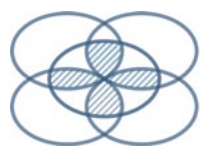


# Flood based farming systems in Africa

# 5



Overview Paper Spate Irrigation



Spate Irrigation  
Network Foundation

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## 1. Introduction

Agricultural systems have been traditionally classified in two categories: rain-fed or irrigated. This has left a huge gap in the middle, as many farming systems are neither rain-fed or irrigated, but depend on floods or, for instance, on water logged soil layers.

This paper deals with the largest group of systems that are neither rain-fed nor conventional irrigation, i.e. flood based farming systems (FBFS). FBFS depend on flood events that may vary in duration from a few hours to a period of months. The flood event may be regulated with floods diverted or the rise and recession of floods guided, but in general FBFS to a large extent adjust to the flood event rather than fully control it. FBFS can be combined with the use of groundwater that greatly enhances their productivity.

FBFS in Africa are amazingly extensive, probably close to 25 M ha, as this paper describes, but also in Asia for instance in Bangladesh, Cambodia, India, Myanmar, Nepal, Vietnam,, etc. The much higher productivity of FBFS in Asia compared to Africa - related to a more intense management and multi-functional use - suggests the immense potential for rural growth in the FBFS areas in Africa. What it takes to make the difference are interventions that will change the landscape yet are relatively low-investment and low skills. One has to think of: local water retention structures, drainage, the introduction of flood-based aquaculture, special varieties and the introduction of complementary more shallow groundwater wells.

In developing FBFS it is important to appreciate the many ecosystem services provided by flood plains, ephemeral rivers and natural depression. These flood-dependent areas include valuable wetland functions (e.g. bird migration, ecosystem preservation, aquatic diversity, water quality), environmental (e.g. buffer areas in arid regions, CO<sup>2</sup> sequestration), social (floodplains are inhabited by numerous communities) and agricultural (FBFS described in this paper). There is a need to take an integrated approach towards the development of the FBFS, including making use of the agricultural potential, In fact given the size of the FBFS in Africa their development constitutes one of the largest potentials for agricultural development in SubSaharan Africa (SSA) – but the techniques and approaches – as mentioned

common elsewhere – are little know in SSA. Another development is that in spite of the high potential, FBFS are often entirely ignored. It is not uncommon that hydropower project or perennial irrigation project are developed at the detriment of downstream FBFS, as if they did not exist and their value is not appreciated.

FBFS are practised throughout different parts of Africa. This Overview Paper aims to construct an overview, realizing that many systems (for instance the inundation canals in Sudan) are not documented. The paper is prepared as part of the activities of the Spate Irrigation Network. The Spate Irrigation Network initially concentrated on the support to one type of FBFS – i.e. spate irrigation - through identifying and promoting good practice, capacity building and the development of programs and policies. It soon realized that there is a large scope to give systematic support to the wider range of FBFS, given the areal extent and the opportunities for high productive use and the fact that they are generally forgotten.

The Overview Note first describes the main forms of FBFS (section 2) and then describes their occurrence in different parts of Africa, respectively of flood plain agriculture (section 3), and other FBFS (section 5). It further identifies some of the most promising areas of improvement and a proposal for systematic support (section 6). Possible risks for FBFS are described (section 6), to finally conclude with a general recommendation (section 7). A survey was undertaken as to where the Spate Irrigation Network could add value: this is given in Annex 1.

## 2. Flood based farming systems; definition and categories

FBFS occur in areas which receive floods on a regular, maybe even annual basis. The floods are not harmful but form the basis of productive farming systems, be it crop cultivation, livestock grazing or fishing grounds. Flooding events can be of short duration (as in spate irrigation) or can cover longer periods (in riverine or lake side systems). The flooding pattern varies with the lay of the land and the discharge from rivers or lakes. Floods may rise and drain gradually or rapidly. They may be shallow or deep. Other important parameters are the sediment load of the flooding rivers and how this is deposited and the soil conditions of the land. In FBFS soils are alluvial but this contains a range of material from fine

clays to coarse gravel. This in turn determines the land use as well as for instance the opportunities to use groundwater.

Depending on the nature of the flood use and inundation, FBFS can be classified in different categories, namely:

- **Floodplain agriculture:** cultivation of flood plains, using either receding or rising flood water<sup>1</sup> or both;
- **Spate Irrigation:** diversion of short term flood flows from seasonal rivers or “wadis” to fields by means of small dams, gabions and canals. This has been a traditional method in Yemen and Pakistan and North Africa but is currently expanding to eastern Africa<sup>2</sup>;
- **Inundation canals:** where land is irrigated by canals fed by temporarily high water levels in rivers, this was the system common in ancient Egypt and still common in parts of Sudan;
- **Depression agriculture around temporary wetlands:** (such as dambos and bas-fonds) common in humid areas in West Africa, Southern Africa and Central Africa.

Apart from managing floods for agricultural development, other productive activities are carried out in floodplains.

- **Fisheries, floodplain ponds and finger ponds:** on lake basins and floodplains when water levels increase, small ponds are filled with water and fish fauna. After the water has receded fish get trapped in the ponds and are grown for human consumption. These systems are typical in West Africa and South East Asia;
- **Flood pastures:** pastoralist communities use recent flooded areas with pastures for cattle grazing;
- **Timber and bushlands:** Forest and bush lands are common in floodplains, used as a source of fuel wood and leaf harvesting;

Time, quantity and recurrence of flood events are variable. There is high uncertainty related to these type systems. Appropriate management practices on FBFS can lessen such uncertainties

- 1) A variation is river bed farming – where not just the flood plains but also land inside the river beds is used. This practice is increasingly common in Nepal, Eastern India and Bangladesh where pressure on land resources is intense.
- 2) Two variations are: (1) seasonal rivers – flowing for a number of months before falling dry (2) peak flows from unregulated perennial rivers that may be diverted for farming and other purposes too.
- 3) Floodplain agriculture can occur far away from rainfall precipitation as sometimes flows come from upper parts of watersheds.
- 4) Rice and sorghum can be cropped in both types of conditions

and increase productivity. Whereas this is common in Asian FBFS, it is still to be developed in the African context.

### 3. Floodplain agriculture

Floodplain agriculture is the most common type of FBFS in Sub-Saharan Africa. This type of agriculture is normally located in floodplains with gentle slope. Water levels rise as a consequence of intense rainfall<sup>3</sup> or rising rivers (or lakes). The higher water levels inundate the floodplains. The sediment load in this type of flows is high, carrying fine particles to floodplains. Therefore floodplain soils have alluvial deposit characteristics (Vertisols, Fluvisols, Gleysols and Cambisols) with high content of fertile silt.

Flood recession agriculture in most cases consists of cropping using the post-inundation residual moisture, left behind once the water levels drop again. There are however also areas where crops are not grown on the receding flood but on the rising flood. This type of agriculture was the matter of study by Harlan & Pasquereau (1969) in the Niger River, Mali. It was described as *crue* and *decrue* (from French: *crue* means rise or flood while *decrue* means recession) agriculture. Flood resistant crops, such as rice and sorghum, can be cropped in rising water levels while others, such as pulses can be cropped in receding<sup>4</sup> water levels. In some areas this is combined and two cropping cycles per flooding season can be developed managing flooding patterns.

Floodplain topography and soil typology (structure and texture) play a key role in flood plain agriculture. Floodplain topography is a factor which affects water distribution. Low lying areas are prone for flood recession as moisture is conserved for longer periods of time. Alike, the spread of the flood is also driven by topographic conditions. In the same way soil typology determines water retention properties and permeability.

**Text Box 1: Asian long tradition of flood farming agriculture**

Flood recession agriculture has been practised at least for 1600 years in the Mekong delta (Fox & Ledger Wood 1999). The Funan civilization was established (in what is nowadays Cambodia and Vietnam) in the early centuries A.D. with sophisticated water control systems. Dry season flood recession rice is believed to have sustained economically not only the Funan civilization but the greater Angkor empire (9th to 15th centuries A.D) as well.

Traditionally, dry season flood recession rice was cropped either by using natural floods in alluvial plains or by storing flood water using field bunds. Floating rice varieties can grow up to 5 metres stem while flood recession varieties can grow with water levels up to 3 metres. This type of flood recession agriculture requires of water lifting technologies. Traditional water lifting systems are described as water wheels (rohat), bucket swings (snach), and balanced scoops (thleng).

Nowadays practises consist of transplanting and broadcasting techniques. Seedbeds are planted in December and transplanted in January. On low lying areas (know as srauv santoung) rice is transplanted whereas in high areas (know as srauv pruos) rice seeds are broadcasted. After transplanting farmers pump water to banded fields (once every five to seven days during three months) through boengs and trapeangs spreading water through small ditches. In March, when fields are left with no water supply for 2 or 3 weeks, rice is harvested. Thereafter, fields are ploughed at the beginning of the rainy season (June). Flood recession rice yields in the Mekong delta are estimated between 2.5 to 3 tons per hectare. Flood recession varieties are preferred as their yields are higher compared to floating rice. Apart from flood recession agriculture, dry season fishing and fish aquaculture is practised.



Figure 1: Flood recession rice cultivation on a Cambodian floodplain (Mekong River Commission 2009)



Country	Total agricultural area (ha)	Flood recession area (ha)	Source
Senegal	9,000,000	150,000 - 200,000 15,000 -20,000	Adams 1992 (1960s) Adams 1992 (1970s)
Sierra Leone	3,000,000	100	Richards (1985)
Mali	40,000,000	2,000,000 3,000,000	Thom & Wells (1987) Deltares
Zambia	26,000,000	900,000	AWM, IWMI (2009)
Botswana	26,000,000	6,500,000 6500	Van der Post (2009) FAO (2005)
Somalia	430,000	100,000	Basnyat (2007)
Ethiopia	35,000		
• Lake Tana		6,000	McCarthy, 2010
• Omo Valley		11,000	Woodroofe 1996
• Wabi Shebelle River Valley		6,800	WWDSA 2003

Table 1: Indication of total agricultural area per country, and area used for flood recession agriculture

As pointed out before, FBFS have high variability making it difficult to estimate total areas. Moreover floodplain agriculture is sparsely documented and seldom included in regional or global statistics. Table 1 nevertheless depicts a set of publications including country areas under flood recession agriculture. Below the areas are explored in more detail. Total agricultural areas are taken from The World Bank (2012)

### 3.1 West Africa

Important floodplain agriculture areas in West Africa are the Senegal Valley, the Sokoto Valley and Hadijja–Jama'are in Nigeria, the Waanje River in Sierra Leone and the Volta River. Adams (1992, 1993) documented flood farming systems in West Africa. When rivers retreat, water and moisture is left in the subsoil or in swamps and

pools. Thereafter embankments and pits are used to store this water for later use. Table 2 gives an estimation of the flood plain area in Western Sahel.

#### 3.1.1 Senegal Valley

The Senegal River valley lies in the lower basin of the Senegal River. The total area of the Senegal Valley<sup>5</sup>, also known as Futa Tooro, is 1 million hectares<sup>6</sup> (10,000 km<sup>2</sup>). The floodplain is 10 to 25 km wide. During the 1960s wet years, between 150,000 and 200,000 hectares were under cultivation. However during the following decade several drought periods diminished the cropped area to about 20,000 hectares.

Local Pulaar language has certain terms to identify different land types and geomorphical features in the floodplain. The word Hollalde

Wetland -Floodplains	Surface area (km <sup>2</sup> )	Country
Sengal	3,000	Senegal and Mauritania
Senegal valley	5,000	Senegal and Mauritania
Niger Inner De;ta	30,000	Mali
Niger Fringing Floodplains	3,000	Nigeria
Sokoto and Rima Valleys	1,000	Nigeria
Hadejia-Nguru Floodplains	4,000	Nigeria
Logone Floodplain	11,000	Cameroon and Chad
Lake Chad Floodplain	10,000	Nigeria, Cameroon and Chad
<b>Total</b>	<b>67,000</b>	

Table 2: Estimation of the floodplain area in Western Sahel (Loth 2004)

5) This region covers north of Senegal and south of Mauritania. It is also known as Futa Toro.

6) The Senegal River has a drainage of 270,000 km<sup>2</sup>, a mean flow of 680 m<sup>3</sup>/s and an annual discharge of 21.5 km<sup>3</sup>



Figure 2: Senegal River Valley (UN Water 2012)

refers to deep clay basin soils which retain moisture for longer time. These are normally the most productive areas of the floodplain. Sorghum and beans (sorghum as tutor) are cultivated in these types of soils. Elevated soils are referred as fallo and are rainfed cultivated plots (as opposed to water receding cropping systems).

Saarnak (2003) studied water recession agriculture in the Senegal River valley. She described cropping of sorghum, beans and melons using residual moisture after the flooding period. Up to three cropping seasons are applied in this area combining flood recession and irrigation. The study stressed the importance of topography and morphology related to water retention and productivity; which then determines land use type (flood recession land, irrigated land and vegetable garden land). High agricultural outputs are obtained compared to low energy inputs, where only labour and land inputs are necessary<sup>7</sup>.

During good inundation years, net per hectare incomes from flood recession even equal those from irrigated agriculture. A major finding of her study identified flood recession outputs of sorghum, beans and melons as an important supplement to household subsistence in terms of food supply. This is acute during January and February when food supply is very limited.

Flood recession agriculture is combined with irrigation of rice fields in Mauritania. This combination has proven effective to assure food security. Irrigation was introduced in the 1960s by the government focusing on rice production. Crop diversification and combining flood recession and drainage techniques improve performance of rice and other staple crops. Here under the fallo system maize and cowpea are sown directly

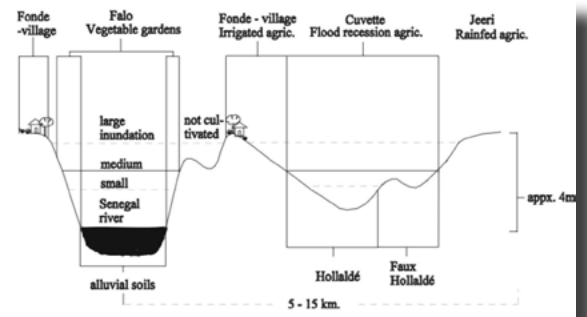


Figure 3: Floodplain land use in the Senegal River Valley (Saarnak 2003)

on the riverbanks. Additionally, the wallo system refers to the use of flood receding water to crop cowpea and sorghum over extended areas.

### 3.1.2 Sokoto Valley, Nigeria

The Sokoto Valley lies in North West Nigeria. The valley is drained by the Sokoto River, a tributary of the Niger. Similar flood recession activities are carried out as in the Senegal River Valley. Rice and sorghum are cropped in synchrony with the rain and receding water levels. However, during the dry season a second crop is cultivated using shallow ground water through Shadoofs<sup>8</sup>.

### 3.1.3 Hadejia-Nguru floodplain, Yobe Basin, Nigeria

The Hadejia-Nguru floodplains are located in north east Nigeria, as part of the Yobe Basin. They are estimated to house nearly 1 million people. Several studies point out three distinguished farming seasons: two wet seasons, one on rising and one on receding floods, and a third dry season farming (Thomas & Adams 1999) (FAO 1997).

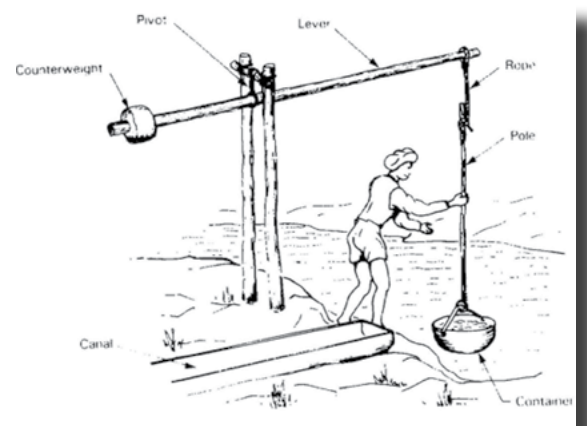


Figure 4: Traditional Shadoof (Fraenkel 1986)

7) Guarding against bird attack constitutes the main labour requirement (72%) in sorghum flood recession in this area.  
 8) Shadoofs were first developed in ancient Egypt as water lifting irrigation tool.

