Agricultural Water Management in Ephemeral Rivers: Community Management in Spate Irrigation in Eritrea

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Summary

This paper describes the mechanisms that underlie the management of spate irrigation systems. Spate irrigation is a fascinating type of river basin water management, unique to semi-arid environments, whereby floods are diverted from ephemeral rivers to cultivate subsistence or sometimes cash crops. In Eastern Africa the area under community spate irrigation is gradually increasing.

An important feature of the traditional spate irrigation systems is the repeated reconstruction of the diversion structures. The institutional challenge is how to organize the reconstruction and maintenance and how to distribute water in the face of the uncertainties and inequities that are inherent to the spate system. The paper describes and analyzes the local organization and water management rules for the Bada system in Eritrea and argues that the local rules and institutions represent precious social capital, that needs to be nourished in the development of spate irrigation in Eritrea.

Key words:
Spate irrigation, river basin management, water harvesting, ephemeral rivers, maintenance, community management, water distribution, Eritrea.

1. Spate Irrigation in Eritrea

Spate irrigation is a type of river basin water management that is unique to semi-arid environments. Water is harvested from river basins or large parts thereof by diverting

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water from ephemeral rivers. Spate irrigators use the infrequent flash floods in short steep canals, supplying cascades of bunded fields. The objective is to divert as much water as possible during the periods, a few hours to a few days, when spate floods occur. Water is stored in the soil profile. Subsistence crops are common but also sometimes cash crops such as cotton and oilseeds and in some minor areas even vegetables. Spate irrigation is inherently risk-prone. The uncertainty stems from the unpredictable nature of the floods, frequent changes to the river beds from which the water is diverted, and the damage to diversions canals and fields caused by uncontrolled spate flows. Even then in many semi-arid areas spate irrigation is the most cost-effective way to retain and store water and improvements in soil and water management and agronomy have considerable potential to improve water productivity.

This article describes a community spate irrigation system in Eritrea and explores the link between local engineering and organization. It particularly explores the organization of maintenance and the distribution of the variable quantities of spate water. Different from other resource systems the special challenge in spate irrigation is the organized cooperation between water users to manage an uncertain resource – with the likelihood of receiving adequate irrigation varying among the water users itself. Spate irrigation is a relatively new phenomenon in Eritrea. Its introduction is traced back to Yemeni settlers from across the Red Sea 100 years ago. The area presently under spate irrigation in Eritrea is assessed at 14,000 ha, which is a fraction of the area that can be developed, estimated to be between 60,000 to 90,000 ha. As elsewhere in the Horn of Africa the area under spate irrigation is gradually increasing. In Eritrea the water management policy in fact is to develop spate irrigation, both in the Western and the Eastern Lowlands. An earlier strategy of constructing micro dams has been abandoned, because of siltation and storage problems. At present there are approximately 11 areas along the Eastern Lowlands where spate irrigation is practiced to a considerable degree. Bada is one of these sites, irrigating in a good year up to an estimated 2000 ha. It is located in one of the most hostile environment of the world, at minus 115 meter below sea level, the Danklyl depression – practically on the border with Ethiopia. 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 30^0C, but July and August temperatures soar to 50 degrees Celsius (MoA, 1995), exacerbated by strong dry winds, that cause soil erosion and reduce soil moisture.

The source of the water for the Bada is the Regali River. The floods originate from the catchments of Adi-Keih (Eritrea), Adigrat and Edaga Hammus in Tigray

(Ethiopia). The elevation of these catchments is approximately about 2500 meter above sea level. Using empirical formula the annual runoff was estimated 117 million cubic meters and the peak discharge estimated 650 m^3 /s. As in other spate irrigation areas the predominant soils of the plains are alluvial silts, which originating from the heavy sediment loads that the spate flows bring. In Bada one flooding can accumulate 5-7 cm silt on the field. This article first describes the Bada system and the organization that sustains it. It then goes into detail into established practices in maintenance and in the distribution of the spate water supplies.

2. The Bada Spate Irrigation System

The Bada area comprises four central villages, using four diversion structures or *agim.* Using the most recent statistics (1996), the population in Badin is estimated at 4884 persons or 848 families. Most people are of the Afar origin and are sedentary farmers. The agricultural system in Bada is to plough the land, to construct the *agim* and to repair the field bunds (*kifaf)* in the period March to April. Flooding the fields and maintenance of the *agim* takes place in July and August and fields are ploughed to conserve soil moisture. The first crop, usually sorghum, is normally seeded in September. The actual seeding date however depends on timing of the floods. If the flood arrives very early, cultivation may start even in August and the crop may be 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 range between 800-1600 kg/ha for the first crop and an additional 500-800 kg/ha for the second or ratoon crop.

