COMMUNITY SPATE IRRIGATION IN BADA (ERITREA)

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1. Introduction

Bada is one of the eleven potential sites of spate irrigation in the Eastern Lowlands in Eritrea, irrigating in a god year up to an estimated 2000 ha . This paper describes the traditional organization and spate diversion structures. It analyses the techniques used in diversion and field water management and makes an assessment of the costs involved..

The Bada system is located in one of the most hostile environment of the world, the Danklyl depression – practically on the border with Ethiopia. Bada comprises four core villages using four diversion structures or *Agim*. The area is situated 250 km South of the Seaport of Mitsewae. The elevation of the study area varies from 74 to 106 m below sea level. The co-ordinates of the area are $44^0$33'00'' latitude and $40^0$06'00'' longitude (MoA, 1995). The four core villages include sixteen scattered smaller sub-villages. The sub villages are: Alitemegala, Aylole, Ayrori, Osta, Humeda, Bolele Kebir and Bolele-Arebur in Bolele village; Adigefaito, Barganto Mohaso-Hada and Andela in Erimile village; Bajur-Hazo, Meskertu, Ambusto and Worko in Leinbada village, and Adimurug village itself. Most of the farmers are settled very close to their agricultural field plots.

Population and ethnic group

The people in the four villages of Bada are mainly of the Afar ethnic group with a small number of the Saho ethnic group. They are sedentary farmers.

Table 1: Actual households and estimated population (1996)

Name of village	Households	Estimated population
Adimurug	124	714
Erimile	253	1457
Bolele	289	1665

Leinbada	182	1048
Total	848	4884

Source: MoA, 1996

Ethnically, 598 (95%) of the sample population are Afar, 23 (4%) Saho and only one person is found to belong to another ethnic group. There are five major clans: 224 (36%) Dahimele, 120 (19%) Sheka, 89 (14%) Hazo, 64 (10%) Damihota, 50 (8%) Bolusna and 75 (12%) from other clans (MoA, 1996).

Climate

The climate in Bada is semi-desert and hot. The months November to March are the coolest periods with an average maximum temperature ranging from 20 to 30^{0}C.The hottest months are July and August with maximum temperatures of about 50^{0}C (MoA, 1995). The mean annual potential evapotranspiration in the area exceeds 2000 mm, taken from the nearest representative weather station Metsiwae (MoA, 1997). The average annual rainfall is less than 200 mm.

The winds In Bada are strong and carry cold air particularly in November and December. The winds sometimes carry a large amount of soil, which raise the air temperature. This wind is locally called *Khamesin*. Between December and March the winds blow both from south and north. The southern winds are cool and do not carry soil dusts. In the months of June to August, very dry and hot winds blow. The effects of strong and hot winds are a reduction in soil moisture and an increase in soil erosion.

Catchment area

The source of the water for the Bada irrigation schemes is the Regali river. The floods originate from the catchments of Adi-Keih (Eritrea), Adigrat and Edaga Hammus in Tigray (Ethiopia). The total area of these catchments is about 3855 km^2. The elevation of these catchments is approximately about 2500 meter above sea level. There are no recorded data of annual runoff and peak floods of the river but there is an estimation made by MoA based on empirical formulas. The annual runoff was estimated 117 million cubic meters and the peak discharge estimated 650 m^3 /s. The return period of the peak discharge is not explained.

Soils

The predominant soils of the plains are alluvial silts originating from annual sedimentation**.** This sedimentation of soils has raised the original level ground surface and resulted in a variation in soil depth. According to the interviewed farmers and personal observation during the field research, during one flooding a plot can receive 5-7 cm silt. During one season sometimes, the field can accumulate up to 10 cm silt (Plate No. 1).

The lower part of the plain area is free of salt efflorescence. This area is the main target of agricultural development and is coated with light brown silt and fine sands. These fine elements are of floodwater and other origins. They may represent clayey particles transported by the floodwater towards the most depressed parts of the basins. Winds capable of transporting a heavy load of sand are responsible for the formation of the present active dunes.

Table (2) portrays a summary of data pertaining to recent soil test results of samples from various areas within Bada fields under cultivation

Table. 2: Soil analysis results of samples from Bada (1996)

Sample		**Texture (%)**			Type of soil	EC_e (1:5) mmho/cm	Total soluble Salt meq/ l
Lab Nº	pH	Sand	Silt	Clay			
1	7.68	10	50	40	Silt clay	0.642	0.785
2	7.94	10	68	22	Silt loam	0.316	0.610
3	7.90	20	66	14	‘’	0.316	0.351
4	8.18	58	30	12	Sand loam	0.153	0.490
5	7.96	20	58	22	Silt loam	0.316	0.600
6	7.84	20	62	18	Silt clay	0.316	0.620
7	8.04	24	50	26	‘’	29.330	10.404
8	8.19	14	56	30	‘’	0.642	0.941
9	8.22	10	50	40	‘’	0.316	0.546

Source: An analysis of soil samples, in April 1996, Research Department of MoA, Asmara

Many farmers believe that silt deposits meet the required nutrients for their crop. According to the soil analysis carried out by the Research and Extension Department of the Ministry of Agriculture in April 1996, the pH of the soil ranges from 7.68 – 8.22 with a mean of 7.99, which indicates moderate alkalinity.

Organic matter content of the soil ranges from 0.343 to 1.99% with a mean of 1.2% showing in turn low nitrogen content. Phosphorus content is between low and medium, ranging from 1.52 to 6.96 mg/kg. Fertilising the soil with Diamonium phosphate (DAP) or Triple superphoshate (TSP) at the rate of 100 kg per hectare could correct the deficiency (MoA, 1996).

Geology

The Dankly depression is studied by different researchers and earth scientist involved in the investigation of the Red Sea, Eastern Africa and the Gulf of Aden rift system, a tectonically, seismically and volcanologically active zone. The MoA and MoME (1995) reconnaissance field survey also noticed that the area is highly influenced by seismetic characteristics. Due to these facts the region can be considered as the least preferred area to be recommended as a site for major engineering activities because of their sensitivity to dissolution of limestone rock, which is exposed with fracture.

This makes the Bada area unfit to be site of any huge construction, unless special treatment and precaution measures are made.

Farming system

The total potential irrigable land in the Bada district is 5,537 ha (MoA unpublished paper, 1999). In the study area the actual irrigated area is highly variable, but in a good season it reaches 2000 ha. The agricultural system typically adopted is to plough the land, to construct the *Agim* and to repair the *Bajur* in the period March to April. Flooding the fields and maintenance of the *Agim* accused in July and August. The first crop, usually sorghum, is mostly seeded in September. The actual seeding date depends on the flood arriving. If the flood arrives early, the first crop is installed in August and the crop is harvested in December. If an additional flood is available, the sorghum is usually ratooned for a further two months, although some farmers plant maize. Occasionally, if water is available, planting watermelon follows the ratoon (FAO 1994).

The average yields from the first crop vary between 800-1600 kg/ha from the second or ratoon crop 500-800 kg/ha.

2. Spate system at work

Several indigenous engineering techniques have been developed to divert and use the temporary flows. In general, their occurrence depends on the local topography. Traditional irrigation methods tend to be elementary, but in overall terms are effective. From the interviewed farmers, site engineers and extension agents and from personal observations during the field research, it is understood that in Bada two traditional ways of diverting spates are found.

i. Deflector type low earthen bands;

ii. Weir type low earthen bands

Deflector type low earthen bands, protected with brushwood and stones from the wadi bed extend into the minor bed of the wadi at an angle in a direction parallel to the current.