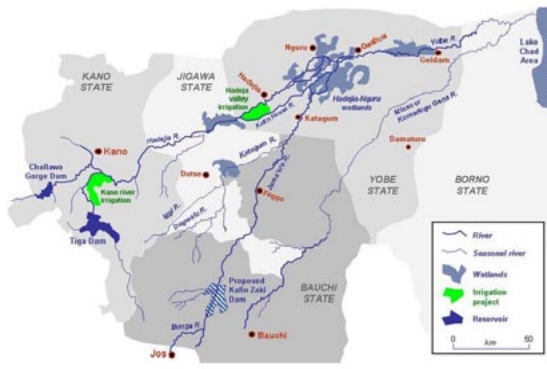


Figure 5: Yobe River Catchment (Wikipedia 2009)

Regarding flood rise farming, rice is sown when the rainy season starts. When the rice has reached 12 cm, it can resist floods and water logging conditions. Therefore farmers protect their plots with bunds to prevent harmful early floods. Sorghum, cowpeas and wheat are cropped under flood recession. During the dry season, low lying alluvial soils with remaining moisture are used to crop sweet potatoes and pumpkins. Local Hausa language refers to these types of soils (with high ground water tables) as Fadamas.

The Nguru floodplain has high productive outputs. Traditionally rice and fish products were exported, and more recently wheat and peppers. Another side-activity in the flood plain occurs in the dry season. Doum palm leaves (used for elaboration of mats, ropes and baskets) are collected as raw materials and Baobab leaves are harvested as ingredient in soups and stews. Fuel wood is also collected from the floodplain as well as fodder for horse feeding.

### 3.1.4 Waanje River, Sierra Leone

The indigenous rice farming systems in the Waanje River, Sierra Leone, was researched by Richards (1985). He identified different flood based rice cultivation systems. On different sections of land along the riverbed; depending on soil moisture, fertility and drainage, different rice varieties are planted before, during and after the rainy season.

Local Mende language identifies different land and rice cropping systems. Seasonal flooded riverine grasslands are referred as Bati. Similarly, there is a categorization of two dry season rice systems, Bongoe and Gbali. Gbali are 3 months duration rice varieties planted on the river terraces and moisture-retentive lower-slope soils using rainfall and residual soil moisture

(February/March to May/June).

On the other hand, Bongoe is a term referred to rice transplanted on receding floods (November-December). Wet season rice farming systems are named Sokongoe and Kogbati. Sokongoe is a rainfed rice that is grown on the higher sandy islands at the back of the river floodplain. Kogbati are rice floating rice varieties planted on flooded land (June) and harvested towards the end of the year. Floating rice varieties are normally low yielding.

### 3.1.5 Niger River Inland Delta, Mali

The Niger River Inland Delta is located in central Mali. The southern part of the delta is a vast alluvial plain subject to annual flooding. In addition, there are a number of temporary lakes on both banks of the Niger River. Thom & Wells (1987) indicated that over 2 million hectares are flooded annually in the Niger Inland Delta; other estimations go up to 3 million hectares (Meijer & Deltares n.d.; Zwarts et al. 2005). The Niger Delta is home to an estimated 1 million people and represents one of the major producing areas of the country, in terms of livestock, agriculture and fisheries.

An already mentioned study performed by Harlan and Pasquereau (1968) studied the Niger inland delta in Mali. They found farmers using floodwater of seasonal floods. Skilled cultivators with useful practical knowledge of the crops to be planted on wet or drier soils were active in the wetlands adjacent to the river. The sequence of crops that performed best from the more upper and drier fields, towards the lower and wetter parts of the floodplain were: pearl millet, long-season durra, mid-season durra, guinea corn and rice. Figure 8 shows a cross-section of the margins of the inland delta and the type of cultivation.



Figure 6: Villages around Mopti, Niger River Inner Delta, Mali from (source <http://stock.parallelozero.com/>)



Figure 7: Niger inner delta flood front (source <http://stock.parallelozero.com/>)

Recessional crops that are cultivated are rice, including the floating rice *Oryza glaberrima*, sorghum, millet, maize, cowpeas, peanuts, manioc, sweet potatoes and cotton. There are several techniques to grow the rice. Some transplant the rice several times with the receding water.

Other practices consist of growing rice which becomes dormant in the dry season, and then harvest after the first rains have started. Small dikes constructed with mud are used to either delay an incoming flood, or retain water when the floods recede. Sorghum usually yields 800 kg/ha (Thom and Wells, 1987) and flood based rice cultivation normally yields up to 1,000 kg/ha (this figure is highly variable due to flooding conditions). Besides agriculture, the delta is used for pasturelands and 900,000 people depend on fishing in the inland delta.

### 3.2 Central Africa

#### 3.2.1 Logone et Chari, Cameroon

The Logone et Chari floodplain lies in northern Cameroon. The Chari River, together with its tributary Logone, drains into Lake Chad. Flood rising and recession agriculture is practiced, where sorghum is cropped on rising floods (later harvested using canoes). Bulrush millet is grown on high laying fields. There are 200,000 inhabitants in the Logone floodplain, whereby the livelihoods of 60% rely on the floodplain (IUCN 2003). Local Marba people have classified land according to its flood characteristics. There are nine categories of flooded land called fulan. Unflooded seasonal damp land is named as temzeina.

#### 3.2.2 Lake Chad, Chad

Flood recession agriculture is practised using small bunds (up to 40 cm) in order to retain water. Masakwa sorghum variety is cultivated in

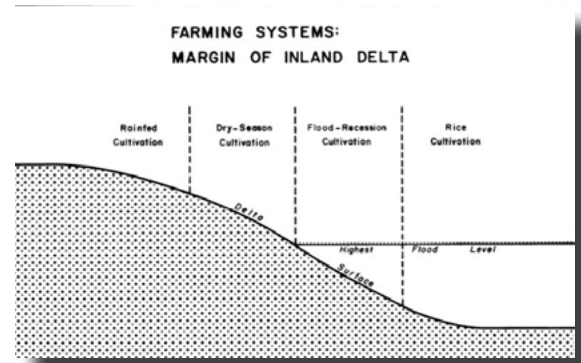


Figure 8: Types of cultivation at the margins of the Niger Inland Delta (Thom & Wells 1987)

black cotton soils around the lake. Loth (2004) also described a dry season sorghum variety that was grown on the Waza Logone floodplain, surrounding Lake Chad in Cameroon. Another sorghum variety called muskwari is cultivated in similar soil types of the floodplain and along the Benue River.

### 3.3 East Africa

#### 3.3.1 Ethiopia

There are rough estimations that figure some 11,000 km<sup>2</sup> of seasonal and perennial wetlands in Ethiopia. Flood recession is practised in different locations: On floodplains surrounding Lake Tana (on the Abay River basin in Amhara region), at Baro-Akobo watershed (southwest of Ethiopia, Gambela Region), in the Omo River valley (Omo-Gibe Basin, Oromia and Southern Nations, Nationalities and Peoples), and in the Wabe-Shebele catchment (southeast of Ethiopia in the Somali Region).



Figure 9: Chari River drainage basin (Wikipedia 2010)



Figure 10: Flood Recession Farming in Lower Omo River Basin

The most relevant floodplains are in Lake Tana with about 15,000 hectares of annual flooding and the Omo river valley with estimated 11,000 hectares.

Rice is cultivated in both flood rising and receding conditions. Other crops grown utilizing residual moisture are sorghum, maize and legumes. In some areas conjunctive use of flood water (and moisture) together shallow ground water (through water extraction technologies) allow up to 3 cropping seasons in a year. Due to unreliable arrival of rains and flooding patterns some farmers face crop failure (not enough moisture for the seeds to germinate or nursery transplanted crops to grow) making them reluctant to diversify their cropping choices. Most farmers in this situation opt to grow sorghum.

### 3.3.2 Tanzania

In Tanzania, flood recession agriculture is widespread in the Rufiji River basin. Adams & Carter(1987) indicated a survey by Marsland (1938) that recorded the mlaou cultivation, based on residual soil moisture in floodplain environments. This mlaou cultivation is also described in Duvail & Harmelynck (2007). They described the lower floodplain area, where the floodplain is 20 km wide and maize and rice were grown traditionally. The survey found that people adjusted to the floods, and fishing and flood recession agriculture were especially good after big floods.

Farmers understand how to effectively use the subtle variability in topography, and how to deal with short and long term floods. Different crops are grown in the non-flooded higher elevated areas (mango, cashew, banana, maize sorghum,

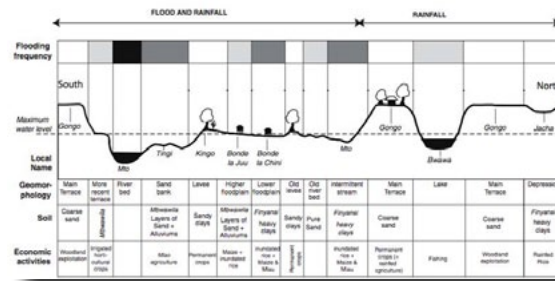


Figure 11: Cross-section showing geomorphology, soil and activities on different parts of the floodplain (Duvail & Harmelynck 2007)

sesame). In lower lying areas, loamy and fine sandy soils of the levees are preferred for mainly for maize production. The slightly lower lying depressions that contain more heavy clays are suitable for rice growth. Small plots are cultivated and intercropped with rice and maize by each household. Different varieties are used depending on the timing and duration of the floods.

### 3.3.3 Kenya

Flood recession agriculture is practised in the Tana delta, in Kenya (Adams & Carter 1987) (Kitheka et al. 2005). Moinde-Fockler et al. (2007) described the Pokomo tribe which practiced riverbank and flood recession agriculture. An IUCN survey on the value of the wetlands of the Tana River<sup>9</sup> gave an overview of activities in the floodplains and wetlands adjacent to the Tana River. This survey found that 115,000 people practised riverbank and flood recession agriculture in the Tana River basin and delta. Agricultural practices are dependent on the flooding of Tana River between April and June. Additionally, around 2.5 million livestock and 50,000 fishermen (yielding 500 tonnes of fish a year) are dependent on the annual flood regime of the river.

Terer, et al.(2004) observed that most of the farmers also own land in higher elevated areas. Besides farming on riverbank and floodplains, rain fed farming is practiced on higher elevated lands for risk mitigation. He described cultivation of rice during and after the floods. Sand and clay mining practices are activities carried out in floodplains and riverine environments which generate income. These practises are also dependant on the flood regime of rivers.

9) This survey was carried out to estimate the effect of a planned hydro dam.

### 3.3.4 Somalia

Flood recession is a common practice in the southern part of Somalia. In the Juba and Shebelle basin farmers grow mainly maize on previously flooded land. A total area of 110,000 hectares is covered under flood recession agriculture in the Juba and Shebelle regions (Basnyat 2007).

### 3.3.5 The Nile Basin, Sudan and South Sudan

The Nile basin is the biggest river basin in Africa, covering 10.3 % of the total surface of the continent and extends throughout ten different countries. It is fed by two main rivers, the White Nile with its source in the equatorial plateau and the Blue Nile with its source in the Ethiopian highlands.

The White Nile, together with its tributaries<sup>10</sup>, form the second largest wetland in Africa, the Sudd. The Sudd is composed by 16,500 km<sup>2</sup> of permanent swamps and 15,000 km<sup>2</sup> of seasonal floodplains (Jorgensen 2009). The Sudd stretches from north to south over 400 km with flat or minimum slope (0.01%). Half of the water entering the Sudd is lost through evaporation and evapotranspiration. Rainfall and flooding occur simultaneously, normally from April until November with average precipitation of 800 mm in the north and 900 mm in the south. This area is inhabited by Nuer, Dinka and Shilluk tribes. The main crops cultivated are sorghum, maize, cowpeas, groundnuts, sesame, pumpkins and tobacco.

The flooding season spans from June to August. It is common practice to use groundwater in the dry-season as an additional water source.



Figure 12: Sudd Floodplain (World Wildlife Fund & Relational World Database 2008)

The area under flood recession is not estimated but is above 200,000 ha.

## 3.4 Southern Africa

### 3.4.1 Zambezi River – Zambia and Botswana

The Zambezi basin is the fourth largest river basin in Africa (covering 1,351,365 km<sup>2</sup>, estimated 4.5 % surface area of the continent<sup>11</sup>).

Beilfuss (2002) and Scudder (1972), who both did research on the Zambezi River described two cropping periods. During the rainy season, the fertile alluvial soils adjacent to the rivers are sowed with cereals, legumes, and gourds that are harvested just prior to the rivers expected annual flood. Rainwater is used for the first batch of crops. Farmers planted a second crop after floods began to recede, sowing seeds just behind the retreating water line and harvesting at the end of the dry season. Floods also recharge local aquifers providing with an essential source of water during the dry season.

The Borotse floodplain, estimated in 900,000 ha, lies in the Western Province in Zambia<sup>12</sup>. According to the timing and extend of the annual flood of the Zambezi River, various crops are cultivated with rising and receding floods (IWMI & AWM 2009). These crops include: maize, sorghum, pumpkin, mango, rice, cashew and vegetables. In these plains shallow water pans exist. Natural or artificial canals connect some of these pans making winter cropping possible utilizing residual soil moisture.



Figure 13: Okavango delta (source <http://stock.parallelozero.com/>)

10) Including Bahr el Ghazal, Bahr el Jebel and Sobat rivers.

11) The Zambezi basin covers 8 countries, namely, Zambia, Angola, Namibia, Botswana, Zimbabwe, Tanzania, Mozambique and Malawi.

12) Wetlands in Zambia cover slightly more than 20 % of the surface of the country - 150,520 km<sup>2</sup> (Mukanda 1998).



Figure 14: Abandoned bund made to retain water in the Molapo(Oosterbaan et al. 1986)

In a publication by Oosterbaan et al. (1986), seasonal swamps called molapos of the Okavango Delta were described. Molapo farming (mainly under flood recession agriculture) make up to 25% of the cultivated lands of Botswana. Farmers use the lands in the delta to grow mainly maize, sorghum and millet. This is concentrated on sandy soils of the uplands and in molapos. Seeds are sown and germinate on residual soil moisture after the floods recede. In optimal conditions rains start before the soils get too dry.

Farmers also build small bunds to protect crops from unwanted floods. The risks involved in depending solely on flood based farming is compensated by activities such as livestock keeping, palm-wine tapping, fishing, hunting and basket weaving. The uncultivated molapos are important grazing lands after the floods recede. The productivity of molapo farming was studied by the Okavango Research Centre (see table 3). Apart from the main cereal crops grown - sorghum, maize, and millet - secondary crops like beans, pumpkins and watermelons, sweet reed and peanuts are also cultivated. Yields vary from year to year mainly due to flood magnitude.

### 3.4.2 Malawi

Malunga (2009 ) described the practice of flood recession agriculture in the Shire valley of Malawi. Sweet potatoes are grown in floodplains of the river at the end of the wet season. Plots sizes are small, of about 2 ha. Farmers own land in higher elevated regions where they grow crops in the rainy season. Flood recession agriculture in this area uses few inputs; no fertilizers or chemicals are used. The only input is labour.

Furthermore in parts of Karonga District in Northern Malawi and in Salima district along the

Crop	Yield (kg/ha)
Maize, dryland	162
Sorghum, dryland	121
Millet, dryland	144
Sorghum, Molapo	500
Sorghum in Molapo with optimal flooding	2,000

Table 3: Cereal crop yields in dryland and Molapo(VanderPost 2009)

lakeshore, flood water has in some traditional ways been used to cultivate rice. This is done through the construction of bunds within the field. Following a flood event, the bunds will fill with water and rice will be grown therein, however the flooding occurs naturally and no diversion structures are constructed to maximize the volume of water.

### 3.5 Summarizing: common practices of flood plain agriculture throughout SSA

Farmers traditionally cultivated in flood receding periods, normally sorghum or rice. This practice in a number of place has transformed into cropping on flood rising conditions. In some places a third cropping season is applied using various techniques; using residual moisture on river banks or impermeable soils, using ground water or combining it with surface water (from lakes or rivers). There is thus a trend to increase agricultural outputs whenever there are favourable flooding conditions.

Food security still remains as a major concern in rural Sub-Saharan Africa. This explains the high priority given to sorghum and rice as the key crops for water recession agriculture. Additional crops are cultivated to add additional income sources for households. Moreover uncertainty related to rains and flood events hampers innovation in crop choices and farming practices.

Flood soil typology and location together with its cropping alternatives; has been conceptualized and identified by communities in flood plains. In practically all locations there is vocabulary directly referring to flood plain soils. This is an indicator of an extended flood recession tradition in sub-Saharan Africa sustaining livelihoods of large populations.

## 4. FBFS in Africa: Spate Irrigation

Spate irrigation is an old irrigation practice developed in arid and semi arid regions. It has long tradition in Asia, particularly in Yemen, Afghanistan, Pakistan and Iran (with about 5000 years tradition) but also common in the Middle East, West Asia, East Africa and some parts of Latin America.

In arid and semi arid environments seasonal rivers, also known as Wadis, run dry for most of the year yet suffer peak flows, many of short span, from rainfall events. These flows are diverted from riverbeds and streams to open canals or diversion structures reaching crop fields. Water can be conducted using furrows or spread as sheet flow.