Several indigenous engineering techniques have been developed to divert and use the temporary flows. The irrigation methods are elementary, but effective. They are similar to local structures found in spate irrigation systems elsewhere (van Steenbergen 1997; FAO 1987). Two types of *agim* are common: deflector type low earthen bunds and weir type low earthen bunds. Deflectors extend into the bed of the wadi at an angle in a direction parallel to the current and are protected by brushwood and stones. In Bada they are of relatively short length, i.e. 20-40 meter. If the flood is very high and beyond the capacity of the off take, the structure will be breached. This serves as a safety valve and spares farmers the destruction of canals and field embankments.

The weir type of *agim* is constructed at more or less at right angles to the wadi banks and extends over its full width. In this system the diversion structure is built from

riverbed material extending across the low flow channel of the wadi with the objective of diverting the entire low stage of the spate flow to their fields. As there is no provision for a spillway, this type of *agim* – as with the deflector type - during a large spate is either breached deliberately or it is overtopped and breaches by itself. 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 will decrease yield and can sometime leads to the total failure of crops. Depending on the location and on the availability of material the *agim* can be built of stones, soil, brushwood and tree trunks, gabions or a mixture of materials.

Different *agim*s have different characteristic. Farmers in Bada assess soil *agim* as having minimum seepage, but being relatively easy washed away by the floods. Stone *agim* resist more the force of floods better, but cannot retain water. An *agim* constructed of brushwood and tree trunks neither resists the force of the flood, nor retains the water. Gabion *agim*s are relatively costly to build initially and the material and skills are sometimes difficult to obtain. Table 1 compares the typical construction and maintenance of different type of *agim* in Bada.

Table 1: 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	Annual 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

Apart from the diversion structures, there is an extensive network of flood channels in spate irrigation systems. 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.

The structures in the channel network consist of:

- Spillways
- Drop structures
- Field channels
- Soil retention structure.

Box 1 describes the different structures. The network of flood channels often represents the major local investment and farmers will carefully avoid too much damage either by uncontrolled floods or heavy sedimentation in the channel network. By having traditional diversion structures that are inherently weak and that are washed away in very large floods, uncontrolled water flows into the command area are avoided.

Box 1: Flood channel network structures

Spillway *(Khala)*

Spillways in Bada are called *khala*. 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.**

Drop structure *(Mefjar)*

Drop structures in Bada are called *Mefjar*. These structures are built in spate canals either when a canal has a steep longitudinal gradient; the water is transferred from a higher canal to a lower one; or the water is diverted from one field to another. The purpose is to dissipate flow energy so that scouring is minimised. The structures are usually 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.

Field channels *(bajur)*

The *bajur* is the channel leading water to the fields. The word is also used for the subsections in the command area. In case of water distribution with permanent distributory canals the purpose of the field channel 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.

Soil retention structures (*Weshae)*

The structure is built on the edge of the wadi to protect the agricultural lands adjacent to the wadi. Besides, the structure is used to silt up plots during the development of new lands. 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 to 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.

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3. Organization and Management of Spate Irrigation

As the continuity of spate irrigation strongly depends on collective labour and collective water management and will fail without it robust organizational structures

have developed in Bada. Unwritten rules govern the distribution of irrigation water as well as the maintenance of the diversion works. The system of collective organization came about in the 1940's and has been sustained ever since then. Although the villages have their own *agim* they are administrated as one system.

The organization has a number of outstanding features:

- Strong linkage with local government, creating a continuum between the formal government organization and the informal user organization
- Articulation into smaller groups, that allow face- to- face contact and facilitate the organization of collective labour
- Accepted manner of distributing the uncertainty in water supplies that is inherent to spate irrigation

3.1. Continuum between Local Government and User Organization

In Bada the local council *(baito)* is the most important institution. It is the link between the community and the local administration. Before the *baito* were established as part of the liberation struggle, village councils or *mahber* were in place. The *mahber* were composed of all male elder and *sheikh*s. The head *sheikh* of the village called on the *mahber* to discuss issues, such as disputes over grazing territory, agricultural lands, blood feuds and many others problems. When liberated areas came under the control and influence of revolutionary movements in Eritrea, new political structures emerged, sustained by younger members of the community. The main responsibility of the *baito* during the war was to secure areas, to mobilize communities for self-rule and self-help and to manage relief and development assistance. After the war the *baito* remained an important political power, but its main function became development oriented. The *baito* is nowadays formed of persons elected by all villagers with voting rights, whereas 30% of the total seats in the *baito* are reserved for women. The Executive Committee elected by the *baito* is composed of a chairperson, a treasurer and a secretary. 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.