In this local system of diversion the *Agim* of a relatively short length, (20-40 m) is constructed from earth with tree trunks and bushes or from stones mixed with wood and wadibed materials. The *Agim* projects into the wadi in the form of low spurs or deflector. This structure diverted a portion of the spate flow over the adjacent fields and acts as a safety valve .

The farmers know from their experience whether it is worthwhile constructing their deflector with a strong protection of brushwood and stones or not. Their decision takes into account their dependence on spate water, the reliability of the spates, the command area by the diversion structure and the risk of breaching the deflector during normal spates. This system has a good controlling mechanism as the structure takes water proportional to the wadi discharge. If the flow in the wadi is smaller, then the amount of water diverted through the offtake will be smaller as well. If the flood is very high and beyond the capacity of the offtake, the structure immediately will be breached. This saves the farmers from the destruction of canals and field embankments or *Kifaf*

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The weir type is constructed more or less at right angles to the wadi banks and extending over its full width. In this system farmers construct a diversion structure or an *Agim* from wadi bed materials across the low flow channel of the wadi with the object of diverting the entire low stage of the spate flow to their fields. This type of structure is called in Balochistan *Ghanda* (Steenbergen, 1997) and in Yemen *Ogma* (FAO, 1987).

As there is no prevision for a spillway, the *Agim* is during a large spate either breached deliberately or it is overtopped and breaches by itself often which a major section of the *Agim* is washed away. The demolition of the *Agim* can happen before the whole command area is irrigated. Repairs works have to be carried out as soon as possible after the breaching before the next spate flow arrives, otherwise an additional irrigation is missed. How soon this can be effectively achieved will depend on subsequent wadi flows and the availability of labour and animal power.

Missing a spate flow can have an effect on decreasing yield and sometime leads to the total failure of crops.

Interviews with engineers and extension agents indicate that the construction costs of the traditional systems are relatively low. Human as well as animal labour and local materials like wood and wadi bed material is all what is needed.

Once these structures are washed away, the reconstruction or maintenance costs are in most cases at par with the initial construction costs. Steenbergen (1997), in the case of Balochistan, also noticed that the initial capital costs and the annually recurrent maintenance costs are often the same. He describes that for small to medium size spates the *Agim* can be effective. Medium to large spates result in expending much effort and money with very little benefits as *Agim* is swept away to the desert or to the sea.

This situation is also valid for the study area and according to FAO (1987) in Yemen too. The basic traditional principle is diverting water at low stages and allowing large spates to pass unchecked. This principle has the advantage to control the silt carried by the wadi. The features of traditional intakes that enables them to carry out this function successfully are:

The diversion spurs or bunds are cut or breached when the flows entering to the offtakes become excessive, and thus the very high concentration of sediments, carried by the larger flood flows, are not diverted to canals;

There are no structures in the canals to pond or retard floods and the possibility of sediment settling on the bed is minimised (Camcho, 1987).

The primary canals taking off from the wadi have a large capacity in relation to the area irrigated because of the short duration of spate flows. According to FAO (1987) and Al-Amarani (1998), in Yemen there are no permanent structures and canals for the control and distribution of spate flows in the system. This situation holds true in Eritrea for the Sheeb, Afta and Zula areas (Annex 7). In the Bada area however, there are permanent canals to distribute water from the main canal to each field. The water distribution system will be discussed more in detail in the next section of this paper

The weir and deflector types of traditional diversion spate system can be traced also in Yemen. Van Hofwegen (no date) has categorised traditional diversion methods into three systems, which are free intake, intakes with deflector and weir type diversion system.

FAO (1987) has divided the way of traditional diversion into two systems: traditional deflector in wadi bed and earthen bund across wadi bed. The last one is more or less similar to Bada's traditional system of diversion.

Steenbergen (1997) described in the case of Balochistan two types of traditional diversion systems based on the type of construction: earthen band and brush wood systems.

3. Traditional irrigation structures

Traditional irrigation structures are those structures, which depend on local materials for their construction and are built by the farmers themselves, relying on experience gained through everyday observations and practice and on knowledge descended from their forefathers.

The interviewed farmers, site engineer and extension agents and personal observations during the field research permit to distinghuis in Bada a number of traditional irrigation structures, which have been developed since the establishment of the schemes.

The structures can be classified according to the way they are built and to the purpose of utilisation:

a) Spillway *(Khala)*

Spillways in Bada are called *khala*. According to FAO (1987) they are called *Al - Masakchil* in Yemen. The purpose of this structure is to control the distribution of water entering to the fields. The structure is therefore constructed on the side of the embankments of the field canals. The size of the spillways varies between 1.2 and 3.5 meters. Any discharge exceeding the capacity of the canals *(Bajur)* will return through this structure back to the main canal. Occasionally this type of structure is also built to transfer spate water from one field to another when the difference in ground surface level is relatively high.

Khala is usually built on the earth embankments of the *Bajur*. The crest of the *khala* is covered by grass or riprap to control erosion. The free board of the spillway varies between 40 and 75 cm.

b) Drop structure *(Mefjar)*

Drop structures in Bada are called *Mefjar*. According FAO (1987) they are called *Al – Masagit* in Yemen.

These structures are built in spate canals when:

a canal has a steep longitudinal gradient;

the water is transferred from a higher canal to a lower one;

the water is diverted from one field to another;

The purpose is to dissipate flow energy so that scorning is minimised. The structure is made from with stones interlocked properly and the gaps filled-in with smaller stone. In some cases the drop structure is covered only by grass. The width of these drop structures varies according to the size of the canals; the height varies between 40 to 60 cm.

c) Bajur

The *Bajur* is the canal leading the water to the fields. In Yemen this structure is called *Al-Qaid* (FAO, 1987). In the Sheeb, Afta and Zula areas of Eritrea called *Mesega;* in the study area the name is *Bajur* (Fig No. 4 and 5). In case of water distribution with permanent distributory canals the purpose of this canals, is to delivery water from the main canal to the agricultural lands in quantities proportional to the irrigated areas independent of the size of the flood in the wadi. But in the field to field system it conveys water from the diversion structure or *Agim* to the field directly.

d) *Weshae*

The structure is built on the edge of the wadi to protect the agricultural lands adjacent to the wadi. Beside that this structure is used to silt up plots during the development of new lands. According to FAO (1987) this type of structure is called *Al -Masih* in Yemen. The structure is usually built from stones and the gaps are filled with stones of smaller size. Stones used in construction are usually laid in one plane as a smooth surface to minimise the tangential flood force on the structure.

According the interviewed farmers, this type of structure is also used to control large floods together with the diversion structure or *Agim*. In this situation the structure is constructed at least 10 m upstream of the diversion structure or *Agim*. The purpose of the structure is to reduce the velocity and the strong current force of the floods. The size of the structure depends on the topographical position of the site. In most cases the length varies between 10 and 15 m and the width between 40 and 60 cm at the initial stage. To farmer's experience in the study area, it can be constructed at any interval because the wadi slope is not changing rapidly.

e) *Agim*

An *Agim* in the Eritrea context is defined as the traditional structure, in spate irrigation systems, to divert irrigation water from the wadi. According the interviewed farmers, the word itself inherited from Yemen and was introduced with the introduction of spate irrigation in the beginning of this century. *Agim* is a temporary structure and is susceptible to damage by floods. When it is submerged it generates strong turbulence which makes it susceptible to be washed away. The structure therefore has to be reconstructed after each large flood. This traditional type of structure is made from local materials available near the site, such as brushwood, stones and soil. It is usually constructed across the wadi bed and extends parallel to the current flow along the main canal.