Spate irrigation systems vary depending on peak flows, sediment load or specific location in the watershed. On the other hand they are meant to serve as main source of irrigation for crops like sorghum (as in traditional systems) or as an additional water supply. The later is more recent and triggered by erratic rainfall events due to climate change. Similarly these systems feed not only crop fields but also grazing pastures or even forest land (van Steenberg et al. 2011).

The main characteristic of spate systems is high variability of flows in terms of quantity, duration and periodicity. This may cause uneven distribution of water among upstream and downstream users, cause crop failure due to late arrival of floods and damage riverbeds and main system structures.

Another important characteristic is the high sediment load flows. Sediment load bring fertile layers to fields (which increase the water capacity). However, if not well managed, it can oversilt structures and alter riverbeds and command areas. Therefore specific design principles (many times underestimated or not conceptualized) together with local expertise (especially in systems with extended tradition) of flood behaviour are critical for achieving optimal performance levels.

## 4.1 Spate Irrigation in the Horn of Africa

Spate Irrigation is under development in Sub-Saharan Africa. However there are countries with some tradition in these practices. This is the case for Eastern Africa where several countries are developing and investing in spate irrigation systems. The following section will give an overview of spate irrigation in the Horn of Africa.

### 4.1.1 Ethiopia

Spate irrigation in Ethiopia has developed in recent times due to several factors. Due to climate change trends, many perennial rivers are increasingly becoming seasonal and with much higher peak flows. On the other hand, lowland regions (below 1,000 metres altitude<sup>13</sup>) are becoming more densely populated due to demographic pressure and disease control (malaria and trypanosomiasis). Therefore several regions are experiencing spate scheme development.

The current area under spate irrigation systems in Ethiopia is estimated in 140,000 hectares however the potential is much higher, especially in the lowlands (Alemaheyu 2008). Spate irrigation schemes are increasingly developing throughout the country; in Northern Tigray (Raja and Waja) and Afar regions, in central Oromia (Bak, Arsi west and east Hararghe), in Dire Dawa, in the Southern Nations, Nationalities and Peoples region (SNNPR)(Konso) and in the Amhara region (Kobo).

Spate irrigation systems can be found in midland (between 1,000 and 1,500 metres) and lowlands, although less common. Midland systems differ as the flows are higher, rainfall complements spate flows and command areas are smaller. On the other hand lowland schemes are more vast and flat (midland topography is hilly), and receive water from big watersheds with high sediment load making wadis less stable.

It has been estimated that traditional spate schemes in Ethiopia cover up to 100,000 hectares. Traditional schemes are normally structured in a series of short free intakes. As an example, in the Amhara region, in Kobo, seasonal streams are diverted to the fields to complement rainfall. There are three categories of diversion structures:

13) The particular Ethiopian topography hinders perennial flows below 1,500 metres whereby most of them are of seasonal nature below this altitude.



- Main diversion (or enat mellée, meaning “mother mellée) – earthen embankment set at convenient angles in the riverbed which divert the flows to fields (with 1 to 3 % slope);
- Secondary canals (awraj mellée);
- Tertiary canals (tinishua mellée);
- Contour or graded furrows (shilshalo).

In Tigray similar distribution system is used. In the Aba’ala scheme<sup>14</sup> there are 27 diversion canals from three different rivers. These canals are dug from both sides of the river bank using stone, boulders, shrubs and tree logs. This type of spate system can be found throughout the whole country (Mehari et al. 2013).

Until recent times, investments in spate irrigation were done by farmers and non government organizations. In the last decade governmental institutions have become aware of the importance of such systems. Hence there have been considerable investments carried out by Water Resource Bureaus in different regions. In the Oromia region, 38 spate irrigation schemes were

under construction in 2008 and many more under study. In Tigray, 13 modern spate schemes have been developed in the last ten years. Investment costs range from 170 to 220 USD per hectare including soil bunds and gabions and diversion canals; to 450 USD per hectare (for small systems) if permanent headworks are included.

Crop yields are difficult to compare as most of spate schemes in Ethiopia are employed as supplementary to rainfed systems. However, on an average year, yields can double or triple simple rainfed systems. Van den Ham (2008) researched the Dodota spate scheme and found significant increases in crop yields for irrigated fields.

Namely, 4 to 13 tonnes per hectare in wheat, 7 to 26 tonnes per hectare in barley, 3 to 6 tonnes in teff (basic cereal used in Ethiopian diet) and 6 to 15 tonnes per hectare in haricot. Midland systems use a wide range of crops; sorghum, maize, groundnut, sweet potato, pepper, onion, garlic, spices, mango and qat (Chat cadulis). Lowland systems rely more on staple crops.

### Text Box 2: Spate Irrigation System Investments in Ethiopia

Investments in spate schemes in Ethiopia have had dissonant results (similar to experiences in other countries). The some problems found out in Aba’ala (Tigray) and common to other spate schemes are detailed below:

- Upstream and downstream users do not share flows in an equitable way;
- Inappropriate canal diversion design trigger river alteration;
- Technical defaults in secondary and tertiary canals causing gully and scouring erosion;
- Excessive sand reaching fields;
- Excessive maintenance works in traditional spate irrigation systems.

There are number of reasons why interventions in traditional spate systems and development of new must be approached with specific principles. The nature of spate flows is significantly different from perennial systems. Flows are highly variable both in quantity and time. Moreover flows carry huge sediment loads which limit certain structural use. Flows must be carried at high velocities in order to prevent siltation and transport the fertile sediments to fields. For this reason there must be the least obstruction of such flows preventing sediment deposition and trapping of trash loads. Therefore high crest weirs, which reduce flow speed, must be avoided as they get rapidly silted up. If this occurs the sediment load, which normally is formed of a great amount of coarsen material along with finer material; can only be removed by excavators (making it economically not viable). On the organizational side several aspects must be addressed. Access and loss of land are issues affecting spate systems. Hence establishment of land and water rights among users is critical. Spate schemes require of high amounts of O & M works, thus the capacity of farmers must be proportionate. In this regard water users must be involved in design process as these systems require of strong cohesion and ownership. Feedback (in traditional systems) provided by local expertise in flood behaviour is another reason to involve farmers in the design process. Finally pastoralists also use flooded fields for grazing; therefore they must be included in land management in order to avoid conflicts.

14) Midland spate irrigation system, at 1,300 metres above sea level, located nearby Aba’ala town covering 10,000 hectares.

#### 4.1.2 Eritrea

Eritrea has been recently experiencing spate irrigation development though there are some indications of an extended tradition. The area covered by these systems adds 14,000 hectares but studies estimate a potential area between 60,000 and 90,000 hectares.

Spate irrigation systems in Eritrea are normally located in the eastern lowlands and coastal regions. There are two distinct types of spate schemes, the ones in the north use flood water prior to planting while in southern parts of the country flows are used as complementary irrigation supply. Water is diverted from rivers using sand, stone and brushwood spurs and earthen guides. Acacia brushwoods are used to intertwine sandy bunds helping to trap sediments and floating materials.

The Bada scheme is a lowland spate irrigation system located in a dry arid region, 150 meters below sea level (in the Danakil depression). In optimal years the area under irrigation can cover 2000 hectares. Diversion structures (referred as agim) in this system are divided in two types, deflector type low earthen bunds and weir type low earthen bunds. Deflector agims are set in riverbeds at certain angles of the flow.

When high peak flows occur (common in this type of systems) deflector agims are breached. Thus the flow passes to the next intake protecting canals and field embankments from destructive peak flows. On the other hand weir agims are set at right angles (covering the whole width of the wadi) in riverbeds diverting low stage flows.



Figure 15: Traditional maintenance of diversion and guide bunds in She'eb scheme (van Steenberg et al. 2011)

During high flows weirs are deliberately breached or overtopped by the flows. Apart from the materials mentioned above. Gabion agims can be constructed though they are expensive and require certain construction skills. The channel network at Bada has the following structures:

- Distributary canals – permanent structures intended to conduct water from the intake to different zones of the spate scheme.
- Field canals (Bajur) – canals leading water to fields in adequate quantity proportions depending of the field size.
- Spillways (Khala) – constructed on the side of the embankment (crest length between 1.2 a 3.5 meters), they act as lateral spillways discharging flows that exceed the capacity of field canals and returning it to the main canal.
- Drop structures (Mefjar) – intended to dissipate flow energy in order to minimizing scouring. Build of rock and stones normally located in steep canals, on joints among higher and lower canals and on field to field water diversions.
- Soil retention structures (Weshae) – designed to protect fields nearby wadis from stream bank erosion and also serve to trap silt sedimentation. Build in a similar way as Mefjars using stones, weshae also function as guide walls to control large floods located at least 10 meters upstream from agims.

Another important region is the Eastern lowlands She'eb region, which includes three remarkable systems: the Wadi Laba, Mai Ule and Wadi Labka. In Wadi Labka floods are too big thus, traditionally, they were split into halves or thirds in order to divert it using brushwoods spurs. O & M was given special attention as this type of diversions had to be rebuilt several times.

Western lowlands have less tradition of spate irrigation. However recent investments (since 1994) have developed up to 26 schemes adding 16,000 hectares in Gash Barka region (with target potential of 50,000 hectares). The typology of western schemes is different given that floods are less violent and spate flows are used as supplementary irrigation. Diversion structures include soils bunds, ungated masonry and concrete weirs and gated weirs. Gated outlets release water from distributary canals to plots where crops are already planted. Guide bunds are used to spread the water. In this type of preplanted systems, it is more suitable to have more irrigation turns as opposed to retaining water (and moisture) as much as possible.

### Text Box 3: Social Organization of Eritrean traditional Spate Irrigation Systems

Social organization in traditional schemes is structured as follows. Farmers are organized in groups (parta) and sub-groups (teshkil) consisting of 30 to 40 farmers (similar to Ethiopia). The group leader is called ternafi. The teshkil leader will supervise water distribution, maintenance works in his area, coordinate works on main structures and reports conflicts and requests to the ternafi. Group leaders form a spate system committee which decide on the entire system issues like design and location of diversion structures, water allocation and distribution; and timing and extent of planting season. As deduced from above, traditional schemes have a high level of water management and social organization. However performance of these systems is hindered by a deficit in draught animals. Ploughing and soil preparation increases moisture retention and enhances soil properties for crops (fields ploughed with oxen increase crop yield by 30 to 50 %). The main crops grown in traditional schemes are sorghum, maize and millet; being the last two used as “safe crops” when rainfall is scarce.

Yield figures differ from Eastern to Western spate schemes. Eastern lowlands schemes produce between 3,000 and 4,000 kg per hectare of sorghum while Western systems are about 500 kg per hectare. Nonetheless, according to the Ministry of Agriculture, the estimated potential is between 1,200 and 2,100 kg per hectare. Better water and field management practices together with the introduction of new varieties and combination with livestock activities can enhance performance levels.

#### 4.1.3 Sudan

Spate irrigation history in Sudan is different from Ethiopia and Eritrea. Apart from farmer developed schemes, large spate irrigation schemes in Eastern Sudan (fed by the Barka and Gash rivers) were implemented under British colonial rule at the beginning of the 20th century mainly for cotton production. With the decline of cotton as cash crop, spate systems shifted to sorghum as the primary crop. The two main spate irrigation systems in Sudan are the Gash and Toskar systems.

The Gash spate system is located in East Sudan; 121 km from the Eritrean border next to the Gash die delta. The floodplain covers 240,000 hectares and has 500,000 inhabitants. The flooding period spans from July (or late June) to September. Floods are characterized by big flows with high sediment load.

The system was constructed in the 1930's and further rehabilitated in the 1950's and recently (2003) through IFAD funding. The scheme was designed for cotton cultivation; however this cash crop was dropped in the 1960's due to international competition. The scheme is structured

in main, link and branch canals equipped with gravity offtakes. Agricultural fields are divided among distributary canals known as misgas. As flows are high bunds are used to guide the floods managed by misga workers commanded by the water master or Sheikh al misga. A remarkable structural design in this system is the location of head regulators. Head regulators and misga offtakes are oriented in tangential upstream faces (on sideway curves) causing flows to enter the system through back currents and eddies; preventing sediment load to enter the system network.

Irrigation turns are set in flushing sequences. The first starting late June until mid-August (covering two thirds of target misgas) and the second from mid-August to mid-September (irrigating the remaining). When sufficient water has been delivered to the misga the offtakes are closed and cultivation practices start as soon as the field is in condition for work. Misga offtakes are paired



Figure 16: Fota intake, silt-laden floodwater, Gash scheme (van Steenberg et al. 2011)

meaning that only 50 % of the total command area is irrigated in one year. Average land tenant holding is 0.5 hectares<sup>15</sup>. There are 50,000 tenants in this floodplain. Cotton was substituted by sorghum (being now subsistence crop for fodder and staple grain) and castor (*Ricinus communis*). Surplus water reaches the Gash die delta sustaining new agricultural land, pastures and forest land.

The IFAD rehabilitation project (Gash Sustainable Livelihoods Regeneration Project, GSLRP) was intended to enhance the system's infrastructure, improve water management practices, create WUAs, eradicate mesquite (*Prosopis juliflora*) and provide individual land titles. The project outcome was not fully satisfactory. Even though cultivation areas increased and improvements were reached at household level, tenant numbers kept increasing and cultivated area didn't reached target 0.75 ha. Moreover land reform was slowly implemented, reducing WUA effectiveness. Finally new sorghum varieties weren't fully introduced keeping agricultural productivity low.

The other mayor spate scheme in Sudan is the Tokar spate irrigation system. It is located along the Baraka River, and covers the Tokar delta (150 km south east from Port Sudan). This floodplain has an area of 170,000 hectares; up to 40 % of the floodplain was under irrigation in the past. Yet in 2007 only 12,000 hectares were under irrigation. This delta has three distinct areas: the Western part (with saline silt clay), the middle delta (with fertile silt soils next to the Baraka River) and the Eastern delta (generally sandy soils). In this system there is no clear canalization or headwork structures. Short main canals divert the water which is then guided through seasonal bunds in order to spread water in sheet flows.



Figure 17: Guide bunds to spread water, sand dunes and depositions impede even spread of floodwater (photo: Ian Macanderson)

This type of spate distribution is complex given that there must be no obstacles in the flooded area which would create uneven distribution. Moreover all stubbles (such as sorghum stalks) must be removed as wind carry sand and silt creating mounds, dunes and sandy ridges. Mesquite tree is also a problem in this system whereby available land is decreasing due to this invasive species. Mesquite together with poor land management has created uneven topography deriving in very difficult water distribution.

Sorghum is the main crop although yields are reported to be low. A significant feature of this system is the so called Tomosay embankment. This embankment is 50 km long and stretches from the western limit of the delta all the way to the north side. It was intended to contain flows in the middle delta (the most productive), limit the spread annual flood to the better lands, protect the Tokar town (2-3 metres below irrigated fields) and restrict flows to the sea in the northern part.

#### 4.1.4 Somalia

Flood based farming in Somalia is concentrated in the south along the Juba and Shebelle rivers. Spate irrigation is combined with flood recession agriculture in along river banks (from 500 m to 30 km away) where maize and sorghum are cultivated. Pastoralist militias and unpredictable floods have reduced riverine agriculture. Furthermore, the long lasting civil war the country suffered has caused most of these schemes to fall in disuse. It was estimated that before the conflict, up to 150,000 hectares were under spate irrigation and flood recession agriculture. Spate irrigation is also found elsewhere in Africa. There are some examples described further.

#### 4.1.5 Kenya

Irrigation has been practised in Kenya for the last 400 years, especially in the lower reaches of the Tana River. This irrigation was dependant on high spate flows. Drainage systems were developed throughout the 1930s in Central Kenya, cropping on large swampy areas. Between the 1950s and 1970s modern schemes were initiated focusing on cash crops like coffee, pineapple and horticultural products.

Traditional spate systems in Kenya have used basic techniques in spate systems. Natural depressions nearby riverbanks are used to divert flows or natural channels would help bring water

15) Government is the official owner of land and land use rights are allocated to farmers under Gash law of 1918. However tribal Hadendowa leaders, amounting 3 % of the total population, are entitled with 60 % of the land.

from streams to low laying areas and fields. Stones, logs and branches are used to slow flows. Efforts for managing water have focused on water retention and recharge measures rather than more sophisticated spate systems alternatives. Water storage has been developed through sand dams, on-stream reservoirs (made of masonry or reinforced concrete) and earth dams, off-stream reservoirs (earth pans and ponds), and dug earth pans (on flat areas).

Spate systems are found in the Tana River, in the North Eastern Provinces, along the Daua River along the Kenyan Ethiopian border and in the northern rift Valley of Kenya. Sorghum, maize, rice and bananas are cropped (last two in the Tana River). As sorghum is less water demanding it can be cropped using soil storage moisture whereas maize needs of an additional rainfall event. Therefore maize is normally grown during the long rainy season.