The Irrigation Committee is a subcommittee of the Baito and extends into the informal organization. In Bada it consists of four members, i.e. one from each village. Under each village's representative there are *bajur (*or irrigation group*)* leaders. The main task of the Irrigation Committee is to assess problems related to the diversion structures. The committee assesses the common 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* (subdivision) the responsibility to distribute the water are with the *bajur* leaders, who also give orders to the farmers concerning the maintenance and construction works. A *bajur* consists of 15 to 45 farmers, the actual number depending on the size of the *bajur*. 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 local rules for the management of floodwater;
- Imposing fines on those who waste water or steal water from adjacent fields.
- Collect land tax among the individual farmers in the group.

If the (*bajur*) leaders are confronted with problems, which cannot be solved by them selves, they have to inform the Irrigation Committee. If this committee cannot find a direct solution, they send an emergency call to the *baito* and its Agricultural Committee to discuss the issue. If even at this level the problem cannot be solved, the case is transferred to the district office, but this does not happen often.

3.2 Articulation into Smaller Groups

The organization is further articulated 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 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 mobilize the farmers for

collective labour and preferably literate. 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.

Before any measure is taken by the committees or *bajur* leaders, they have to organize meetings. Most of the *bajur* have regular meetings during a year. Other *bajur*s meet only if there is a need. In general, at system level there are four regular meetings during the year. The first meeting is typically 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 decide to which fields the water of late floods should be diverted. The fourth meeting takes place after the planting period to organize the protection of the field crop and to discuss measures to control floods especially in the field to field system. The general consensus is that 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 organized 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.

3.3 Fair Rules On Contributions

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. The nature of spate irrigation however is that, different farmers have different probabilities of being served by irrigation. Inequity is hence part of the system and the challenge is to develop rules and practices, which are accepted as fair.

The reconstruction activities are organized by the Irrigation Committee, which 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 cumbersome as the agim are built from soil, brushwood and/or boulders. They tend to fail several times every season (see table 1), and have to be rebuilt repeatedly. The unproportional benefit is caused by the fact that upstream farmers can irrigate their land several times per season (especially in the field to field system), while 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.

Van Steenbergen (1997) noticed in Balochistan (Pakistan) that at the reconstructing of *agim*, upstream farmers might be reluctant to participate in constructing the later version, unless they can utilize 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."*

4. 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; and
- 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 water levels are low, soil *agim* are constructed and the main activity will be the scooping of wadi bed materials. None of the work is mechanized in Bada and 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[3] (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. Transporting boulders takes place before the construction of any type of *agim*. Even soil *agim* need boulders as foundation, and brushwood *agim* needs boulders to press the brushwood after the alignments.

The farmers indicate that one person can transport a cubic meter 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 farmers the 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. Scooping soil (*Mejehaf*) is considered the easiest job.

[3] 1 USD is 13.5 Nakfa

The traditional spate irrigation system demands a great deal of labour and large amount of draught power. A minimum critical mass of human and animal resources is essential. In Bada, this determines the timing of the major activities in the construction and the repair of *agim* as well as that of the field level preparation activities (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 irrigation and harvesting activities, but not in the repair of the diversion and field structures.

Several unwritten rules create a tight discipline in the preparation of land, labour contributions, the maintenance of field bunds, construction of *agim* and non co-operation of farmers. Farmers are highly interdependent and the neglect of someone's field bunds upstream can cause a loss of water to the areas downstream. 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 (see box 2). The rules are best understood as norms and agreed sanctions. Actual punishment is often based on the judgment of the Irrigation Committee members and the rules are not applied rigidly. Reputation and the relations of the farmer with the committee member, influences actual punishment.