Agim can be divided in five categories according to the construction material:

i. Stone *Agim*

ii. Soil *Agim*

iii. Brushwood and trees trunk *Agim*

iv. Mixed *Agim*

v. Gabion *Agim*

Stone *Agim*

This type of *Agim* is constructed in most cases from the bank of a river. Its main purpose is to guide the wadi into a certain direction. In order to use this type of *Agim* for diverting the floods, firstly big stones or boulders are laid down along a selected line in the wadi. Thereafter they are interlocked by smaller size stones and gravel will be put into the gaps. In turn, they will be pressed by larger size stones. Large trunks will be laid at the upstream side of the *Agim* to resist the hammering attack of the strong current of the floods. According to the experience of the farmers, this type of *Agim* it is not often used for complete diversion due to the permeability of the structure and the fact that it takes a long period of time to be sealed by silt and debris.

The size of the structure depends on the availability of material, the width and depth of the wadi. According the interviewed engineers, extension agent and farmers most have a width of 1 to 3 m and they are 0.5 to 1.50 m high.

The interviews revealed that a for 10 m long stone *Agim* with a height of 1.0 m and 1.2 meter width, 12 camel days (transport of collected stones or boulders) and 35 man/days are needed. The initial cost expressed in terms of money is about 885 Nakfas. They are not easily damaged and are mostly they reconstructed only one time during a normal monsoon season. The maintenance cost is around 50% of the construction costs. The yearly costs for this type of structure reaches to 1245 Nakfas or about 124 US dollars.

Soil *Agim*

This type of structure is made up from homogeneous wadi bed material, mostly sandy soil. It is constructed in places were other materials as boulders, tree trunks, etc. are scarce and only found far away from the site of diversion. The structure is mostly made during low spate flow or before the spate season.

The responses of the interviewed farmers indicate that they do not construct this type of *Agim* when there is a high flood. In case of higher floods during construction, the soil is mixed with brushwood or boulders especially to protect the upstreamside of the structure and the inlet of the diversion structure as shown on plate No. 4. This type of *Agim* has the advantage compared to others types that it can be easily constructed by scooping *(Mejehaf)* the soil available in situ. On the other hand, most of the time the type of soil is sandy, which makes the structure vulnerable to scouring. Therefore farmers put big boulders, tree trunks or bushes on the inlet and on the upstream side of the *Agim* to stabilise the structure. At the bank of the wadi the soil *Agim* is stabilised by planting grass on it. If well protected and stabilised the soil *Agim* could be the best structure to divert water from the wadi.

The required width and height of this type of *Agim* depends on the slope and the ground surface elevation of the selected site of the diversion line . In most cases the structure has width of 1 to 6m and a height of 1 to 4 m.

To the Bada farmers experience, the construction of a soil *Agim* of 10 m long with a width of 3 m and a height of 1 m, needs 8 ox/days (oxen with scoops) and 5 man/. The labour requirements are to plough and to move the soil up wards or to scoop the soil .

If we convert this labour and drought animal requirement in terms of money it totals about 315 Nakfas. This is only the initial cost. Since an *Agim* is reconstructed again and again after each flood, the yearly costs depend on the number and on the strength of the floods. According the interviewed farmers most of the time they reconstruct the *Agim* 2 to 4 times in a normal monsoon or season. So the yearly amount of money needed for this type of *Agim* will vary between 945 to 1575 Nakfas (94 to 157 US dollars).

Brush wood and tree trunk *Agim*

This type of *Agim* is constructed in the middle or at the bank of the wadi and is used to divert part of the stream. Wooden piles (pieces of trunk) make up its core. The brushwood is placed in such a way that the leaves are facing upstream and the sticks downstream. Holes are excavated and the piles are put to a depth of 0.5 to 0.75 meter in to the ground. The holes are then compacted with wadi bed material, and after that the piles are cushioned by brushwood. The piles increase the stability of the *Agim* by their gravity and the brushwood leaves help the deposit of sediments on the upstream side, so the gaps between the piles becomes partially sealed by sill and debris, which reduces the leakage of water through the *Agim*.

This type of structure has the advantage of easy construction if the sites for cutting trees are not far away from the site of diversion. This type of structure is more resistant to the force of the floods, due to its permeability at initial stage, allowing the water to pass through it. The disadvantage of this structure is the fact that a lot of trees are needed, which causes deforestation problems in the area. However, nowadays the sites for cutting trees are very far away (at least one hour walking) and limited in number. For this reason farmers prefer to construct another types of *Agim*.

The field investigations indicate that a typical structure of this type has a width of 0.5 to 2 m and a height of 1 to 3 meters (Plate No. 6). To construct a 10 m long *Agim* with a height of 1 m need 7 pairs- of-ox/days or 7 camel days and 13 man/days. This estimation counts people for a distance of 1.5 km from the forest area to the site of diversion. The initial cost is 405 Nakfas. This type of *Agim* rebuilds 2 to 4 times. The maintenance cost is estimated 60% of the initial cost. The yearly cost ranges from 405 to 1371 Nakfas or 40 to 137 US dollars.

Mixed type of *Agim* (soil, boulders and brushwood)

This type of *Agim*, which has a conical shape, is usually constructed in the middle and the bank of the wadi. It is the most common type of *agim* used in Bada. The core is made by wooden piles (pieces of trunk) cushioned by brushwood (Plate No. 7). The outer part, which is exposed to the flood, is strongly pressed by piles and heavy boulders. The bottom part of the structure is covered by scooping mostly sandy wadi bed material. The boulders increase the stability of the *Agim* by their gravity and the brushwood helps the deposit of sediment and traps the debris carried by the water. According to the interviewed farmers, extension agents and engineers and from observations during the field research it is understood that the construction of such a type of *Agim* starts with the collection of large boulders from the surrounding areas and putting them on the diversion. Then brushwood is brought in and put alongside of the boulders, pressed by stones. Finally, sand, silt and gravel from the riverbanks is scooped and put at the bottom over the structure.

This type of structure typically has a width of 3 to 6 m and a height of 0.75 to 1.2 m. Its main purpose is to divert the whole flood at low stages and part of the flood at high stages. The mixed types of *Agim* have a superior quality in retaining water and they resist the floods reasonably well as they are constructed with a combination of materials. According to the interviewed farmers, this type of structure has been developed not long ago through a trial and error experience. Nowadays, the farmers prefer the mixed type of *Agim* is, not only because of its relatively durability, but also it solves part of the problem of the scarcity of construction materials like tree trunks. Human labour and time requirement is relatively low, although its construction requires more drought animal power than others types of *Agim.*

To construct a 10 m long *Agim* with a height of 1 m and a width of 3 m, the requirement is 10 pairs of ox/days, 4 camel/days and 12 man/days. This type of *Agim* rebuilds 2 to 4 times and the maintenance cost is 405 of the initial cost. The yearly cost reaches 600 to 1560 Nakfas or 60 to 156 US dollars.

v. Gabion *Agim*

This type of *Agim* was not locally known and was introduced by deferent governmental and non-governmental organisations in the study area during 1980's. Farmers said that this type of *Agim* is very strong and less effected by spate floods. The farmer added that, since the construction material is not locally available, they are very expensive to construct with the desirable size on the desired time. But in practice the gabion type of *Agim,* if properly designed, can resist high floods far better than other types of *Agim*. To make proper designs is beyond the capacity of the farmers. Beside that, additional skills such as surveying and masonry construction are necessary. Farmers state that they do not have such skills. Therefor, farmers need assistance from outside during construction, which makes this type of structure even more expensive. This is the main reason why farmers prefer to construct an *Agim* with local available materials. To construct 10 m length of gabion *Agim* of 1 m width and 1 m height, the needs are 3 mason/days with 5 assistant, 10.5 man/days for dislocating boulders and a 10 m long gabion box (1*1.5*1 m). The cost is 3250 to 3900 Nakfas or 325 to 390 US dollars.