Kenya is estimated to have 7 million hectares of potential agricultural land lying on medium rainfall areas (between 750 and 1,000 mm per year). Only 1.5% of this area was found under irrigation in 2003. The potential for flood recession and spate systems is still to be developed as indicated in table 4. Additionally, spate irrigation could be expanded to another 800,000 hectares (reaching 1.3 million hectares) with proper implementation of water harvesting and storage techniques. In order to develop the full potential, detailed studies on water harvesting and storage of flood water together with documentation of traditional spate systems would help contribute to a better understanding of these systems and possible interventions to be made.



Figure 18: Stream reservoir built to hold run-off from dry riverbed (Muthigani 2011)

Basin	Potential (hectares)	Development (hectares)
Tana	205,000	68,700
Athi	40,000	11,000
Lake Basin	200,000	10,700
Kerio valley	64,000	5,400
Ewaso Ngi'o	30,000	10,000
Total	539,000	105,800

Table 4: Potential for spate irrigation development in Kenya (Muthigani 2011)

#### 4.1.6 Morocco

Spate Irrigation has traditionally developed in the southern and eastern Morocco using run-off from the Atlas mountains. These regions have arid to semi-arid climate with rainfall less than 100 mm per year. Therefore the only viable agriculture comes from irrigation practises. Ephemeral rivers called "oueds" are used as source of water. Spate irrigation is known as "fayd". Traditional spate systems use basic tools and techniques, namely earthen, stone and brushwood structures for water diversion. Traditional spate systems have been developed since many centuries.

Seasonal and spate irrigation schemes are the main categories where traditional systems fall in (apart from perennial irrigation schemes - out of the scope of this paper). In table 5 the three main categories for irrigated schemes are detailed by surface. Table 6 gives an indication of the total area under spate irrigation in the country specifying each hydrological unit. The total area under spate irrigation is estimated in 83,000 hectares (Oudra 2011).

Spate irrigation in Morocco is on a small scale with systems varying from few hectares up to 500 hectares. Traditional diversion structures are combined with small intakes with short canals. Water diversion structures include ancestral techniques;

- spur type deflectors – the flow is diverted to earthen canals with lower levels than the one of the riverbed (high river bed slope is requires 5% – 10%)
- bund type diversions – bunds block flows rising water level which thereby convey water to canals constructed above the river bed level (flow low gradient required an a well-established riverbed).

- retention dams – flows are dammed which consequently inundates valley bottom areas of floodplains (used in desertic areas – large riverbed with very low gradient required)

Modern diversion structures include gabion, masonry and concrete. These structures have been introduced to improve water diversion efficiency and to regulate floods in a more reliable way. However in some cases these interventions have increased inequality among upstream and downstream users and complicated cropping practises due to infrastructure within the irrigation scheme.

Therefore the approach to upgrade spate systems has shifted to a combination of traditional and modern techniques. This combination facilitates O & M as well as improved usage of water intake structures.

Water distribution is carried out in two ways; without secondary canals where water is diverted to fields through triangular dissipation structures made of gabion. The number of farmers benefiting from small floods is limited due to location of the structure. Systems using distribution with primary and secondary canals are divided into separate zones. At the end of the secondary canal, a triangular energy dissipation structure is located allowing water distribution from the upstream part of the scheme.

This type of system is more costly but covers more beneficiaries and it is easy to operate. Moreover the order of water distribution is similar to the traditional way.

Spate systems have not awoken much attention from government and development organizations due to association low value crops. Traditional spate systems may be limited in overall agricultural output, yet it is less expensive

Type of irrigation	Large Scale Irrigation System	Small Scale Irrigation System	Total
Perennial	880,160	484,900	1,364,250
Seasonal and spate	-	300,000	300,000
<b>Total</b>	<b>880,160</b>	<b>784,900</b>	<b>1,664,250</b>

Table 5: Irrigable lands in Morocco (Oudra 2011)

and easier to maintain. On the other hand modernization of traditional systems call for participatory dynamics involving beneficiaries in planning and design, O & M activities and water distribution priorities (respecting equitable rules and norms).

In order to improve spate irrigation systems in Morocco efforts must be focused in the design of a global watershed strategy for flood control and erosion mitigation, perform studies on hydrological data for more accurate design of infrastructure, develop flood prediction models and flood warning systems, integrated rehabilitation programmes for spate schemes including better agricultural productivity, encourage exploitation of both surface and groundwater sources, and capacity building in field water management, O & M activities and soil and agronomic practises.



Figure 19: Distribution Structures in a number of spate schemes in Morocco (Oudra 2011)

Hydrological unit	Irrigated area (in hectares)		
	1995-1996	2000-2001	2005-2006
Oriental highlands	2,237	2,237	2,237
Figuig	5,000	5,000	5,000
Guir-Bouanane	900	900	900
Ziz-Rheris	13,500	13,500	13,500
Maider	10,800	10,800	10,800
High and Middle Draa	0	0	0
Low Draa	6,300	6,300	6,300
Tiznit-Ifni	3,635	3,735	3,835
Guelmim-Assa Zag	38,415	38,415	38,415
<b>Total</b>	<b>80,787</b>	<b>81,177</b>	<b>82,937</b>

Table 6: Irrigated area under Spate Irrigation in Morocco (in Hectares) (Oudra 2011)

## 4.2 Spate Irrigation in Asia – lessons, best practices and experiences

Asia has an extended tradition of spate irrigation. There is evidence in Iran and Pakistan where old water diversion structures can be traced back thousands of years (i.e. qanats – underground galleries used for water storage and distribution in Iran). In many cases spate irrigation has been a method used to improve water storage and ground water recharge, especially in arid environments.

In spite of such historical background, spate irrigation has received little attention by national governments, donors, academic institutions and engineering organizations. This may be triggered by low interest in staple crops, low investment figures (as engineering firms are normally interested in bigger investments) and common mindset of irrigated vs rainfed approach.

All in all, spate irrigation systems have proven high returns compared to costs per hectare (see table 7). Yields in spate systems vary but are comparable to those of perennial irrigation systems (see table 8).

There is still a need to document traditional systems and improve data availability on hydrology. This would help to understand this type of FBFS and contribute to improve investments on spate systems. The same can be applied in Africa, such systems are seldom documented.

### 4.2.1 Lessons and Recommendations

Floods are normally regarded as a natural threat for communities and as a destructive force to the environment. However, when properly managed, floods can help recharge the groundwater and increase retention capacities in water scarce environments. For this reason spate irrigation systems play a key role in managing floods and peak flows. Additionally, it provides flood control measures and helps tackle erosion in poor quality soils. As many peak flows carry high sediment load, properly managed streams can bring fertile alluvial sediments contributing to increase soil fertility and water holding capacity. Given the arid agro-climatic conditions of some of central Asian ecosystems, spate irrigation has been in many cases an adaptive choice for communities living in these regions. This may explain why these systems have such a long tradition in Asia.

Types of irrigation structures	System	Cost US\$ / ha
Permanent diversion structure	Primary and secondary canal	500 – 1000
Permanent small structure	Tertiary or on-farm canal	200 -300
Temporary structure/bund	Local diversion on-farm level	70 – 100
Operation and Maintenance	Primary, Secondary, Tertiary	2 – 5 % of structure cost/year

Table 7: Incurred costs by structure in Spate Irrigation system in Afghanistan (MEW 2009, IRDP 2011)

Crops types	Yield (kg /ha)
Wheat	9,500
Barley	7,850
Onions	2,500
Sweet Potatoes	5,000
Cumin	1,400
Lentils	8,500
Melons	15,000
Water Melons	2,000
Sesame	350

Table 8: Common crops and expected yields under the Lashkari System, Afghanistan (MEW 2009)

In order to optimize performance on spate irrigation systems, governments have focused on investments to improve traditional systems as well as in construction of new systems. However these investments have sometimes undermined traditional water distribution and maintenance practices. Similarly, principles and traditional knowledge of flood behaviour haven't been always included in design of the so called "modern systems".

Consequently, some investments have failed to expand command areas and improve water distribution. Instead of constructing modern spate schemes, efforts should also be focused on improvement of traditional spate systems. Apart from of a cost effective solution, it can incorporate principles of O & M as well of water distribution incubated throughout time in traditional systems. Moreover, participatory processes in design and construction assure better involvement of water users, enhancing performance of systems.

Apart of rethinking investment for modernization of schemes, national governments can promote policies to support spate schemes. An example of this is the bulldozer programme in Pakistan where earth moving services were subsidized. This programme helped build water diversion structures and carry out maintenance works in spate schemes.

### 4.3 Best Practices - experiences

Yields may vary from one spate system to another. Productivity is a key factor regarding agricultural output performance. In Pakistan several factors have been pointed out as drivers for better performance:

- diversification of crops – depending on suitable conditions (e.g. oilseeds, pulses, livestock feed, wild vegetables, etc)
- improvement of grain storage – bringing down production losses
- joint use of surface and ground water – helping diversify water sources
- investment of structures at command area level – this may help improve moisture management

Experiences have revealed that an integrated approach at watershed level enhances water resources mobilization and allocation. This has been the case in Afghanistan where basins are shared among several regions and countries. Moreover, expansion of irrigated areas call for optimization of water sources regarding water diversion and storage. Conflict can also be avoided from a holistic approach, in line with IWRM approaches promoted by donors and academics.

Major floods occurred in 2010 in Pakistan, and other similar events elsewhere, have brought the attention of the international community on flood and natural disaster mitigation. Apart from mitigating effects, warning systems would help protect diversion structures and avoid damage to irrigation systems. Satellite images could be used to monitor and forecast flood extents. In this regard there have been recent studies to develop a reliable tool for flood prediction, peak flood level, extent and time in the Niger inner delta (Zwarts 2013). Based on this tool, predictions are used for flood forecasting (available on the internet) and broadcast in local radios. This may serve as model to replicate elsewhere.

City migration in Iran is triggered by water shortages in arid environments. Nomad pastoralists and agricultural communities can benefit from spate systems construction. enhancing livelihood conditions. Moreover ground water recharge provided by spate systems could have a positive impact on regeneration of qanats. The same applies elsewhere, in Asia and Africa, where pastoralist communities have to adapt to climate variability and erratic rainfall.



#### Text Box 4: Sub-Saharan wetland and floodplain surface estimations

Several studies have estimated wetland and floodplain areas for the Sub-Saharan Africa. These estimations give an overview of the vast surfaces covered by floodplains and wetlands in the African continent. These figures reveal huge potential land resources of FBFS.

Category	Area		
	1.000 km <sup>2</sup>	% of the wetland area	% of the total area
Coastal wetlands	165	7	1.5
Inland Basin	1075	45	9.0
River floodplains	300	12	2.5
Inland Valleys	850	36	7.0

Table 9: Categories and areas of wetlands in tropical sub-Saharan Africa (total area 12.2 million km<sup>2</sup>) (Andriess 1986)

Balek (1989)	340,000 km <sup>2</sup> (34 million ha)
Denny	>345,000 km <sup>2</sup> (35 million ha)
University of Leiden	600,000 – 700,000 km <sup>2</sup> (60 – 70 million ha)
Andriess et al. 1994	220,000 – 520,000 km <sup>2</sup> (22 – 52 million ha)
FAO (based on soil map of the world)	1,250,000 km <sup>2</sup> (125 million ha)

Table 10: Different estimates of total wetland extent in Africa (Bullock et al. 1998)

Drainage system / geographical area	Area km <sup>2</sup>	Major floodplains /comment /reference
Democratic Republic of Congo	70,000	Middle Congo depression, Kamulondo Malagarasi
Niger/Benue system	38,900	Niger central delta, Benue River
Nile system	93,000	Sudd, Kagera basin
Zambezi system	19,000	Kaflue flats, Barotse plain, Liuwa plain
Western systems	19,000	Floodplains along the Senegal (excluding delta), Volta and Oueme
South east systems	100	Pongolo floodplain
Eastern systems	8,600	Kilombero, Rufiji, Tana River
Chad systems	63,000	Chari and Lagone River system
Gash river	3,000	Inner delta in Sudan
Tana delta	670	Endangered by upstream dams

Table 11: Distribution and extent of selected fringing riverine floodplains (including a few rain-fed floodplains) in Africa (Howard-Williams & Thompson 1985; Thompson 1996)

## 5. Depression agriculture – Bas-fonds and dambos

Apart from flood farming and spate irrigation, depression agriculture is another type of flood based farming system. It consists of cultivation on depressed valley land, using residual headwater moisture and high ground water tables. Raunet (1985) defined this type of land as Bas-Fonds (from French “bottom land”), namely levels or concave bases of small valleys or depresses lines of drainage inundated or submerged for periods up to a year. According to climatic regions he identified several areas where bas-fonds occur, see Figure 20.

In Southern Africa the bas-fonds are called dambos. According to Raunet, dambos (meaning “grazing meadow” in Bantu)<sup>16</sup> occur in areas with precipitation between 1000 and 1300 mm.

However Acres et al. (1985) opened the definition to regions with rainfall volumes between 600 mm and 1500 mm concentrated in four to six months periods. Strictly speaking, dambos are defined as land which holds an ecosystem where the soil is under shallow seasonal waterlogging conditions on headwater zones of drainage systems or along streams (Mackel 1985; Turner 1986). As they are located in headwater zones of drainage systems, dambos have high ground water tables and retain moisture for longer periods than interfluves<sup>17</sup>

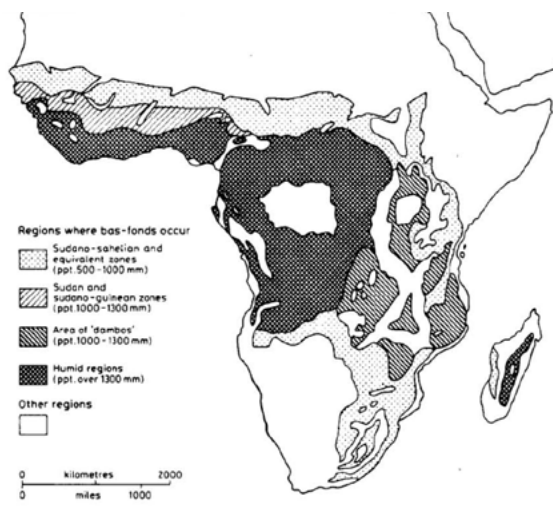


Figure 20: Regions in tropical Africa where bas-fonds occur (Raunet 1985)

Therefore decomposed vegetation under seasonal anoxic conditions leads to organic matter accumulation and formation of hydromorphic and peaty upper soil horizons.

Gleysoils are the common type of soils in dambos. Seasonal inundations and burning result in dambos covered by grasslands and sedges (thus treeless). Hence dambos are distinctive compared to surrounding interfluvial dry miombo woodland. Dambos are characterised by being stretched out, normally more than 200 metres long up to several kilometres, and concave shape with shallow slopes usually below 2 degrees gradient (as opposed to flat Sahelian and Sudanian bas-fonds).

Moisture retention properties, specially during dry periods, render dry season grazing as the most common form of dambo land use. In a study done in Malawi, Young & Goldsmith (1977) recommend grazing in dambos as the best land use alternative for this country. Other studies point out the potential of dambos as grazing grasslands in sub-Saharan Africa (Bell 1986), especially in drought prone environments.

However overgrazing can lead to dambo erosion, encouragement of less palatable species (such as *Sporobolus* spp) and reduction of height and grass ground coverage (Roberts 1988).



Figure 21: Bas-fond in Senegal

16) Dambo is a Bantu word of Zambian origin. However other languages have tagged this type of land; mbuga (Swagili), vlei (Afrikaans), matoro (Shora) and fadama (in Nigeria) and bolis (in Sierra Leone).

17) Interfluves are upland areas between rivers

On the other hand dambos are of great potential for small-scale agriculture with high fertility properties compared to surrounding interfluves. Dry season cultivation of vegetables and maize in small garden plots have been reported in Malawi<sup>18</sup> (Russel 1971). In Zimbabwe dambos are cultivated throughout winter dry seasons and low rainfall rainy seasons (Windram et al. 1985). Similar practices are carried out in Zambia, where maize is planted in September and harvested in December thenceforth cropping vegetables in the dry season (Perera 1982). Estimations account for 50,000 hectares of dambos cultivated in Zimbabwe, generally small garden plots (Lambert 1987). Mackel (1974) estimated that 5% and 10 % of Zambian plateaus are covered by Dambos. There are an estimated 100,000 km<sup>2</sup> (1 million hectares) of dambos in eastern and southern Africa of which less than 5% is under micro-irrigation (Roberts 1988).