Box 2: Penalties in maintenance of distribution network in Bada

- **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;**
- **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;**
- **If damage is caused by failing to construct the two types of *kifaf* (outer or inner field bund) 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 construct the kifaf or to pay the cost of its repair;***
- **a farmer who breaks the *gasbet* (small field channel) will be fined 120 Nakfas. In addition, he will be forced to repair it or pay the costs of its repair;**
- **if a farmer opens 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.**

5. Water Distribution System

In Bada two types of water distribution systems are in existence. The first is the field-to-field distribution system without permanent division structures and without canals at field level. Water travels from one bunded field to another. The second type of water distribution system in Bada has a network of division structures and distribution canals supplying the different fields. This second type is predominant in Bada.

5.1 Field to Field Systems

In the field- to -field system 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 bund is called *kifaf* and the longer side is called *sherje*. The size of a bund 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. This is because the silt that is deposited annually in the field is partly removed and scooped to the field bunds. 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 of the rivers and the distance from the point 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 field to field system has however a number of shortcomings:

- The system operates on first come, first served basis. Furthermore the conveyance and the distribution system are 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 nothing at all;
- As most of the fields are not well leveled, 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 often erodes the *kifaf*, due to the difference in ground levels between the fields;
- In most cases it is difficult to control erosion, as there are no reinforced overflow or escape structures between the plots.

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5.2 Permanent Networks

These shortcomings are avoided in permanent distribution networks. In such areas – most common in Bada – water is conveyed to the fields through separate channels. There is a main canal, which supplies water to smaller canals (*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, water is conveyed from the *bajur* through 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 these off-takes varies, but mostly the width is between 1 and 2mts.

The *kifaf* is a bund constructed for retaining water inside the farmland. There are two types of *kifaf*. The inner *kifaf* or *zebir* is constructed within the plots in case of high elevation differences. In this way water is spread relatively uniform within the plot. The outer *kifaf* is larger in size and is constructed around the entire field to retain the floodwater and to prevent erosion.

5.3 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. The most important ones being the sequence in which the different fields along a flood channel are watered. Sequence rules in Bada are called *Dinto.* In Pakistan they are called *numberwa*r and in Yemen *rada'ah.* 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 are irrigated at the same time. There is restriction on second irrigation turns. Particularly in the areas with a permanent network, upstream farmers are not allowed to irrigate for the second time before all fields downstream have received water.

Water distribution depends on the availability of water. If the Irrigation Committee believes that there is enough water, all four *agim* operate simultaneously. But if the water is insufficient, then the upstream *agim* is given first priority. In times of scarcity, the Irrigation Committee further decides which part of the fields – served by a certain agim - will be irrigated. This is not necessarily the upstream land. The

selection of fields is often based on their moisture condition. The first fields to be irrigated preferably are those with the driest soil, not necessarily those that are found in the upstream part. Both the restriction on second turns and the preference to serve dry fields first in times of water shortage serve to maintain a certain degree of equity. In turn this equity serves to keep all water users on board in the organization of the common labour tasks.

6. Conclusion: Managing Inequity and Managing Uncertainty

The risks in spate-irrigated agriculture are high and not equally distributed throughout the system. There are fields with high, medium and low probability of irrigation. This probability depends in first instance on the location along the wadi. In Bada 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 water supply.

There are however a number of mechanisms in Bada to reduce inequity in water distribution. First is the prevalence of the permanent channel network that avoids water that is concentrated excessively in the upper reaches, as is the case in field- to-field irrigation. The second set of rules that modifies the difference between upstream and downstream plots are the restrictions on second turns and the practice of distributing water to the driest fields first in times of water scarcity.

These mechanisms serve to reduce the difference between landowners and help to keep the local organization intact that is required to undertake the continuous maintenance on the bunds. As mentioned in restoring the *agim* and undertaking the other maintenance work, a critical mass of human and animal labour is required. Inequities are further mitigated, because farmers, 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 and seasonal labour are widespread in the area and are partly a response to the differences in water supply 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. Hence the inequity is being compensated through the inequity reducing mechanisms above and through the labour market.

On top of that, there is a robust local organization that combines a number of features – integration into the local administration, articulation into smaller groups, a set of penalties to induce discipline and the flexibility of a local irrigation committee to apply these measures at discretion. All this represents considerable social capital that needs to be nourished and carefully considered in the development of spate irrigation systems, as is the current policy in Eritrea. Investments in the local organization managing the water systems are equally if not more important than other investments that help to increase the utilization of scarce flood water in the country.

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