Comparison of different *Agim*

The Bada farmers said that the soil *Agim* has minimum seepage and is easily washed away by the floods. Stone *Agim* can resist more than others type to the current force of floods, but it can not retain the water as it is permeable. An *Agim* constructed of brushwood and tree trunks neither resists the force of the flood, nor retains the water. From the interviewed farmers, engineers and extension agents, it is understood that at present the most preferred type of *Agim* is the mixed type. According the perception of the farmers brush wood *Agim* is the cheapest and the easiest to construct, if the distance for cutting trees is not too far away. The farmers said that the gabion type of *Agim* is expensive, but durable. In reality if a comparison is made for longer periods of time, the gabion *Agim* is the cheapest. But as the farmers said, the material is not easily available and the need for additional skills is a large disadvantage of this type *Agim*. Table 3 shows the construction and maintenance of different type of *Agim*.

Table 3: Cost Comparison Traditional type of *Agims*

Type of *Agims*	**Initial cost** in $	**Estimated damage in % of initial cost during normal spate season**	**Number of repetitions of construction during normal spate season**	**Maintenance cost in $**
Stone	**88**	**50**	**1**	**44.5**
Soil	**31**	**100**	**2-4**	**63.5 - 126**
Brush wood	**40**	**60**	**2-4**	**48.6 - 97.2**
Mixed	**60**	**40**	**2-4**	**48 - 96**
Gabion	**325**	**20**	**-----**	**65**

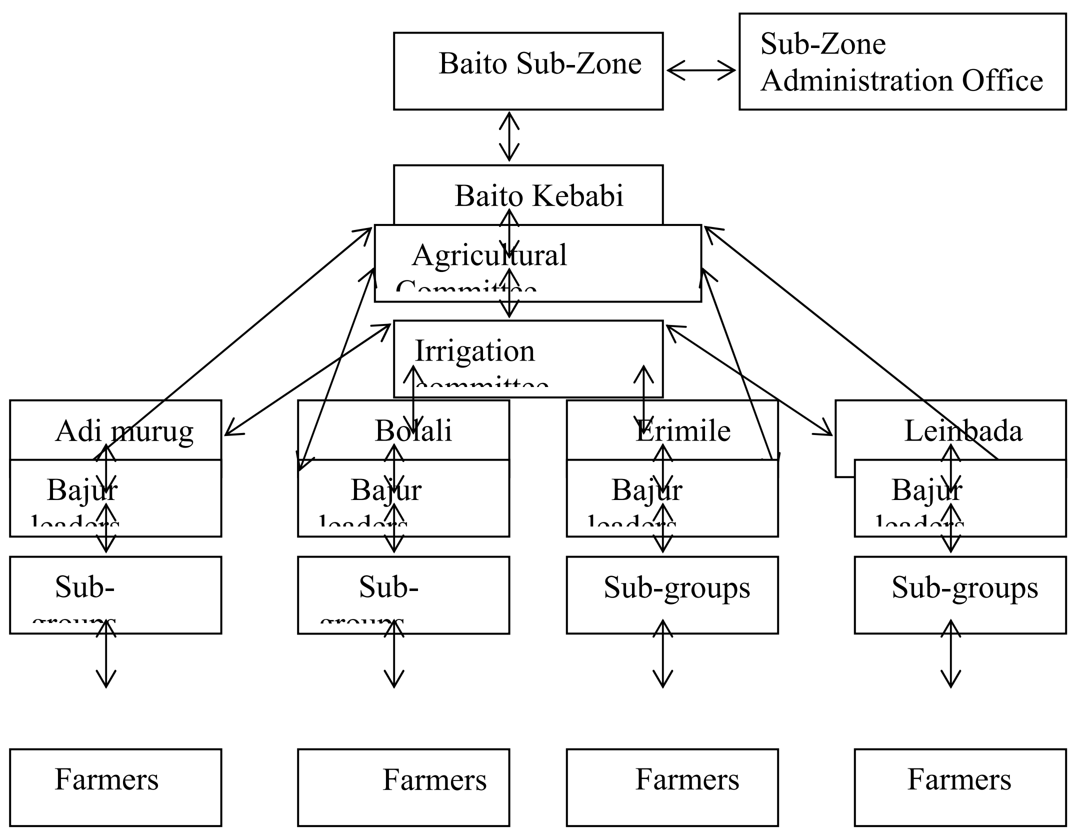
4. Organization and management of spate irrigation

The purpose of this section is to describe the structure and functioning of farmer organisations as the most suitable institutions for the proper construction and maintenance of the irrigation works. The section begins with a detailed description of the existing irrigation institutions in the study area, which have been developed by the farmers over many years, and which enable farmers to manage and organise the construction and maintenance of the existing spate irrigation systems properly. The need for collective labour and collective water management resulted in the fact that the farmers in the study area developed their own traditional organisational structures. Unwritten rules and regulations govern the distribution of irrigation water to their fields as well as the maintenance of the upstream major diversion works commanding the supply of water into the irrigation system. In the beginning of the 1920's, almost all activities were performed by human labour, so it was a very tiresome and time-consuming job. Hence, the farmers started to organise themselves in groups to solve the work burden and they found it very effective. Since 1940 they adopted collective work in the area, which is practised till now in the schemes. The Bada spate irrigation system comprises 4 core villages. Each village has its own diversion structure or *Agim: Agim* Lain Bada, *Agim* Bolali, *Agim* Erimile and *Agim* Adimurug. Lain Bada *Agim* was constructed first and is found upstream of the other *Agim.* The most downstream is *Agim* Adimurug. Although the villages have their own *Agim* they are administrated as one system. In Figure 3 the structure of the farmer organisation is presented.

4.1. Baito (village council)

Baito the most important community-based local institution in the scheme, is the key-link between the community and local administration. Before the *Baito* were established in the early 80's, village councils or *Mahber* existed. They were composed of all male elder and sheiks (the least ones being the leaders known for their integrity and sound judgement). The head sheik of the village or settlement called on the *Mahber* to discuss the major issues affecting the community, such as disputes over grazing territory, agricultural lands, blood feuds and many others problems. When, as the liberated areas came under the control and influence of revolutionary movements, new political structures emerged, which include the younger, enlightened members of the community who supported the independence struggle. The *Baito* then replaced the *Mahber*. The main responsibility of the *Baito* during the war was to secure areas, to mobilise communities for self-rule and self-help and to manage relief and development assistance in the liberated areas. The village council or *Baito* is formed of persons elected by all villagers with voting rights. 30% of the total seats in the *Baito* is reserved for women, apart from the seats obtained after election. An Executive Committee elected by the *Baito* is composed of a chairperson, a treasurer and a secretary. Sub-committees deal with juridical affairs, social affairs and health care, education and culture. Additional sub-committees can be formed according to needs.

Figure No.3: Organisational structure



The establishment of the *Baito* led to significant changes in terms of power relations. Groups of lower strata, including women began to dominate these political institutions. After the war the *Baito* remained an important political power, but its main function became more development oriented than political.