Dambos cultivation has advantages compared to rainfed systems. High ground water tables allow cultivation on dry seasons using residual moisture. Additionally, ground water can be easily accessed through shallow wells (using simple water lifting techniques such as shadoofs or rope pumps<sup>19</sup>). Moreover, dambos are more resilient to droughts than rainfed systems, allowing cultivation under extended dry periods, increasing food security. Moreover, where urban areas are close, vegetable production can produce an additional income source. Nevertheless dambos require of special management, regarding burning practices, fertilization and manure application both for cultivation and grazing activities.

## 6. Other flood based farming systems; Inundation canals and dug outs

There are several spatial modifications applied in floodplains to optimize water supply to FBFS. The main example are the inundation canals. Inundation canals are canals next to river or floodplains: they are either dugout or they are formed by old creeks and off-shoots. When water level rises these inundation canals fill up and transport the water flow from the adjacent rivers. In floodplains they are used to facilitate water rising and receding flows. This has been observed in the Niger Inner delta. Furthermore, in active deltas, they can serve to shorten flow routes

for incoming flood waters. As described before, fishermen dug canals in floodplains to trap fish when these migrate to lakes and rivers.

Inundation canals have a long history: before the construction of the Aswan Dam Egypt dependent on them. They are still common in Sudan and can be found along the Nile river banks. Some main inundation canals in Sudan are;

- Argo Khor – the canal is 38 km long located near Dongola. Covers an area of 8,000 feddan;
- Bangarti Khor – total length of the canal is 14 km. Feeds 4,000 feddan (Aldabba locality)
- Shidat Artimiry Khor – on the left bank of the Nile, it's 3.8 km long and supplies 2500 feddan;
- Hibrab Khor – on the right bank of the Nile north of Dongola, 16 km long;
- Ardwan Khor – north from Dongola, 5 km long and irrigates 500 feddans.;
- Elhamak Khor – 5km long irrigating 700 feddan;
- Surgud Khor – north from Abri, 4 km long feeding 400 feddan.

Another technique applied in floodplains are dug outs. Dug outs are excavations done in floodplains of rivers and streams. They are recharged by surface water coming from flood flows or runoff<sup>20</sup>. Hence they are normally located in depressed areas within the floodplain. Dug outs can also be located in non-perennial riverbeds. This type of dug outs, referred as riverine alluvial dugouts, are recharged by ground water seepage. This type of technology has been reported in the White Volta sub-basin in Ghana (Ofusu 2011).



Figure 22: Initial stages of alluvial dug outs (Ofusu 2011)

18) Locally know as "dimbas

19) Plot size in Dambos is normally small (0.2 ha) not requiring big flows for irrigation

## 7. Overview of livelihood systems

### 7.1 Adapted crop agronomy

Agricultural practices are key to assess and enhance FBFS performance. Cropping cycles are determined by water availability and crop choices. Crop agronomy of FBFS differs from flood rising, flood recession and dry season conditions. Flood rising varieties – Rice varieties such as *Oryza glaberrima* (African rice), *Oryza longistaminata* (endemic to most of SSA), *Oryza rufipogon* and *Oryza Barthii* (or African wild rice) are suitable to cultivate under rising flood conditions (also known as deepwater rice). Floating rice varieties can grow up to 6 metres long, with a growing and maturation period between 150 and 270 days. Rice seeds are broadcasted in fields and require a germination and emergence of at least a month prior to flood arrival. One of the measures used by farmers is found in the Nguru floodplain build soil bunds to protect fields and let rice grow up to 12 cm (critical height). Yield ranges between 0.5 and 1 ton per ha (DeDatta, 1981).

Alternatively some grassland varieties are tolerant to flooding conditions. *Echinochloa stagnina* also known as Bourgou or hippo grass is grown over extended areas in SSA, in the Niger Inner Delta floodplain for instance. Its seeds are used for food and beverage production. *Vossia cuspidata*, is a grass with great potential for pasture during flooding periods as well as the dry season with spontaneous shoot emergence. Other flood resistant varieties common in floodplains are *Phragmites australis* and *Phragmites communis* (used for food); *Cyperus papyrus* (food and paper production), *Typha domingensis* (healing properties).

Flood recession varieties – Flood recession agriculture is based on using residual moisture and fertile sediment left after floods.

Therefore crop varieties suitable for flood-recession agriculture must tolerate semi-saturated soils at early stages and high ground water tables. Crop selection may vary according to soil properties and flood conditions, medium textures are suitable for Maize (*Zea mays*), Sorghum (*Sorghum bicolor*, *Sorghum* spp.), Millet species (e.g. *Pennisetum glaucum*) and Wheat (*Triticum* spp.) while more impermeable soils are

optimal for flood recession rice. As an example, maize is normally cropped on high parts of floodplains as it does not support water logging conditions. In addition, it is preferable that flood recession crops tolerate high temperatures and drought conditions. Pulses such as chickpea (*Cicer arietinum*), cowpea (*Vigna unguiculata*) and lentil (*Lens culinari* or *Lens esculenta*) are also grown under flood recession conditions.

Pulses require little crop maintenance, they fix rich nutrients in soils and render grains with high protein and calorie content.

The average time span for wheat, maize and sorghum is between 120 and 150 days. The rainy season in northern hemisphere floodplains normally ends toward September. Therefore flood recession crops are likely to be harvested towards February or March. Thus there is chance to sow a third crop (with a time span of about three months) before the floods or otherwise leave the land fallow.

Inter-flooding varieties – Crop varieties under this group are dry season crops. Thus inter-flooding varieties can be sown right after floods recede or after flood recession crops are harvested. In some floodplains varieties of *Cucubita pepo* (Pumpkin *Curcubita pepo* var. *pepo*; Zucchini *Curcubita pepo* var. *cylindrica*) are sown after floods. The cropping period for these varieties relatively long ranging between 5 and 7 months, thus will only allow to have two cropping seasons per year. Nevertheless these species tolerate well saturated soils and heavy rains and can be combined in the same plot with maize, beans or vegetables for instance.

Sweet potato (*Ipomea batatas*) is known to be grown in SSA floodplains (e.g. Nguru floodplain) after flood recession crops in low lying fields during the dry season (4 to 5 months crop duration). As a general rule tuberous species do not tolerate well saturated soils. Therefore sandy and well drained soils within floodplains are the most suitable locations. Potato (*Solanum tuberosum*) and sweet potato are crops with high yield return, provided high production costs and adequate pest and disease control (120 – 150 days crop duration). Both crops can be grown either as rain-fed or as irrigated crops.

20) Dug outs are differentiated from small reservoirs as the later are located in river channels and are filled with river flows whereas dug outs are located in floodplains. Similarly dug outs tend to be smaller than reservoirs.

Pulses such as Lentil and chickpea or staple crops like Sorghum can be considered as inter-flooding varieties. Flooding intensity and duration may drive farmers to grow these crops in the dry season. An example of this can be found in the Fogera floodplain in Amhara region, Ethiopia. After cropping flood recession rice, farmers sow chickpeas as dry season, rain-fed crop.

Vegetables such as Onion (*Allium cepa*), Garlic (*Allium sativum*), Tomato (*Lycopersicon esculentum*), Pepper (*Capsicum annum*) or Cabbage (*Brassica oleracea* var. *capitata*) are common cash crops. Floodplain agriculture has been widely used for staple crop production. However the potential for commercial agriculture through cash crop production is large. Wherever water availability for irrigation is assured (by use of shallow ground water resources for instance) and farming skills are well developed, there is great potential to use floodplain areas for vegetable production. Given that floodplains are often vast and with a range of topographic and soil conditions, vegetable production can be developed provided the necessary conditions and inputs.

## 7.2 Pastoralism in floodplains

Livestock rearing in Sub-Saharan Africa is a socio-economic phenomenon with great cultural values attached to it. Pastoralist communities have adapted their lifestyle to nomadic behaviours in order to manage space and time in their own benefit, developing an optimal use of grasslands for grazing. Livestock is a source of various valuable products (meat, milk, blood, etc.). Moreover it serves as a risk avoidance strategy as herders tend to have multiple types of livestock, not only cows but goat and sheep, and have substantial numbers (in case drought periods decrease their livestock).

In some countries such as South Sudan owning cows is at the heart of culture and matters more than any other worldly possession. Pastoralists may also have agriculture side activities as an additional source of income.

Cattle herders migrate to different areas where pastures are available. In some flood plain area (as in South Sudan) they follow the receding flow with grazing land (toic) coming available as the flood retreats to the main river course. During dry periods livestock is kept in dry uplands or in case of fully nomadic pastoralism they have to travel



Figure 23: Cattle camp in South Sudan

more distance decreasing milk yields for calves and thus increasing calve mortality.

A good example of this occurs in the Niger Inner delta. The northern part of the delta receives 100 mm of rainfall per year while the southern part collects up to 750 mm. During the wet season flooded fields make grazing not feasible. Hence herders migrate north in search for grasslands. When flood recedes Cyprus and other grasses grow vigorously. From January to early May pastoralist migrate south and their cattle graze on the floodplains. It is estimated that 1.2 million cows enter the southern inner delta floodplain in decrue together with 400,000 sheep and goats (Leeuw de & Milligan 1983).

There are several plant species of interest. Floating aquatic grasses that grow on the floodplain, namely wild rice (*Oryza longstaminata*), floating rice (*Oryza glaberrima* and *Oryza barthii*), *Vossia cuspidata* and *Bourgou* (*Echinochloa stagnina*, also known as *Burgou* millet or hippo grass). *Bourgou* is a “wild grain” particular of Africa with high productivity values (sprouts are estimated to yield 3 to 5 tonnes per ha (Zwart et al. 2005) and high nutritional values.

Cattle can be also a hazard for rural communities. In the Okavango delta in Botswana, the floodplain was protected from cattle by a fence constructed in 1983. Its purpose was to stop the spread of diseases (mouth and foot) carried by livestock. Therefore it prevented pastoralists to enter the floodplain and graze in the Molapos. This triggered overgrazing in areas outside the fence (especially acute in years when rains were late). Conflicts can also arise between farmers and pastoralist over land use. Fertile floodplain soils after decrue are used by both groups. On the one hand farmers need to harvest crops such as rice

on receding floods (and moisture) while pastoralist ought to graze on the floodplain as aquatic plant quality decrease rapidly in the absence of water. Due to unique pastoralist characteristics (nomad lifestyle and fragmented distribution), they lack of associations or institutional framework. This restricts their status compared to farmers who are part of water user associations or other institutions. Thus in conflict management they can lack of representation.

Ancient laws are sometimes articulated in order to grant land use rights. This is the case in the Niger Inner delta with 19th century Dina law still being enforced.

Pastoralism in floodplain systems is common throughout Africa. This is the case in most of the major African floodplains, namely, the Okavango and Niger Inner Delta, the Yobe Basin, in Ethiopian lowlands (Afar and Tigray regions), in the Senegal river valley, in the Logone floodplain, in the Zambezi basin and the Nile Basin amongst others. Only in the Horn of Africa, it has been estimated a pastoralist community between 12 million (ICRC 2005) and 22 million (Morton 2008).

### 7.3 Other floodplain resources, timber and non-timber products

Forest and bushlands are common in floodplains. They provide a source of fuelwood for local inhabitants as floodplain are sometimes located in remote areas with no electricity or road connexion. Apart from timber products, certain leaves are harvested.

Doum palm leaves (*Hyphaene thebaica*) are harvested in the Hadejija-Nguru floodplain (FAO 1997). These leaves are used for mat, rope and basket production or sold as raw material. Baobab leaves are also collected for diet purposes. This leave is considered as “drought food” used for soups and stews during the dry season. Similarly, *Sporobolus robustus* and *Acacia nilotica*, are harvested in the Senegal River Valley. They are harvested by women and employed for mat making. It has also been suggested that the ubiquitous reeds could be used for the production of briquettes. These are some of the opportunities of added value which are used by communities in floodplains.

## 8. Fishing and Aquaculture in floodplains

One major additional use of the FBFS areas is fishery. Fish culture requires less inputs for protein production compared to agriculture (e.g. fertilizers and fodder)(Maar et al. 1966). Therefore aquaculture in sub-Saharan Africa poses great potential for improving diet and food supply alternatives. In Asian FBFS aquaculture and controlled fishery is very much part of the resource system.

Fisheries in floodplains and riverine environments are FBFS are also common throughout sub-Saharan Africa<sup>21</sup>, though not the same level of intensity as in Asia<sup>22</sup>. In several areas inland ponds are constructed to breed fish in freshwater conditions using floodplain water resources. Another way of fish production is using fingerponds. Fingerponds are ponds set aside from lakes. When floods occur and water level rise, fish migrate to the floodplain. When floods retreat fish get trapped in fingerponds and are breed for several weeks until they have enough weight and size to be marketed. Finally, besides ponds; fishing is carried out in floodplains. Fishing is common in vast floodplains such as the Inner Niger delta in Mali using rising and retreating floods to catch migrating fish and trapped fish in smaller flood creeks.

### 8.1 Riverine and floodplain fishing

Fishing activities can be developed in permanent lakes, main rivers channels, flood fed seasonal creeks, pond depressions and in floodplains.

In the Waza-Logone floodplain fishing starts when flood water is at its highest levels, normally in October<sup>23</sup>. Fish species like *Clarias spp*<sup>24</sup> use the floodplain to spawn while others like *Oreochromis niloticus* and *Petrocephalus bovei* do it in water courses. There are two main fishing seasons, one in October (known as “the great fishery”) and one throughout the dry season (called “small fishery”) when seasonal swamps are almost dry (de Longh et al. 1998). Catfish are known to be the first specie to spread through the floodplain and the last to leave. Catfish are fished when flood recede using baited traps set along the floodplain

21) Evidence in Egyptian tombs proof Tilapia fish culture tracking back to 2500 B.C

22) See also: A Wise Use of Flood Water Resource at the Mekong Delta of Vietnam. Online available at: [http://spate-irrigation.org/wp-content/uploads/2012/01/OP\\_11\\_Vietnam\\_SF.pdf](http://spate-irrigation.org/wp-content/uploads/2012/01/OP_11_Vietnam_SF.pdf) [Accessed on 17th February 2015]

23) Rains start in June but the highest water levels are reached after the rainy season starts.

24) This is the preferred specie for fisherman as it is marketed with the highest price.

**Text Box 5: Common types of inland floodplain ponds (Maar et al. 1966)**

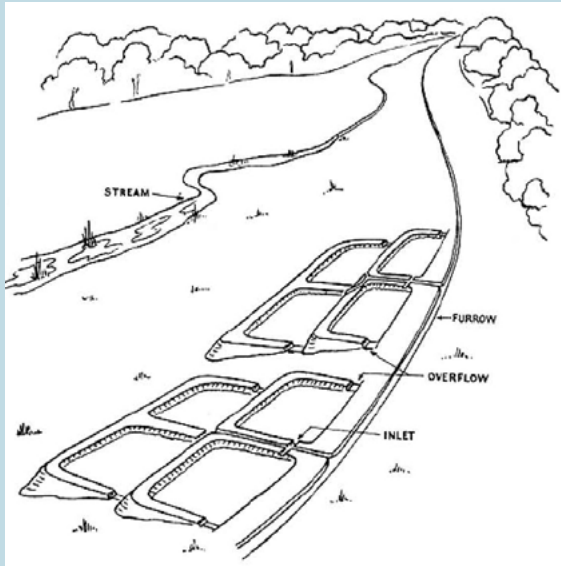


Figure 24: Contour ponds

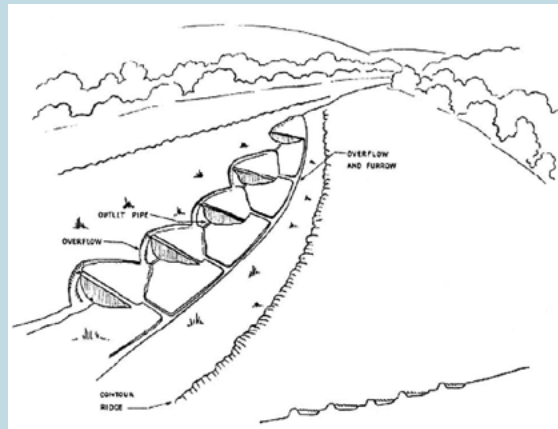


Figure 25: Barrage ponds

There are three main types of inland floodplain ponds used for fish aquaculture. Namely, contour ponds, barrage ponds and paddy ponds.

Contour ponds are constructed along valley sides and dambos along the slope. These ponds are fed by streams or conservation dams.

Barrage ponds are commonly set in small dambos. They differ from contour ponds as each pond overflows to the one below. Likewise ponds are supplied with water from the same furrow. Contour ridges are made beside the ponds to protect them flooding. Barrage ponds are sometimes constructed below conservation dams.

Paddy ponds are built in flatlands; namely dambos, swamps and floodplains. Therefore four walls are set to construct the ponds (as opposed to three walls of contour ponds or one wall of barrage ponds). Water is distributed in furrows on top of the ponds. Water usually comes from a spring or seepage area.

