream users
CAC BanK	Cooperative and Agriculture Credit Bank
DHV	DHV Consulting Engineers
EC	Electric Conductivity
FAO	Food and Agricultural Organization
GARWSP	General Authority for Rural Water Supply Projects
GP-CooCoN	GP: Groundwater in the Political Domain, CooCoN: A knowledge, research and innovation programme on **Co**nflict and **Coo**peration over **N**atural Resources in Developing Countries.
GSCP	Groundwater and Soil Conservation Project
IDP	Irrigation Development Project
IFAD	International Fund for Agricultural Development
IIP	Irrigation Improvement Project
ILRS	Irrigation and Land Reclamations Sector
LRD	Land Resources Division
NIP	Irrigation Improvement Project
NWRA	National Water Resources Authority
PRA	Participatory Rural Appraisal
PWP	Public works Project
SFD	Social Fund for Development
TDA	Tihama Development Authority
TDA-SA	Tihama Development Authority - Southern Area
TEPP	Tihama Environment Protection Project
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USD	United States Dollar
WUA	Water User Association