According to the interviewed farmers and *Baito* members in Bada the main developmental functions of the *Baito* are the following:

controlling the construction and the repair of irrigation structures;

organising cash for work activities;

supervising farm input distribution;

facilitating credit for farm implements and drought animals;

identifying vulnerable groups for farm input distribution;

collecting land tax for the local administration;

liaison with the administration in all aspects of community development work.

4.2. Agricultural Committee

The Agricultural Committee (AC) has seven members: two from each of the four villages except for Adimurug which is represented only by one member. The committee has a chairperson and a secretary nominated by the committee members. The Agricultural Committee is the main agent of farmers and acts as a bridge between farmers and governmental as well as non-governmental organisations concerning agricultural activities. The main responsibility and tasks of agricultural committee are

to pass information, directions and support from *Baito* or other governmental organisations to the farmers;

when farmers face problems, which can not be solved by themselves, the Agricultural Committee seeks solutions by consulting the authorised body;

to solve problems that can not be solved by irrigation committee;

to take decisions concerning the distribution of land and problems associated with land tenure;

to set penalties for controversies associated with the distribution of water and land. In addition it informs the *Baito* about controversies that can not be solved by the committee.

The committee remains in charge until farmers feel that new members should be elected.

4.3. Irrigation Committee

The Irrigation Committee (IC) consists of four members, One from each village. Under each village's representative of the Irrigation Committee there are *Bajur* leaders. The main task of the Irrigation Committee is to assess problems that may exist on the *Agim* and to find possible solutions. The committee assesses the kind of work to be done, the human and animal labour requirements for each type work and the kind of raw materials (boulders, stones, soil, brushwood) needed. Another task of this committee is to decide which *Agim* should receive water and for how long. Within the *Bajur* the responsibility to distribute the water is with the *Bajur* leaders, who also give orders to the farmers concerning the maintenance and construction works. The interviews indicate that the work of the Irrigation Committee includes as well the evaluation of previous *Agim* and the selection of a new site. The person elected to this committee should be more knowledgeable than other farmers on the construction and maintenance activities of traditional spate irrigation systems.

A *Bajur* consists of 15 to 45 farmers, the actual number depends on the size of the *Bajur*. Out of the four villages, Lain Bada has the largest number of *Bajur* and the largest irrigable area (Table 4)

Table 4: Irrigable area and number of Bajur

Name of Villages	Irrigable area (ha)	Number of Bajur
Adimurug	170	4
Bolali	580	4
Erimile	460	4
Lain Bada	790	7
Total	2000	20

Bajur leaders mostly accomplish administrative works within their groups. In general, they fulfil the requests for construction and maintenance work from the Irrigation Committee according to the materials, human labour and draught animals needed from their particular *Bajur*. They also fulfil the requisitions after emergency calls from the Agricultural Committee. The *Bajur* leaders have the following responsibilities:

- organising and supervising their group during construction and maintenance
- of the main and sub-system;
- supervising the water distribution within their group and solve any problems
- arising;
- implementing community rules for the management of floodwater;
- imposing fines on those who waste water or steal water from adjacent fields.
- to collect land tax among the individual farmers in the group.

If the (*Bajur*) leaders are confronted with problems which can be solved by themselves, they have to inform the Irrigation Committee. If this committee can not find a direct solution, they send an emergency call to the *Baito* and the Agricultural Committee to discuss the issue. If even at this level the problem can not be solved, the issue is transferred for further solution to the sub-zoba office of *Baito,* but this does not happen often.

Each Bajur is divided into sub-groups. The sub-groups have been formed for administrative reasons and allow information to reach each individual farmer easily. For instance, individual farmers can be member of a specific sub-group, because their houses are in the vicinity of each other, or their fields are situated next to each other. Each sub-group has a leader, who is an important intermediary between the individual farmers in his sub-group and the *Bajur* leader in conveying information and orders of the *Bajur* leader to individual farmers and in submitting messages and requests of the individual farmers to the *Bajur* leader. The sub-group members elect the leaders of sub-group.

The farmers apparently elect their sub-group leader, *Bajur* leader and committee members directly, without any intervention of others. In general, leaders are elected for an unlimited period of time. In order to be elected as *Bajur* or sub-group leader, a candidate should be physically fit, having authority to mobilise the farmers for collective labour and he should be literate. Occasionally illiterate persons also can be elected. The different leaders do not receive any remuneration for their services and they even have to cover themselves all administrative costs involved, such as the purchase of paper and pens. Most interviewed leaders are not requesting any reward for their services, but they would like to see that these costs are refunded.

4.4. Organisation of collective work

The interviews with the farmers and the committee members indicate that before any measure is taken by the committees or *Bajur* leaders they have to organise meetings. Most of the *Bajur* have regular meetings during a year; other *Bajurs* meet only if there is a need. In general, at system level there are four regular meetings during the year. The first meeting is held after the harvest to discus the reconstruction of the *Agim*. The second meeting takes place after the reconstruction work to evaluate the work on the *Agim*. The third meeting is held before the start of the planting season to discuss if *Agim* requires additional maintenance and the measures to take to avoid damage to the crops by pests and livestock. During this meeting the farmers also decided to which fields the water of late floods should be diverted for additional irrigation. The fourth meeting takes place after the planting period to organise the protection of the field crop and to discuss measures to control floods especially in the field to field system. According to the interviewed committee members, the meetings should be attended by at least two-third of all farmers. Farmers absent during a meeting have to accept the decisions made. At system level the meetings are in general organised if there are new issues to be discussed. For routine work, the committees and the Bajur leaders make all decisions. In urgent cases the chairperson of the Agricultural Committee has the authority to give direct orders to the *Bajur* leaders or sub-group leaders

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5 Maintenance and construction of *Agim*

The most important activity by farmers in the study area is the construction and maintenance of *Agim*. Without these structures farmers will not be able to cultivate crops and thus suffer from draught and hunger. All the farmers in this area consider these activities part of their main livelihood strategy.

Farmers start the construction of *Agim* as early as April does, before the wadi starts flowing. The Irrigation Committee (or local engineers as fellow farmers call them) studies the place and they select the site for diversion and the type of construction materials. They also evaluate the impacts of the previous year floods on the landscape features. Observations are made as to where siltation has occurred, which part of the wadi has been widened and to what extent has it been widened. Then they determine the amount of human labour, oxen drawn scoops, camels and materials such as boulders and tree trunks, that are needed for the construction or repair of the *Agim*.

The Irrigation Committee then orders the 20 *Bajur* leaders to bring the required amount of labour and materials. Each of the *Bajur* leaders has the responsibility to bring their members to the destined place on time. This is arranged before the floods start. If the structure fails during a high flood, the Agricultural Committee gives an emergency call and even small children have to participate in maintenance activities. In the construction of the *Agim* everybody in the village should participate except for females heading a farm. After the main diversion structure has been constructed, *Bajur* cleaning and reinforcement of the individual field embankments (*Kifaf*) proceed. The contribution of labour for construction and maintenance work depends on the size of land holding of the individuals and is proportional to that holding size.

For example: if a farmer is having 1 ha of land he is ordered to work for one day, the one who has 3 ha should work for three days. Steenbergen (1997) also noticed in Barag (Las Bela district in Pakistan) that all landowners are expected to participate in the repair work in proportion to the size of their holding irrespective of its location. According to the interviewed farmers this rule has been developed throughout the times and to some extent avoids the inequality in the system. The benefits however, are not proportional to the contributions made because of the inherent uncertainty of spate diversion.