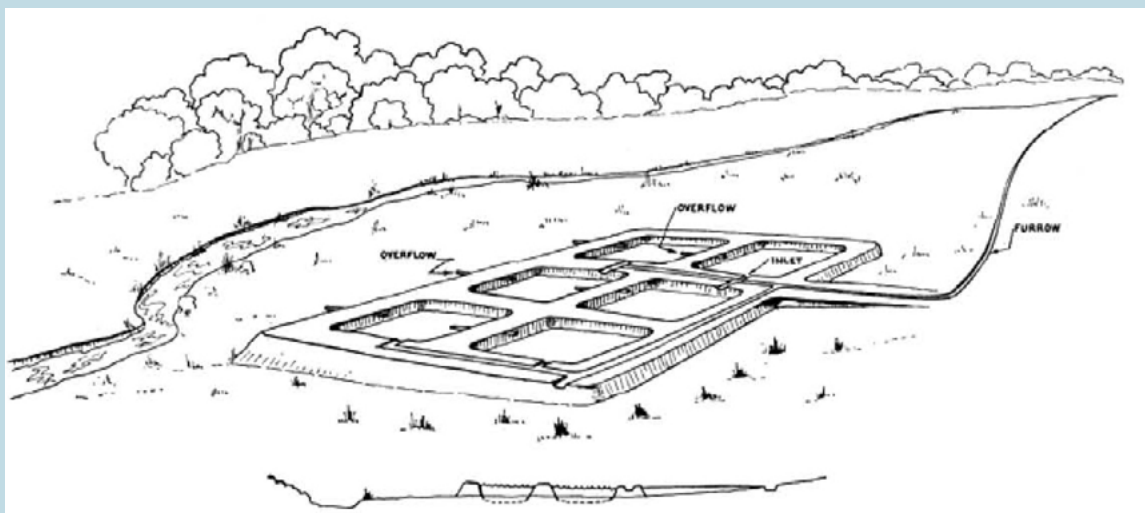


Figure 26: Paddy ponds made in a flat dambo

25. Sardine fish (*Alestes* sp) are more sensitive to changing water levels and are the first to go back to rivers. Thus when water starts to recede sardines are fished as they promptly migrate back to rivers in mass numbers.

Dragnets and shaped traps are used in dry season fishing (activity also done by women and children) when swamps are dry enough and fish have grown to optimal levels. Another technique developed in this area is using trenched canals dug in the dry season. These are excavated in depressed lands next to rivers. Nets are placed in the canals to trap fish heading back to rivers (normally in January and February). Species collected through this technique are mostly *Clarias* spp and *Tilapia niloticus*.

The total fish production in the Logone floodplain, estimated 12,000 tonnes in 2,600 km<sup>2</sup> of floodplain surface (46 kg of fresh fish per hectare).

Fishing in South Sudan is widespread; particularly in the Sudd floodplain and in small lakes in South Sudan (e.g. Yirol and Neyi lakes). The total fish production of the country is estimated in 200,000 and 300,000 metric tonnes per year. Out of this figure, the estimated annual catch is 40,000 to 45,000 metric tonnes (FAO/WFP 2010). In the riverine environments in South Sudan fishing take place in two main seasons, using the most basic of methods. When floods arrive and water levels rise, fish are collected from floodplains. In the dry season fish trapped in declining are fished using, nets, hooks and spears.

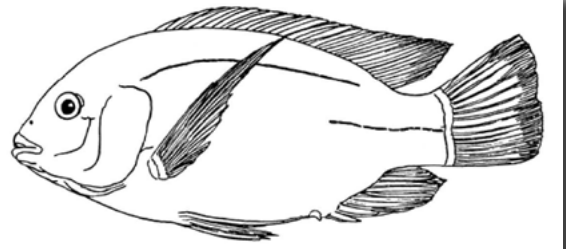


Figure 27: *Tilapia macrochir* common in Congo, Upper Zambezi, Kafue and Okavango river systems (Maar et al. 1966)

Floodplain fishing is also common in the Niger Inner delta (see also Zwarts et al. 2005). It is estimated that out of the 900,000 inhabitants of the delta; 300,000 directly depend on fisheries. Zwart et al (2005) observed that fish catch depend on the previous flooding season. The duration of the flooding period determines fish growth and reproduction and thus affects fish population for the following season. This has been observed also in the Kafue river (Zambia) (Welcomme 1979), the Amur, Danube and Nile rivers (Lae 1992). The total production of the Niger Inner delta in 1987 was estimated in 8,400 tonnes of dry fish and 14,000 tonnes of fresh fish. Increasing pressure on fish stocks has stagnated yields in the delta. One of the reasons pointed out was the introduction of nylon nets in the 1960s with continual decreasing mesh sizes.

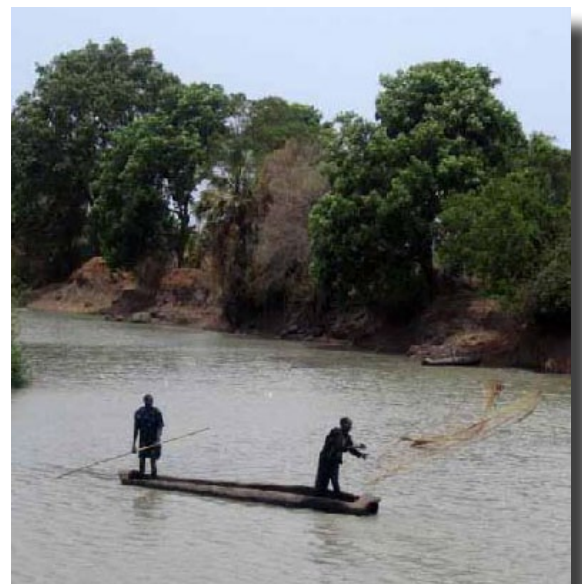


Figure 28-29: Fish trap in Lake Yirol (left) & Fishing with a throw net (right), South Sudan.

25) On shallow water catfish can be speared or clubbed.



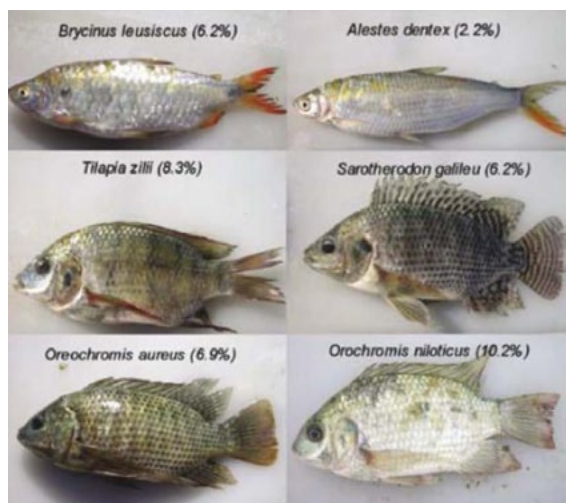


Figure 30: Economically most important fish species in the Inner Niger Delta (Zwarts et al. 2005)

Welcomme (1986) estimated the total fish production in African floodplains in 3,83 tonnes per km<sup>2</sup>, meaning 38,3 kg per hectare of floodplain. However this figure can vary significantly from one floodplain to other<sup>26</sup>. There is a range of technology – from basic trapping and collecting to the use of ponds – that explain much of the difference. More sophisticated managed fishery systems combined with the growth of aquatic crops, as practiced in Southeast Asia are still to come in SSA.

## 8.2 Fingerponds

Fingerponds are excavated next to lakes or permanent swamps. As water rises during the flooding season, fauna from lakes expand to nearby floodplains. Ponds are excavated next to lakes so as to trap fish when water levels fall. They usually have rectangular shape and are orientated towards the lake, hence the term “finger” ponds (see )(Van Daam et al. 2006).

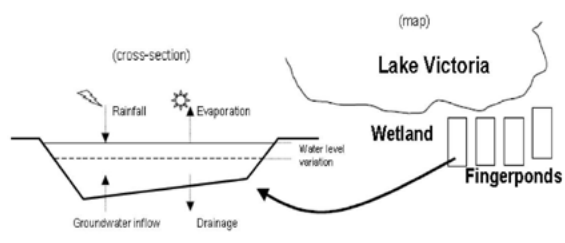


Figure 31: Fingerpond orientation and cross-section (van Daam et al. 2006)

After the flood recedes, water levels in fingerponds are balanced by rainfall and ground water recharge (as inputs) and seepage and evaporation (as losses). Depending on the flooding season, fingerponds can also run dry at the end of the dry season. It has been observed that between the ponds vegetables are grown.

Fingerpond bottom soils, rich in organic matter, are used as fertilizer (collected when ponds are dry)(Kaggwa et al. 2006). Manure from livestock can be added to increase fish yields. Manure application increases periphyton biomass which enhances fish yields (Loth, 2004). Fingerpond fisheries systems have been developed next Lake Victoria (Kenya, Uganda and Tanzania) (Luoga 2001, Loth 2004). Fingerponds have also been documented next to Lake Tana in Ethiopia. Common fish species for these systems are Oreochromis (tilapias), catfish (Clarias spp.), lungfish (Protopterus sp.) and various haplochromine cichlids.

## 9. Potential for FBFS development

FBFS are widespread in Sub-Saharan Africa. They are the livelihood base for large often remotely situated communities, yet at the same time harbour enormous potential of sustaining higher yields of staple, livestock and fish and provide more ecosystem services. The changes required are often not complex or costly, but require a good understanding of the local resource base and insights in opportunities for improvement.

### 9.1 Agricultural practices

The use of rising flood as well as flood recession in several areas in western Africa has permitted double cropping: first rice or flood tolerant sorghum varieties grow on the rising flood and subsequently other crops, such as several sorts of pulses, grow on the residual moisture. This transformation may offer opportunities for other areas too, depending on the pattern of flood rise. In some areas the introduction of floating rice varieties may be considered, very fast growing varieties that keep up with the speed of the rising flood and can reach 3-5 meters in height. Floating rice varieties grow in areas as varied as Mali and Cambodia and Vietnam.

26) Sudd floodplain in Sudan estimated 8,8 kg per ha while Cross floodplain in Nigeria is 25 kg per hectare. As mentioned above Logone floodplain fish yield is of 46 kg per hectare.



Figure 32-33 Floating rice cultivation, Vietnam.



Improved sorghum, rice, maize and varieties of other staple crops can boost agricultural performance. There has been comparatively little effort in breeding and agricultural research in FBFS – and more research is required in plant breeding for the often specific flood based conditions. A start point would be to systematically exchange and test varieties between different parts of the world where comparable FBFS occur.

## 9.2 Floodplain water management – skills and practises

In order to optimize flood flows, better floodplain water management is required. Sophisticated field water management practises can be found in countries like Bangladesh (Wester & Bron 1998). Floods are managed through retention and drainage structures, retaining water enough time to cultivate crops. At the same time fields are protected against excessive waterlogging and extreme flood events. Better field water management practises require of a deep understanding of flood behaviour in the context of floodplains.

By their nature the productivity of FBFS are dependent on moisture management. As rainfall events are unpredictable and sometimes erratic, farmers face limitations on water supply. Therefore optimization of floods retention and moisture management are critical for an optimal agricultural performance.

Field water management is key to enhance moisture retention and avoid harmful waterlogging for crops. In order to improve water infiltration, ploughing practices may be performed before the arrival of the flood. This is sometimes difficult as before the floods or rains, soils are too

dry to plough. Alternatively, ploughing practices after the harvest might be more feasible. Similarly, stubbles incorporated in soils through ploughing is a good way to increase the organic matter content. An increase in organic matter contributes to soil fertility and water holding capacity of soils.

Water distribution at field level entails a set of techniques. Soil embankments have been the traditional of retaining water at plot level. However it requires proper plot levelling and depends on the lay of the ground. In some cases floods are spread as sheet flow thus making this technique unsuitable. On the other hand drainage is a way to redistribute water (apart from decreasing water levels and saturated soils). Depending on soil textures (e.g. sand), some soils are easier to drain. Then again, crop selection might help mitigate insufficient drainage in waterlogged prone soils.

The essence of most FBFS is the multipurpose nature of floodplains. Diversification in several activities can mitigate risks and help cope with uncertainties related to climate change and variability regarding FBFS. Relying on one source of income (e.g. flood recession) may pose risks which can be otherwise reduced by intensifying in several farming systems (flood recession, fisheries, livestock rearing, etc.).

An example of the former is especially acute for pastoralist communities. With current land intensification by agriculture and industry, pastoralist communities face new challenges regarding their livelihoods. Some communities have embraced diversification as resilience strategy. Little (2013) described diversification of pastoralist activities as an on-going process distinguishing two types of diversification:

survival-type (based on unskilled labour and with low performance) and accumulation-type (based on business driven activities). Pastoralist diversification on small scale irrigation has been pinpointed as of big potential and scope (Sandford 2013). This alternative is not free from complexity due to competition for water resources, public health impacts and high costs. All in all this process is critical for the sustainability of pastoralist livelihoods.

### 9.3 Artificial Flood Releases

In order to cope with negative effects of dam construction in floodplains, artificial flood releases have been contemplated as a possible solution. Several studies have demonstrated that artificial flood releases are beneficial for FBFS and not necessarily opposed to power generation. However, the latter requires of an integrated basin approach and detailed studies of best dam management practices (Klaassen 2007).

A study carried out by Duvail & Hamerlynck (2003) in the Senegal River, concluded that artificial flood releases can perform better than natural flooding as climatic variability is tackled and dry years with reduced flooding can be avoided as reservoirs keep enough water in these periods. Their findings were based in data collected including agricultural outputs, fishermen income, livestock rearing, harvesting of non-timber products and ecological values. On the other hand, as artificial flood releases are controlled in quantity and time extent, stakeholders may have different demands. As an example, fishermen are more likely to need larger flooding periods compared to livestock keepers as the latter seek high quality pastures which can be affected by extended flooding periods. At the moment artificial flood releases are though sporadically applied from rivers that are dammed – but the flood releases are sometimes timed erratically: without consultation or prior announcement to downstream community and in the off-season – rendering them useless.

### 9.4 Innovative Technologies

Shallow ground water is a resource of great potential for FBFS. Floodplains normally have high water tables throughout the year. Hand dug wells have been the traditional way to exploit ground water. However they require big investments (due to high labour requirements) and demand considerable area. After flooding seasons they

tend to collapse increasing maintenance costs. Another way to approach ground water resources is by hand drilled shallow tube wells. Hand drilling is an innovative technique which is still under development in Africa (see Table 12). This type of drilling technique is done with human labour. Depths between 10 and 30 metres are reached, enough to tap shallow ground water (including water extraction). Manually drilled boreholes are of small diameter. This makes it possible to seal wells with slab, apron and capping. These improvements make wells flood proof and protects them from pollution. Moreover they employ local workers and demand materials which can be manufactured in local markets. This type of value chain can encourage local business development and entrepreneurship. Because this technology requires of local labour and manufacturing, the cost per drilled meter is significantly lower than mechanically drilled wells.

Shallow ground water availability can cope with uncertainty related to erratic rainfall and unpredictable flooding. Manual drilling technologies are not the only way of tapping into this resource. As noted previously, dug out technology is another way to approach ground water use. Combining surface and groundwater can increase significantly agricultural yields as water is the main limiting factor.

Regarding water lifting technologies, these can be either manual (treadle pump and rope pump) or motorized (common diesel pumps or benzene micro-set pumps) depending on the water flow needs, depth of ground water table and financial availability. As floodplains are vast and sometimes remotely located, electricity is seldom available. Furthermore it is desirable to use pumps that can be installed and moved easily, to prevent the pumps from being flooded or stolen (in general farmers do not live in the floodplains) Therefore treadle pumps and a range of motor pumps are recommended.

#### Rope pumps

Rope pumps can lift water up to 35 metres depth. Its construction and maintenance cost is low. The main disadvantage is that the flow is relatively low for irrigation purposes: water delivery ranges between 0.17 L/s at 35 metres depth and 0.67 L/s at 10 metres depth (Olley, 2008). Furthermore it takes time to install the pump, making it unsuitable to take home daily.