The traditional way of constructing the diversion structure is problematic as they are usually built from soil, brushwood and boulders. They tend to fail several times every season, and have to be rebuilt repeatedly. The unproportional benefit is caused by fact that upstream farmers can irrigate their land several times per season (especially in the field to field system), while the some of downstream farmers may not irrigate at all. In more equitable systems, some landowners benefit from the first constructed *Agim*, others from the second, yet others from the third and so on. Who will benefit from which *Agim* is not known in advance.

Steenbergen (1997) noticed that at the reconstructing of *Agim*, upstream farmers might be reluctant to participate in constructing the later version, unless they can utilise water for a second time. In turn, tail-enders may refuse to contribute to the construction of the initial *Agim*. In the case of Bada all farmers participate in the construction and reconstruction of *Agim*, irrespective of the location of their plot. One farmer from the tail-end said, when asked why he did not terminate his participation since he received less water than others:

"*This system has been used by our fathers (predecessors). We have to take the same path, in the some sprit in order to achieve what we are getting now. Refusing the inherited traditional culture is not acceptable by the community. So we make a comparison and work together. But water is a gift of God no other one is capable to take or to give this natural resource."*

From the above statement can be traced that the basic principle of the system based on labour contribution for construction and repair *Agim.* But the system not provides proportional benefit for all users because of the uncertainty of spates and this situation is acceptable by all users.

5.1 Construction and maintenance activities

Various activities are carried out during construction and maintenance of Agim:

- cutting and transporting bushes and tree trunks;
- dislocating and gathering boulders from the wadi;
- stone quarry and transporting from other places;
- enforcement of *Agim* by scooping the wadi bed materials.

The type of work differs with the type of wadi, the type of *Agim* and the period of the year. During winter, when the level of water is at low stage, the soil *Agim* is constructed and the main activity will be the scooping of wadi bed materials. Farmers participate with their oxen drawn scooping tools, locally called *Mehar*. This activity needs a minimum of two pairs of oxen: one to break the crust of the topsoil and the other one to scoop the soil *(Mejehaf)*. The rental cost per oxen/day is 30 Nakfas (one oxen/day is 4 hours during the hot season and 7 hours in the cool season). Two pair of oxen can make an *Agim* of 5 m length, 0,5 m height and 1.5 m width, if the soil is sandy or silty. Dislocating of boulders takes place before the construction of any type of *Agim*. As mentioned before, even soil *Agim* needs boulders as foundation, and brushwood *Agim* needs boulders to press the brushwood after the alignments.

The interviewed farmers indicate that one person can locate 1 m^3 of boulders per day at the construction site, at a cost of 15 Nakfas. If the quarry site is far away, camels are used to transport the stones. The rental cost of a camel/day is 30 Nakfas. The total cost per m^3 of boulders depends on the distance of the quarry area from the diversion site.

Tree cutting and transporting takes place during the construction of brushwood and mixed *Agim*. This activity is carried out with the help of oxen and camels. The time and the quantity of work depend on the distance of the forest area from the diversion site. If human labour is used to transport, it will take 10 - 15 men to carry one trunk.

According to the interviewed farmers the dislocation and transport of stones and boulders is the most labour consuming activity, followed by the transport of trunks. Farmers said that their oxen have to spend much power to transport tree trunks. Farmers said also that scooping soil (*Mejehaf*) is the easiest job.

The traditional spate irrigation system demands a great deal of labour and large amount of draught power. In general, the availability of labour constitutes a major limiting factor for crop production and for construction and repair works in particular. In Bada, together with the availability of animal power, human labour determines the right time for the construction and the repair of *Agim* and for land preparation activities within the plot (such as levelling, enforcement of *Kifaf* and building the perimeter bunds, locally called *Sheham*). Mostly men and boys above 12 years of age do the reinforcement of the plot embankments, levelling and ploughing and participate in the construction of main *Agim.* Hired labour is only used by those who can afford it. Women are participating only in flooding and harvesting activities. The interviews clearly stated that children's labour is vital to the household. Especially boys are engaged in nearly all activities.

Table 5 below shows the major activities, the months in which the tasks are accomplished, the average number of mandays required to complete the tasks and the persons engaged in the specific tasks. The data are derived from discussions with the farmers and with the Agricultural Committee and can be considered as average for 848 households in the area.

Table.5: Activities and allocation of time in Bada

Activities	Months	No. of work days[1] on each activity	Person(s) doing the work[2]
Construction of Agim	April - June	37	1,4,6
Maintenance of Agim	July- September	48	1,4,6
Field banks & levelling	March- June	28	1,4,6
Flooding fields	July - October	5	1,2,4,6
Ploughing / seeding	August-September	25	1,4,6
Harvesting Main crop	December-January	15	1,2,3,4,5,6
Wage labour	January- February	35	1

1) Working day: from March to August four hours, other months seven hours

2) Persons doing the work: (1) Husband, (2) Wife, (3) Daughter, (4) Son, (5) Neighbor/ relative, (6) hired labour

5.2 Internal rules for construction and maintenance

At present in the study area exist unwritten rules, developed by the farming communities in the past, related to the preparation of land, labour contributions, maintenance of field bunds, construction of *Agim* and non co-operation of farmers. The Agricultural and the Irrigation Committees are responsible to set additional rules when needed and then the rules have to be approved by all farmers at system level. These rules also include fines to be paid in cash, if a farmer does not obey. The rules are as follows:

i. If a farmer is ordered to contribute labour or to bring his oxen with scoop, for the construction or maintenance of *Agim*, but fails to do so, he is penalised. He has to pay an amount of money equivalent to the value of the expected contribution. The treasury of the Baito keeps the income from the penalty and used to cover cash expenses at system level;

ii. A farmer who does not take care of his farm (especially with respect to erosion control, during the first 6 months is liable to pay 30 Nakfas;

iii. if damage is caused by failing to construct the two types of *Kifaf* (outer and inner) the penalties differ:

- a farmer who refuses to construct the inner *Kifaf* is liable to pay 30 Nakfas and should do the work which he was supposed to do or he should pay for the work to be done by others;
- a farmer who knowingly damages the inner *Kifaf* during irrigation is liable to pay 60 Nakfas and should repair the damage or pay for the maintenance cost;
- a farmer who refuses to construct the outer *kifaf* after his leader order, will be fined 60 Nakfas;
- a farmer who knowingly damages or breaks the outer *kifaf* during irrigation will be fined 120 Nakfas. Beside that, he will be forced to econstruct the *Kifaf* or to pay the cost of its repair;
- a farmer who breaks the *Gasbet* will be fined 120 Nakfas. In addition, he will be forced to repair it or pay the costs of its repair;
- if a farmer open the *Gasbet* before the upstream field is fully irrigated, he will fined 30 Nakfas. If, due to the consequence of this action the above field is not irrigated, half of the farm land will be confiscated and given to the owner of the farm land above so that he can plant his crop for that particular cropping season;
- any farmer who does not leave enough space for *Gasbet* on in his farm land will be fined 30 Nakfas;
- any farmer who rejects the orders of a *Bajur* leader will be fined 30 Nakfas;

- any farmer who rejects the order of the sub-group leader will be fined 15 Nakfas.

From the interviews with the farmers, it is understood that actual punishment is often based on the perception of the Irrigation Committee members rather than on the described internal rules. The individual relationship of the farmer with the committee members is also influencing the actual punishment.

5.3. Tools used in the construction and maintenance of agim

Tools used during the construction and maintenance of *Agim* in the study area are scoops and tilling devices made from wood and metal. The scoop is locally called *Mehar* and the tilling implement is called *Sehab*.

The standard metallic scoop size is 40 cm wide and 80 cm long. It has two extensions on both sides for chain attachment and it has a metallic handle. The chain is attached to the yoke of the oxen. This metallic scoop is nowadays replacing the traditional wooden scoop, which has a width of 80 cm and a length of 110 cm.

The wooden scoop has a wooden handle that extends from the centre of the scoop and there are two holes on the two edges of the scoop for the attachment of the yoke. This kind of scoop is scarcer nowadays, because it is hard to find large trunks from which they are made of. Metallic scoops can be easily obtained from the extension agents. Farmers prefer wooden scoops to metallic ones since they are lighter and can be pulled easier by oxen. With a metallic scoop a farmer is forced to scoop small amounts of soil.

The tool used for tilling is called *Sehab*. It is used only on sandy or other light soils. It has a length of 25 cm and a width of 20 cm. The harnessing system is of the double yoke type. This type of harness consists of a beam, which may be shaped to fit the animals' necks. This yoke is utilised with two animals. It is simple and low cost. Serious disadvantage of these types of yokes is that animals of different size may not fit in to the same yoke. The throat fastenings tend to choke the animals and decrease their power, especially when they pull heavy loads.

6. Water distribution system

Traditional floodwater distribution systems in spate irrigation have a universal character. The intakes of the main canals are un gated; thus water flows until the *Agim* is breached. In small command areas, there might be an intake on one side of the wadi only. Where command areas are large and the topography allows irrigation on both sides of the wadi, more intake head works are constructed. A canal is then often subdivided into branch canals on its way downstream.

From the interviews and personal observations during the field research it appears that in the study area there are two types of traditional water distribution systems exists. The first is the field-to- field distribution system without permanent division structures and without canals on field level. It is used in places like Sheeb, Afta and Zula. The second one is the water distribution system with permanent distribution canals on field level and division structures. This type, where fields are irrigated individually, is dominating in the study area.

6.1 Field to field distribution

The main canal or *Bajur* diverts the water to a block of fields. The bunded fields, locally known as a *Seham,* are surrounded by raised earthen dikes. The shortest earthen band is called *Kifaf* and the longer side is called *Sherje*. The size the band in a new developed field ranges from 75 to 150 cm in height and from 100 to 200 cm in width. In older fields the height might reach up to 300 cm and the width up to 400 cm. The *Sehams* are most of the time rectangular in shape and vary in size. Most of them have a width of 40 to 80 m in the down-slope direction and about 110 to 200 meters in the contour direction. Normally a field has one opening to allow water to enter. During irrigation the water will be ponded up till a depth of 60 to 100 cm. Water is conveyed to the next *Seham* by breaching one of the inner *kifaf,* facing the field to be irrigated. So water flows from the top-most field to the next until all fields under the command of a branch canal are covered.

When all the fields in a certain block are watered, the farmers breach the check bund in the *Bajur*. Flow along the *Bajur* continues until it is diverted by the check bund in the *Bajur* commanding the next block of *Sehams*. This process is repeated until the entire spate flow is dissipated. The reliability of getting water through this system is directly related to the distance to the wadi on both flanks and to the distance downstream from the site of diversion. The system is quite effective with regards to sediment transport. Nearly all the sediment carried by the natural wadi flow is conveyed with reasonable efficiency to the fields.

The system has however a number of disadvantages:

- The system operates on first come, first served basis. Furthermore the conveyance and the distribution system is not well developed. The farmers at the top of the system receive a relatively high amount of water, while those at the tail-end receive smaller amounts or even not at all;
- As most of the fields are not well levelled, the water depth in the field is varying. This results in highly varying yields with in one field. Scoring and deposition of spate flow sediments create the unevenness in field level;
- Overtopping of water from one *Seham* to another is eroding the *kifaf*, due to the difference in ground surface elevation between the fields;
- In most cases it is difficult to control erosion, as there are no overflow or cascading structures between the plots.

To produce a fair water distribution in the system the above mentioned problem must be over come. An improvement in the design of the canals distribution and conveyance structure is a viable solution

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6.2. Individual field distribution

Most of the land in the study area has a permanent distribution canal network to convey water from the diversion structure to each field. There is a main canal, which supplies water to the *Bajur*. The width and the length of *Bajur* depend on the extent of the fields irrigated from the specific *Bajur*. In most cases the width of *Bajur* varies between 1 to 3 m. Where the topography is not allowing to supply water directly from the *Bajur* to the field, the water conveyed from the *Bajur* by a smaller canal to the field. This canal is called *Gasbet*. The width of the *Gasbet* varies between 0.75 and 1.25 meters. Each field has an off-take locally known as *Mekfel*, which regulates the amount of water entering the fields. The size of this off-takes varies, but mostly the width is between 1 and 2 m.

Kifaf is a bund constructed for retaining water in side the farmland. There are two types of *Kifaf*. The inner *Kifaf* or *Zebir* is constructed within the plots in case of high elevation differences. With the *Seham* the uniformity of water distribution within the plot can be improved. The outer *Kifaf* is larger in size and is constructed around the entire field to retain the floodwater and to prevent erosion. *Sherje* is the longest side of the embankment. *Mekfel* is the intake in the *Kifaf* or *Sherje*, which allows the water to enter the plot.

6.3 Water distribution rules

Unpredictability is inherent to spate irrigation. Water distribution rules regulate the distribution of the unpredictability water supplies. They impose a pattern and reduce uncertainty by at least regulating the relation between the landowners that have access to flood water. In Bada there exist several types of rules, but in this research they were not studied rules in depth, because of time constraints. Chapter three of this paper describes five categories of water distribution rules for the case of Balochistan in Pakistan. These rules are:

- the demarcation of land that is entitled to irrigation;
- the proportion of the flow going to different flood channels and fields;
- the sequence in which the different fields along a flood channel are watered;
- the depth of irrigation that each field is to receive;
- the practice regarding second water turns.

The first, the second and the fourth rules are not common in the Bada area The third and fifth rules are valid to some extent. In actual practice, additional informal rules and water distribution regulations are applied in the study area.

The third rule is the pre-arranged sequence in which fields are irrigated or which *Agim* will be supplying water to which area. Sequence rules in Bada are called *Dinto* in Pakistan *Numberwa*r (Steenbergen, 1997) and *Rada'ah* in Yemen (FAO, 1987). The sequence usually adjusts to the level of the floods. If the flood is low, the water will only flow in one or two of the priority *Bajur.* But if the flood brings large quantities of water, it will find its way through a large number *Bajur* simultaneously and a large number of fields is irrigated at the same time. Equity issues also figure in the fourth water distribution rule, which concerns the depth of irrigation. There are no rules concerning on irrigation depth in Bada. The last rule is common, by applied and restrict to irrigate the upstream farmers to irrigate for the second turn before all fields downstream have received water.

In Bada there are two types of irrigation water supply are distinguished:

- large amounts of water, loaded heavily with sediments, flowing during the rainy season;
- small amounts of water during base flow in the dry period, relatively free of sediment .

Bada farmers said that the rule used, have been inherited from their predecessors. But in fact the responsibility for the actual water distribution is based on the perception of the Irrigation Committee rather than on the traditional water distribution rules. According to the farmers, the rules are not practised because of the uncertainty of the spate system from year to year or even within one season.