Technique	Description	Advantages/ disadvantages
Hand Auger	<p>Consists of extendable steel rods, rotated by a handle. A number of different steel augers (drill bits) can be attached at the end of the drill rods. The augers are rotated into the ground until they are filled, then lifted out of the borehole to be emptied. Specialized augers can be used for different formations (soil types).</p> <p>Above the water table, the borehole generally stays open without the need for support. Below the water table a temporary casing may be used to prevent borehole collapsing. Drilling continues inside the temporary casing using a bailer until the desired depth is reached. The permanent well casing is then installed and the temporary casing must be removed. Augers can be used up to a depth of about 15-25 meters, depending on the geology</p>	<p><b>Advantage:</b> easy to use above groundwater table; cheap equipment.</p> <p><b>Disadvantage:</b> it may be difficult to remove the temporary casing.</p> <p><b>Geological application:</b> Sand, silt &amp; soft clay.</p>
Sludging	<p>Uses water circulation to bring the drilled soil up to the surface. The drill pipes are moved up and down. On the down stroke, the impact of the drill bit loosens the soil and on the up stroke, the top of the pipe is closed by hand (or valve), drawing up the water through the pipe and transporting the cuttings to the surface. On the next down stroke, the hand (valve) opens the top of the pipe and the water squirts into a pit, in front of the well. In this pit, the cuttings separate from the water and settle out, while the water overflows from the pit back into the well. The borehole stays open by water pressure. Thickeners (additives) can be added to the water to prevent borehole collapse and reduce loss of working water (drill fluid). Water mixed with cow dung is often used for this matter. Sludging can be used up to depths of about 35 meters.</p>	<p><b>Advantage:</b> easy to use and temporary casing is not needed.</p> <p><b>Disadvantage:</b> working water has to be maintained during the drilling process. The level of the water table is not known during drilling.</p> <p><b>Geological application:</b> Sand, silt, clay, stiff clay and softer- consolidated rock formations (weathered laterite)</p>
Jetting	<p>Is based on water circulation and water pressure. As opposed to sludging, water is pumped down the drilling pipes. The large volume of water has an erosive effect at the bottom and the 'slurry' (water and cuttings) are transported up between the drill pipe and the borehole wall. A motor pump is used to achieve an adequate water flow. The drill pipe may simply have an open end, or a drill bit can be added and partial or full rotation of the drill pipe can be used.</p> <p>Thickeners (additives) can be added to the water in order to prevent borehole collapse and reduce loss of working water (drill fluid). Jetting (with rotation) is generally used up to depths of 35- 45 meters,</p>	<p><b>Advantage:</b> very quick in sand.</p> <p><b>Disadvantage:</b> a lot of working is needed at once. The level of the water table is not known during drilling.</p> <p><b>Geological application:</b> limited to sand and thin layers of soft clay</p>

Table 12: Manual drilling techniques

### Treadle pumps

Introduced as a low cost technology for irrigated agriculture, its use has been handicapped by the arrival of motor pumps. It uses treadles serving as levers to pump the water up. Like all suction pumps, its suction depth is maximum seven meters. Treadle pumps require little maintenance. The total dynamic head is of 8 or 14m, depending on the type. Water delivery is 1.4 L/s at 4 metres depth (Olley, 2008). The maximum irrigated area by one treadle pump is on average 0.26 ha (Abric et al., 2011).

### Motor pumps

Motorised suction pumps are the most popular pumping technology for small scale irrigation in floodplains, since they are physically less demanding, widely available and easy to install. The African market knows a large range of diesel pumps between 2.5 and 5 hp. The suction depth is 8 m maximum, the total dynamic head is around 20 – 30m.

To reach groundwater that is situated deeper, the pumps can be installed inside a large dug hole. The models from 3.5 – 5 hp can be used to irrigate 1-2 ha, which largely exceeds the average irrigated plot size cultivated by smallholder farmers. These pumps are also difficult to transport and know an excessive fuel consumption if used for small fields only. Models from 2.5 – 3.5 hp are notably lighter, though still exceeding 50 kg. These pumps can be used to irrigate fields of 0.5 – 1 ha (Abric et al., 2011). Since most smallholder farmers have smaller fields, they tend to run the pumps on a low rate that is not fuel efficient.

A recommended alternative is the use of micro pump-sets of 1.5 – 2.5 hp. Its flow of about 3 L/s can be handled by smallholder farmers to irrigate fields of around 0.5 ha. Fuel consumption is more efficient and with a weight of 10 kg farmers can carry them home daily.

#### Text Box 6: Chinese low cost micro pumpsets

Motorised suction pumps are the most popular pumping technology for small scale irrigation in floodplains, since they are physically less demanding, widely available and easy to install.

The African market knows a large range of diesel pumps between 2.5 and 5 hp. The suction depth is 8 m maximum, the total dynamic head is around 20 – 30m. To reach groundwater that is situated deeper, the pumps can be installed inside a large dug hole. The models from 3.5 – 5 hp can be used to irrigate 1-2 ha, which largely exceeds the average irrigated plot size cultivated by smallholder farmers. These pumps are also difficult to transport and know an excessive fuel consumption if used for small fields only. Models from 2.5 – 3.5 hp are notably lighter, though still exceeding 50 kg. These pumps can be used to irrigate fields of 0.5 – 1 ha (Abric et al., 2011). Since most smallholder farmers have smaller fields, they tend to run the pumps on a low rate that is not fuel efficient.

A recommended alternative is the use of Chinese micro pump-sets of 1.5 – 2.5 hp. Its flow of about 3 L/s can be handled by smallholder farmers to irrigate fields of around 0.5 ha. Fuel consumption is more efficient and with a weight of 10 kg farmers can carry them home daily.



Fertilizing is regarded as another limiting factor. Although alluvial soils, common in floodplains, have good fertility properties; organic composting can also serve as an extra agricultural input. Organic soils have higher water holding capacities and productivity rates. Therefore, composting of agricultural surpluses and livestock dung can be an additional source of fertilizer of no extra cost and of simple management, enhancing agricultural performance in floodplains. Information and communication technologies are of great interest for potential application in

FBFS and pastoralist communities (Little 2013). Rainfall and flood forecasting, estimations of flooded areas, drought prediction, pest control, market prices and many other applications can be developed through these technologies. Mobile phone and smartphone introduction in Africa may serve as a catalyst for ICT development in the continent. Floodplain users can use this information to accommodate choices and improve management through this type of technology. There is great scope for ICT development in both agriculture and FBFS in Africa.

### 9.5 Mapping groundwater potential zones in floodplains.

Shallow ground water is a resource that can be easily accessed and exploited in floodplains. Rainfall and flood flows recharge shallow ground water tables by surface runoff, percolation and seepage. The ground water table (phreatic level) can be found in the first 25 meters. However groundwater development across much of sub-Saharan Africa is constrained by a lack of

knowledge on the suitability of aquifers for borehole construction.

Mapping groundwater potential zones is essential for planning the location of new abstraction wells to meet the increasing demand for water. The occurrence, distribution, and movement of groundwater mainly depend upon the geological and hydro-geomorphological features of the area. A detailed study of groundwater occurrences can be made by surface and subsurface investigation methods. The use of remotely sensed data along with Geographic Information System (GIS) is well suited, and it can be easily combined with the data generated from conventional and ground measurement systems (Gumma & Pavelic 2012).

It is also important to map the areas where flood based farming holds promise - existing areas that can be improved and new areas that can be developed. The mapping can be done systematically - looking at the catchments, the run-offs and the agricultural areas. Particularly in many lowland plains there may be unutilized potential. All this would need to be better identified - to start at reconnaissance level.

As FBFS have been left out of academic and policy agendas, it is of interest to carry out detailed studies to document such systems. Studies would help gain knowledge of FBFS work and their scope for further potential development. In this regard academic institutions should include FBFS in university programmes contributing to teach experts and strategic thinkers in this field.

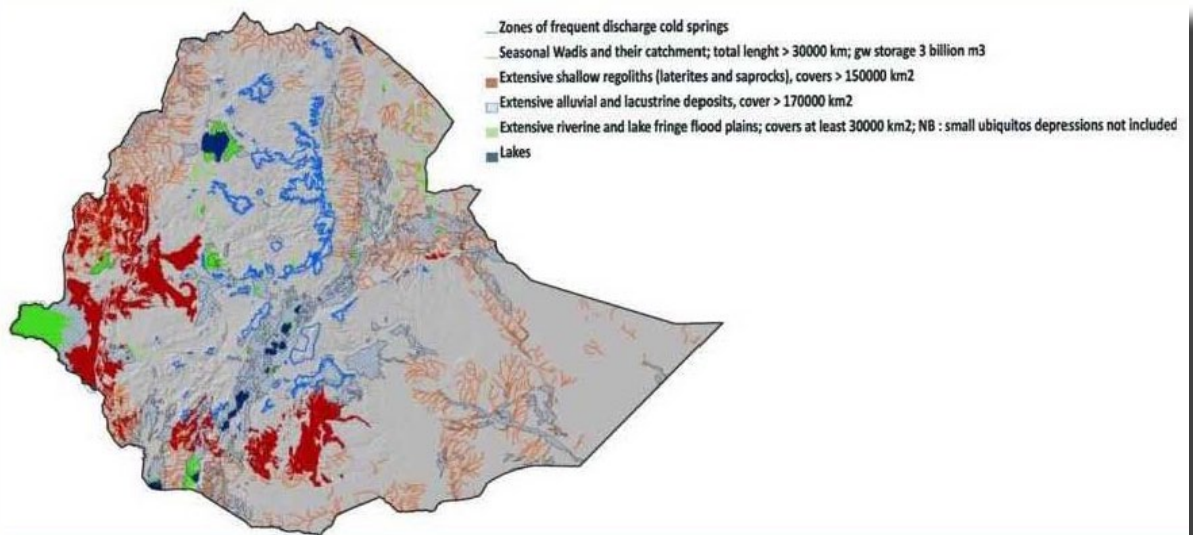


Figure 34: Mapping shallow groundwater for Multiple Use Systems

Moreover, policy advisers and government officials should be included in capacity building programmes as well. There are already some examples of failures - i.e. public works in dam construction - due to insufficient knowledge and lack of awareness of FBFS.

Conventional agronomy and design principles are not appropriate for the systems described in this paper (e.g. spate irrigation systems design differs greatly from the ones of perennial irrigation). Therefore guidelines in agronomic practices, enhancement of field water management, moisture conservation measures, design principles, improved varieties, amongst others; are topics where the capacity building and knowledge base must be focused. With this approach professionals in this field can advocate for FBFS development and form core groups of experts for each country or region.

Investment plans and strategic development policy in FBFS could use lessons and experiences developed elsewhere. FBFS are extensive throughout Africa, hence investments in modern systems could come in the way of enhancing existing ones (as recommended from experiences in spate systems in Asia) or mix traditional and modern systems making investments more cost effective. On the other hand using floodplains for agricultural development can serve to protect these rich ecosystems from degradation and erosion (i.e. recharge of shallow ground water or soil erosion control).

Food storage is another field where policy programmes could be focused. Grain storage facilities could cope with food security crises, enhance food safe processing and improve market services for agricultural products. Moreover these type of initiatives can encourage early chain value creation.

## 9.6 Upscaling

FBFS are agricultural systems which have great potential for up-scaling. Given that FBFS are worldwide present, and floodplains and wetlands are increasingly given attention by its ecological relevance; the potential of floodplains as areas of agro-ecological is huge.

Capacity building at different levels may be one of the drivers for up-scaling FBFS. Policy makers, decision makers, and governmental authorities must be familiar to FBFS. Thus

awareness campaigns and trainings must capacitate officials to understand and apply new techniques and technologies linked to FBFS. Likewise, there is great need to include FBFS in Universities curricula, as these systems are still unknown to many agronomists and engineers. New engineering principles which consider FBFS as alternative and unique systems are required. Engineers and water professionals must acknowledge the intrinsic characteristics of FBFS and therefore elaborate design standards accordingly. At field level, practitioners, entrepreneurs and model farmers shall be approached and involved in bringing knowledge and expertise to FBFS.

Another strategic field which can help upscale FBFS is research. A core of national and regional experts and academics specialized in FBFS for every country, where FBFS are important, must be formed: to build up local knowledge and a core of specialist and have a better interface with farmers and practitioners.

The role of governments in development of FBFS must be strengthened. Regulatory policy regarding land and water access in dry and flooding season can accommodate different needs amongst different floodplain users. Possible gaps in early value chain, such as food early processing and storage are sectors institutions and agencies must develop. Apart from supporting farmers and other floodplain users, extension officers can monitor and evaluate performance of FBFS at a medium scale. This information can help decision makers formulate strategies adapted to flooding patterns, changing rainfall events or migration fluxes.

## 10. Risks and threats for FBFS development

The potential that FBFS offer is undone in several area by a number of often large developments.

### 10.1 Infrastructure development

FBFS are the basic source of livelihoods for many rural communities in Sub-Saharan Africa. They also provide important outputs serving as an important economic asset in arid and semi-arid regions. However the trend set by national governments to provide electricity through hydroelectric power, constructing medium and big dams, has encroached floodplain development

in several of the major basins. Hydraulic interventions are meant to provide hydroelectric supply and control flows in river basins. Yet, they pose several drawbacks in terms of social, economic and environmental dimensions.

Dams store and divert water courses in rivers and streams. This has an effect on natural distribution and timing of stream flows which has an immediate consequence downstream, reducing floods peaks and therefore reducing the frequency extent and duration of floodplain inundation (Bergkamp et al. 2000)( McCartney et al. 2000). Bergkamp argued that this reduces productivity of floodplains and deltas, which has been confirmed in some dams constructed (e.g. in the Senegal River, with the Diama and Manantali dams)(Duvail 2001).

Upstream inundated areas displace local population. Hence surrounding areas face population pressure in both land and natural resources. Permanent inundated areas may pose health risks for water related diseases. Health impact of large dams is not only located at the reservoir but also upstream and downstream from the dam. Water related diseases such as malaria, schistosomiasis, encephalitis, hemorrhagia fevers, gastroenteritis, intestinal parasites and filiarisis are increased by dam construction (Lerer & Scudder 1999).

Environmental and economic impacts of dam construction are related to the change in flows and annual flooding patterns. This has a negative effect on multiple FBFS as it disrupts flooding seasons affecting fisheries, flood recession agriculture and pastoralist activities. Another side effect is the loss of biodiversity and disturbance of avian migration.

Impact Area	Effect of the dam	Health Impact
Upstream catchment and river	Loss of biodiversity, increased agriculture, sedimentation and flooding, changes in river flood regime	Changes in flood security, water-related diseases, difficulties with transportation and access to health facilities
Reservoir area	Inundation of land, presence of manmade reservoir, pollution changes in mineral content, decaying organic material, pollution	Involuntary resettlement, social disruption, vector borne diseases, water related diseases, reservoir induced seismicity
Downstream river	Lower water levels, poor water quality, lack of seasonal variation, loss of biodiversity	Food security affected in floodplains and estuaries (farming and fishing), water related diseases, dam failure and flooding
Irrigation areas	Increased water availability and agriculture, water weeds, changes in flow and mineral content, pollution	Changes in food security, vector-borne and water related diseases
Construction activities	Migration, informal settlement, sex work, road traffic increase, hazardous construction	Water related diseases, sexual transmitted diseases, HIV/AIDS, accidents and occupational injuries.
Resettlement areas	Social disruption, pollution, pressure on natural resources	Communicable diseases, violence and injury, water-related diseases, loss of food security
Country/region/global	Reduced fuel imports, improved exports, loss of biodiversity, reallocation of funding, sustainability	Macro-economic impacts on health, inequitable allocation of revenue, health impacts of climate change

Table 13: Potential health impact of large dam projects(Oud & Muir 1997)



Closely related to hydropower development is the development of perennial irrigation. This is often assumed to be superior to FBFS but often this is not the case. As described in this note, floodplains are sustaining many economic activities and different livelihoods. Unfortunately, there are several examples (e.g. Manantali Dam in the Senegal Valley, the Tiga and Challawa dams in the Hadejia –Jama'are Basin in Nigeria, Phongolo river in South Africa, the Diama dam in Mauritania and in the Logone floodplain) where the lack of economic and environmental assessments in this type of interventions have led to disastrous consequences both socially and economically (Acreman 2000).

Another hazard for FBFS is road construction works. This is an issue which is emerging in many African countries as road construction is increasing throughout the continent. Roads are meant to connect and create communication networks which enhance economic activities. Nevertheless road development, especially if not included in design criteria, can cause disruption of shallow ground water fluxes and surface runoff and disturb for instance fish movement. There is a need for a larger sensitivity and creativity in planning and design here.

## 10.2 Civil Conflicts

Civil conflicts and social unrest can hinder FBFS development and discourage public investment. This has been the case in eastern Africa (e.g. Somalia). Moreover conflicts arising over land use and resources (e.g. pastoralists and farmers) are also present in floodplain systems. Clear defined land and water rights are critical to prevent

and solve disputes. In some regions there are tribal and traditional rights, sometimes informal, regulating land use. Nonetheless traditional rights shouldn't enforce inequity or alienate certain social groups. Legal rights must compromise all users in floodplains while making the optimal use of resources.