Rules for the distribution of irrigation water are different during the rainy and the dry seasons. During the rainy season, when there is a high flood, the upstream fields receive water first. If the Irrigation Committee believes that there is enough water, the four *Agim* operate simultaneously. But if the committee estimates that the water is not enough or scarce, then the upstream *Agim* are given priority. The Irrigation Committee decides which *Agim* can divert the water and which part of the fields will be irrigated. Not necessarily only the upstream fields are irrigated, b the committee selects also fields in the middle and downstream parts of in the system. The selection of fields is based on the moisture condition of the plots. The first fields to be irrigated are those with the driest soil, not necessarily those that are found in the upstream part. The actual practice takes place entirely informal. There are no rules guiding the committee in this particular issue. During the dry season the flow is limited. Only one field of 1 ha is irrigated for 5 hours only. Farmers who own large fields are allowed to irrigated only one ha. Just in case of there is surplus water, they can irrigate the remainder of their fields after the other fields have been irrigated.

There is no fixed rule with respect to the depth of water to be applied. In the farmers perception, the type of soil and the height of the embankments are similar, but in reality there exist substantial differences in both. The actual depth of water applied reaches up to 60 or even 100 cm during the first irrigation. If there is a growing crop in the field, the applied depth of water will only be 5 cm.

6.4. The in-equity characteristics of the spate system

The risks in spate irrigated agriculture are high and not equally distributed throughout the systems, within the area served by one *Bajur* and within the commend area of one off take. There are fields with high, medium and low probability of irrigation (stenbergen,1997). This probability depends in first instance on the location along the wadi. In the study area the upstream fields take often precedence. The sequence of irrigation depends heavily on the ability to control the flood at any given location. Where the river is deep and its bed is steep, the management and the control of floodwater is precarious because obstructions will not withstand high floods. If floods are moderate, the downstream intakes will be dry and all the water will be diverted by upstream off-takes. Fields that are located in the head reaches of a flood channel usually take priority in diverting water, in particular when the flow in the channel can be controlled and the land is not located far above the bed of the channel. On the other hand if the channel slopes are steep and flows relatively large, the water can not be blocked and a free distribution will take place. Water finds its own way through the command area and low-lying areas will have the largest probability of irrigation. Allocation rules further modify the probabilities. An important allocation rule is the right to a second irrigation.

The internal differentiation in the spate irrigation systems in Bada has several consequences. The most important one is that some lands are cultivated and others not. Another consequence is that cultivated fields receive their irrigation at different times. During an elongated flood season, the high probability lands may be supplied from the early floods, whereas others have to rely on later floods. This situation is also observed in Balochistan (Steenbergen, 1997). Crop choice is determined by the timing of the first irrigation and therefore depends on the highland monsoon rainfall. Variation in crops causes that planting and harvesting activities are spread out and peak labour demand will be lower. It also effects the protection of the crops against birds, particularly Qulea. If a few fields only are planted in a certain time, the fields can be severely attacked by birds and farmers may harvest only small amounts and they may even loose their whole crop. But if many fields are planted at the same time, the problem can be shared and it is easier to protect the crops. Early irrigated fields have the possibility to harvest a main crop and a ratoon crop. The later irrigated ones will have only the main crop. The farmer, whose land did not receive a single watering during the season, may employ themselves as labourers on land that was irrigated. This is particularly true of farmers who own draught animals. Tenancy (most of the farmers in the area are tenants) and seasonal labour are widespread in the area and are partly a response to the differences in income generation in Bada. The question arises if farmers frequently deprived of irrigation and farmers with fields watered during every flood should contribute in the same proportion to the building and the repair of *Agim*. To apply a differentiation in labour input is however very difficult, as it is impossible to weigh the different probabilities in receiving irrigation water and the rules with respect to the right on a second irrigation.

Steenbergen (1997) noticed that in Balochistan all landowners are expected to join with all their draught animals the repair works, irrespective of the size of their holdings and the probability to receive irrigation water. But in the Bada case this is not common. All farmers should contribute according their land holding size, irrespective of the probability to receive water. Construction and maintenance of spate system is often problematic due to these inequities.

It is concluded that to create a more equal water distribution, the spate flow should be better controlled and flood water supply should be more secure. This needs changes in the existing traditional diversion structures and the conveyance system, accompanied by change in the distribution rules.

7. Risk coping strategies in the study area

With crop returns being low, even in good years, and the likelihood of the absence or failure of a crop always there, spate irrigated agriculture makes a precarious living (steenbergen, 1997). Bada farmers have adopted a number of practices to cope with the recurrent setbacks in compensating bad years by good years.

One method can be to save a surplus of grains from a peak year. This self-subsistence strategy is not common in Bada, due to inadequate storage facilities and the hot climate. According the interviewed farmers it is very difficult to keep seeds for more than one year, as over time some strains loose their power to germinate. A more common method of compensating bad years good years, is to sell the surplus crop and invests it in other activities (e.g. trade). In Bada an equally common type of risk coping is the diversification of the household economy. Generally families depend on multiple sources of income. Livestock keeping is usually part of the spate irrigated farming system. Small ruminants in particular, are an integral component of the household production system and often serve as a buffer to overcome dry years. Where possible, animals are foraged on the local ranges and receive supplementary feeding from the stubble, stalks and fodder crops.

Wage labour and tenancy are important sources of family income in the area. There is, for instance, substantial migration to Yemen and Saudi Arabia. So, the risks inherent to spate irrigation in Bada are primarily absorbed at household level and less at community level. At community level two opposite responses are noticed. The first is the insurance strategy, in which labour and means of production are shared to limited extent. The most wide spread manifestation of this strategy in the study area is that fellow villagers borrow draught animals, when they do not have their own. Another, completely opposite community level response, can be summarised as the "dog eat dog" strategy, along the one of a spate irrigation system in Yemen (Dresch 1989, cited in Steenbergen, 1997). In this area, landowners faced with a series of failed crops, were forced to raise cash by selling their land to persons who had been more fortunate. As a consequence, there was a constant turnover of land titles. Persons having good yields during a number of years accumulate land, to lose it again in a series of bad years. In the study area however, this "dog eat dog" strategy is not very common. Land property in most rural communities of Eritrea is not an object of speculation, but rather a birthright.

8. Conclusion

The spate irrigation system in Bada was developed by farmers in response to their needs, at their own cost, independently of any government support. The farmers operate and maintain the system by themselves and there exists a considerable sense of scheme ownership and a spirit of self-reliance among the farmers, which is a sound basis for sustainable irrigation development.

In general the Bada farmers are capable of floodwater management. They have a good experience in construction and repair of the diversion and on-farm structures. The traditional spate practices are still maintained by the farmers. However, the way of constructing the diversion structure and the conveyance system, and the implementation of informal rules and regulation has some disadvantages. Changes to the existing traditional diversion structures and conveyance system will not require major changes in farmer organisation, but it will be necessary to have the farmers' organisations formally constituted as a legal body. In other words, the farmers' organisations have to be registered with the government to be recognised as a legal body. A clear framework of making such registrations needs also to be put in place.

As far as development is concerned, the practices and farmers' knowledge should be preserved and be used as a base for modern practices and scientific knowledge. Collaboration and co-operation between the traditional local practices and possible modern practices are desirable.

Therefore, it is advisable that any intervention program must be careful not to destroy the present culture, as it is one of the major factors for sustainability of farming and livelihood in the study area. Any government policy towards the improvement of existing spate systems should take in to account these traditional practices and should rather be oriented to promote the traditional practices than to introduce totally new practices.

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