## 10.3 Invasive species

Invasive species pose another hazard for FBFS. An example of this is mesquite tree (*Prosopis juliflora*). Its introduction in Africa has caused rapid invasion of agricultural land<sup>27</sup>. Originally from Latin America, mesquite tree is a shrub type tree with several invasive characteristics. Its seeds spread easily, especially where livestock is active in the area. Moreover seeds germinate easily triggering rapid spread. Mesquite root system inhibits other specie growth, hence encroaching grazing lands. It also tends to expand to waterways and riverbeds fracturing them and destabilizing flows. As mentioned before, it is an increasing problem for some spate irrigation schemes in Ethiopia and Eritrea.

Mesquite was initially introduced for dune stabilization but has become an increasing problem. It is estimated that 10 million hectares have been invaded in India, Pakistan, Yemen, Sudan and Ethiopia over the last 10 years. Eradication programmes have been launched in Sudan and Ethiopia focused in uprooting and later rapidly transforming "cleared" land into agricultural fields.



Figure 35-36: *Prosopis juliflora*

27) See also: *Controlling and/or Using Prosopis Juliflora in Spate Irrigated Systems*. Online available at: [http://spate-irrigation.org/wp-content/uploads/2011/06/PN25\\_Prosopis\\_Juliflora\\_SF.pdf](http://spate-irrigation.org/wp-content/uploads/2011/06/PN25_Prosopis_Juliflora_SF.pdf) [Accessed on 18th of February 2015]

## 11. Conclusions

This paper gives an overview of FBFS in sub-Saharan Africa. It is clear that FBFS have a broad scope for alternative uses of water resources. Unfortunately, FBFS haven't received the necessary attention by national governments, donors and development agencies. The blind spot is closely related to a lack of understanding and appreciation of how these systems work, and consequently, their potential for agricultural development. The international consensus to classify agricultural systems in either rainfed or irrigated hasn't contributed to highlight the importance of alternative systems as FBFS do not fall into this categorization. Hence it is vital to firstly understand how these systems work, secondly what social and environmental conditions are the best for their development and thirdly the potential scope for exploiting their full potential.

If we assume an estimation of 25 million hectares under FBFS, a mean plot size of 0.5 hectares, we then can estimate a target population of 50 million people directly using and benefiting from these systems. If we include pastoralist communities, who also make use of floodplains, and people who indirectly benefit from these systems (i.e. food provision), the figure increases substantially. It becomes clear the scope and importance of FBFS as well as the necessity for improvement, research, investment and inclusion in strategic development policy of such.

Apart from the area covered and population impact, FBFS are sometimes present in isolated semi-arid areas of difficult access. In these areas FBFS are the only source of income and sustain of livelihoods. Therefore FBFS not only represent potential productive systems, they also provide resources to accommodate food security and income generation in remote areas of Africa. Asia's long tradition in spate irrigation serves as a valuable example. Experiences incubated throughout centuries as well as new developments in investments and modernization programmes pose several lessons and hints regarding FBFS development. Floods are many times regarded as harmful and destructive.

As pinpointed in this document, floods are the source of several farming systems with remarkable positive impact on rural communities. Rural communities have been using floods long ago (e.g. spate schemes in Asia and fisheries in East Africa) proving that they can be used

in productive ways. Hence floods are not only harmful but can have positive impacts and provide useful services in rural communities across sub-Saharan Africa.

As described in this paper, FBFS pose great potential for agricultural development with low inputs and low cost technologies. However FBFS require of precise management practices and knowledge on flood behaviour. For this reason more attention has to be brought on capacity building and agricultural extension services (through educational and training centres). Likewise, practitioners and entrepreneurs willing to implement new technologies and techniques must have financial and institutional support. Thus, human capital is one of the main challenges and goals for strengthening and exploiting the full potential of FBFS. Annex 1 shows the results of a survey done under FBFS practitioners.

At the moment FBFS are used to ensure food security. Yet there is potential to manage these systems for commercial agriculture purposes. Likewise diversification strategies have proven to be effective in coping capacity and risk management, particularly for pastoralist communities. Therefore there is still room for improvement and optimization of FBFS as potential productive systems.

All in all, climate change and increasing pressure on land and water resources call for alternative systems apart from traditional approaches for agricultural production. Ergo, FBFS represent an encouraging option to tackle social and economical challenges faced by rural sub-Saharan Africa.

Furthermore issues which require further development are the optimization of shallow ground water use through manual drilling, shallow wells, affordable pumping technologies and groundwater development maps that indicate the availability of groundwater resources and the techniques required to find and develop groundwater in flood plains. However, such measures should be embedded in a wider water management plan at floodplain level including improved flood management and drainage systems, agronomy of flood tolerant and flood recession varieties; floodplain fishing culture and alternative uses of floodplain resources.

### **Text Box 7: Conclusions from the survey FBFS practitioners**

There are several conclusions that can be extracted from the survey:

- Firstly the geographical coverage of the survey reflects relevance of FBFS in sub-Saharan Africa, Middle East and central Asia;
- Secondly it becomes clear that the spate irrigation network is well established in the academic and research sector with professionals mainly working in spate irrigation systems and floodplain farming systems;
- Thirdly, given the broad nature of FBFS, it is agreed that the first priority is to understand these systems and the necessity of their integrated management;
- Fourthly, in order to improve management of FBFS, the respondents selected four main fields of action; namely international experience exchange, university education development, strategic policy development and skill development at vocational and extension service facilities;
- Fifth, the future endeavours of the spate irrigation network are recommended in different directions emphasizing international experience sharing, documentation and policy dialogue as the three main axes;
- Finally government bodies and research organizations were identified as the key organizations the spate network should approach.

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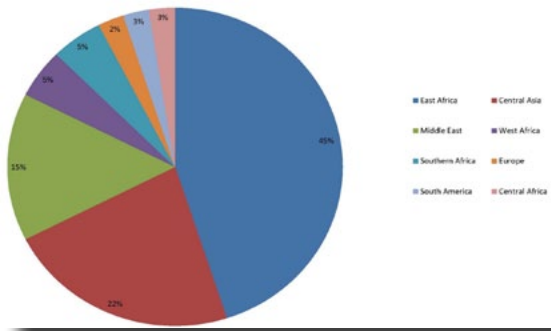


Figure 37 Geographical distribution of survey respondents

### Annex 1: Possible support to wider flood-based farming by Spate Irrigation Network Foundation

#### Results from Survey

In order to have a wide coverage of FBFS functioning and improvement, a survey was sent to provide feedback and other opinions of these systems. Forty one respondents of 15 different countries answered the survey (see annexes). The geographical distribution of respondents is detailed in Figure 37. The first three regions with more respondents; namely East Africa, Central Asia and Middle East, indicate the widespread use and implementation of FBFS in these areas (as pointed out in the paper). It is therefore necessary to advocate for spate irrigation and other flood farming systems to other regions in sub-Saharan Africa.

Most of the respondents belong to the academic sector (close to 60%), namely research and education. The other major employment sector

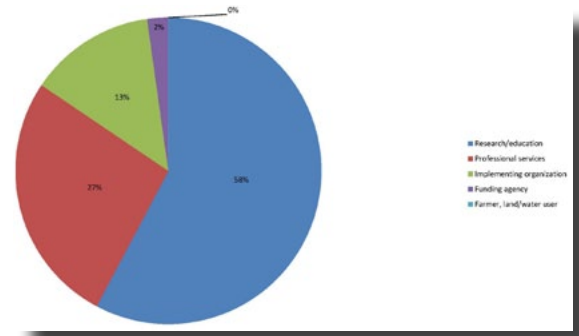


Figure 38: Employment sector of the different respondents

is professional services. The survey was unable to reach farmers and water users and barely covered employees of funding organizations. Both groups of stakeholders ought to be engaged in FBFS development. The former as key actors in expanding FBFS and implementing innovative alternatives whereby the latter can drive attention and financial opportunities for FBFS.

Figure 39 indicates the type of FBFS the respondents are engaged in<sup>28</sup>. Spate irrigation and floodplain systems add three fourths of the selections. Clearly, both FBFS are by far the more extended and required most of the focus. So far, the spate irrigation network has focused on documenting and researching spate irrigation systems in both Asia and Africa. Additionally there has been capacity building of water professionals on spate irrigation principles, techniques and their improvement. Yet there is still much scope for further documentation of other FBFS (i.e. flood recession agriculture) as well as to disseminate their relevance and potential for sub-Saharan Africa.

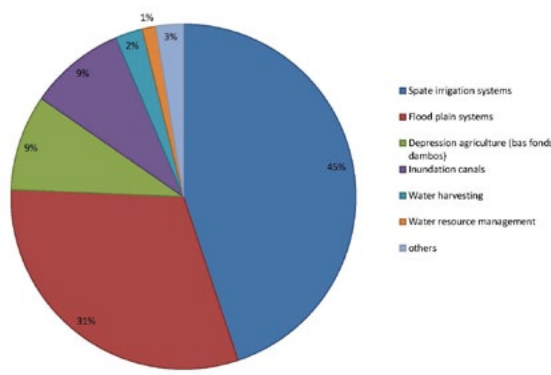


Figure 39: FBFS occupation by respondents

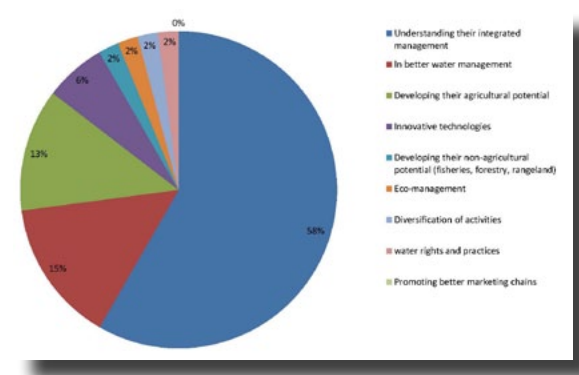


Figure 40: Largest priority to develop FBFS, according to respondents

28) It was possible to give more than one answer



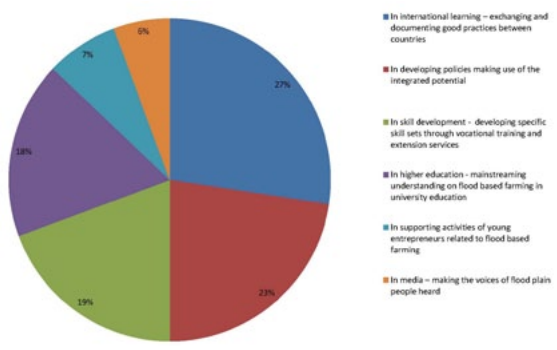


Figure 41: Prioritization for better use and management of floodplains, according to respondents

According to the respondents, the main priority for FBFS development was to understand their integrated management (58%). The uniqueness of such systems compared to traditional rainfed and irrigated systems could explain why respondents stress this point.

Moreover, FBFS are broad in terms of practices and techniques, therefore it is sensible to first understand how these work in an integrated way. The other two main selections were better water management (15%) and development of FBFS agricultural potential (13%). Only 6% selected innovative technologies as the main priority. Diversification, an approach advocated by researchers and practitioners was only selected by 2% of the respondents. The selections reflect concerns for the conceptualization and recognition of FBFS as opposed to implementation of new technologies and practices.

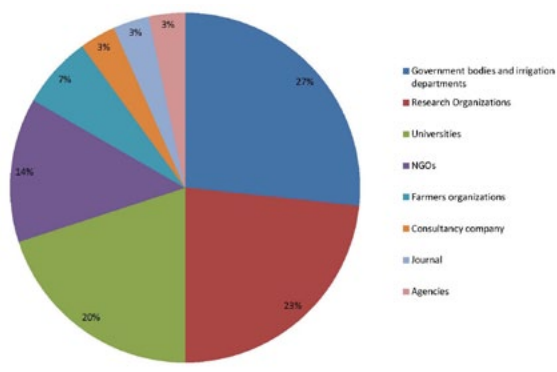


Figure 43 Organizations the Spate Irrigation network should approach

29) The respondents could choose up to 3 different priorities

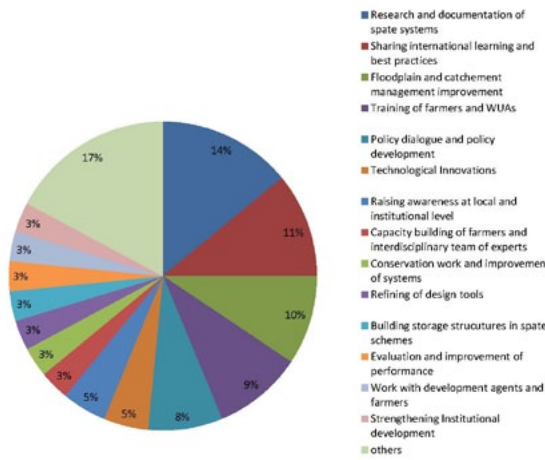


Figure 42: Suggestions on different fields the Spate Irrigation should work in the future

The fifth question of the survey inquired about opinions on different priorities to make a better use and management of floodplains. In this regard, the survey reveals disparity in priorities<sup>29</sup>, as indicated in Figure 41. Yet of the six different alternatives, 5 can be divided in two main groups of opinion. On one hand international learning (27%), development policies (23%) and higher education (18%) sum up 68% of the total.

These can be classified as top down approach priorities; this is, activities driven by institutional and academic actors with the purpose of raising knowledge, awareness and political support for FBFS. On the other hand skill development (19%) and supporting entrepreneurs (7%) are grass root type of measures which move towards improvement of floodplain use at field and water user level. Media broadcasting, an alternative way of raising awareness and attention, was opted by 6% of the respondents. All in all, the great variety of FBFS calls different approaches to enhance floodplain use and water management performance at field level.

The sixth question (open answer) was addressed as to formulate suggestions in what fields the Spate Irrigation Network should work in the incoming years. Respondents gave multiple answers and ideas, with 14% regarding research and documentation of existing systems as the way forward. Moreover, 11% suggested sharing of experiences and best practices at international level. Floodplain and catchment management improvement was recommended by 10% of the respondents. Additionally, training and capacity building of farmers and WUAs

(9%), policy dialogue and exchange (8%), technological innovations (5%), and raising awareness at institutional and local level (5%) were the other main answers provided. Looking again at the occupation of respondents, it is logical that the first two suggestions (adding up 25%) are linked to the academic sector. On the other hand floodplain management requires the involvement of practitioners, extension services and water users. In fact, the Spate irrigation network has been carrying out activities related to research, sharing of international experiences, capacity building at higher education and of water professionals. Therefore it may be of interest to expand activities to field management improvement and capacity building of farmers and water users. Additionally this would have impact on the improvement of performance of flood farming systems.

Finally, the last question of the survey asked about which organizations the Spate Irrigation Network should approach and what links could be set to on-going activities. Government bodies and irrigation departments (27%) were the most frequent answer followed by research organizations (23%), universities (20%) and NGOs (14%). Farmer's organizations were suggested by 7% of the respondents. The spate-irrigation network is formed by an ample set of stakeholders, including government officials, university staff, model farmers, etc. Yet it is relevant to keep linking to government officials at local, regional and national institutions. Farmers and WUAs representatives shall be approached if the spate irrigation network wishes to support them through capacity building and participatory design development.

### Conclusions from the Survey

There are several conclusions that can be extracted from the survey.

- Firstly the geographical coverage of the survey reflects relevance of FBFS in sub-Saharan Africa, Middle East and central Asia.
- Secondly it becomes clear that the spate irrigation network is well established in the academic and research sector with professionals mainly working in spate irrigation systems and floodplain farming systems. Thirdly, given the broad nature of FBFS, it is agreed that the first priority is to understand these systems and the necessity of their integrated management.

- Fourthly, in order to improve management of FBFS, the respondents selected four main fields of action; namely international experience exchange, university education development, strategic policy development and skill development at vocational and extension service facilities.
- Fifth, the future endeavours of the spate irrigation network are recommended in different directions emphasizing international experience sharing, documentation and policy dialogue as the three main axes. Finally government bodies and research organizations were identified as the key organizations the spate network should approach.



**Colofon**

This note was prepared by Diego Garcia-Landarte Puertas, Frank van Steenberg, Abraham Mehari Haile, Matthijs Kool, Tesfa-alem Gebreegziabher Embaye and is part of the Tube Wells in Floodplains project. Preparatory work by Sander Nederveen is acknowledged.

The Tube Wells in Floodplains project, supported by Partners voor Water, aims to increase the productivity of marginally used floodplains by introducing a low-cost package of shallow tube well drilling techniques including pump technologies that can provide smallholder farmers with access to shallow groundwater.

The Spate Irrigation Network Foundation supports and promotes appropriate programmes and policies in flood-based farming, exchanges information on the improvement of livelihoods through a range of interventions, assists in educational development and supports in the implementation and start-up of projects in flood-based livelihood systems. For more information: [www.spate-irrigation.org](http://www.spate-irrigation.org).

