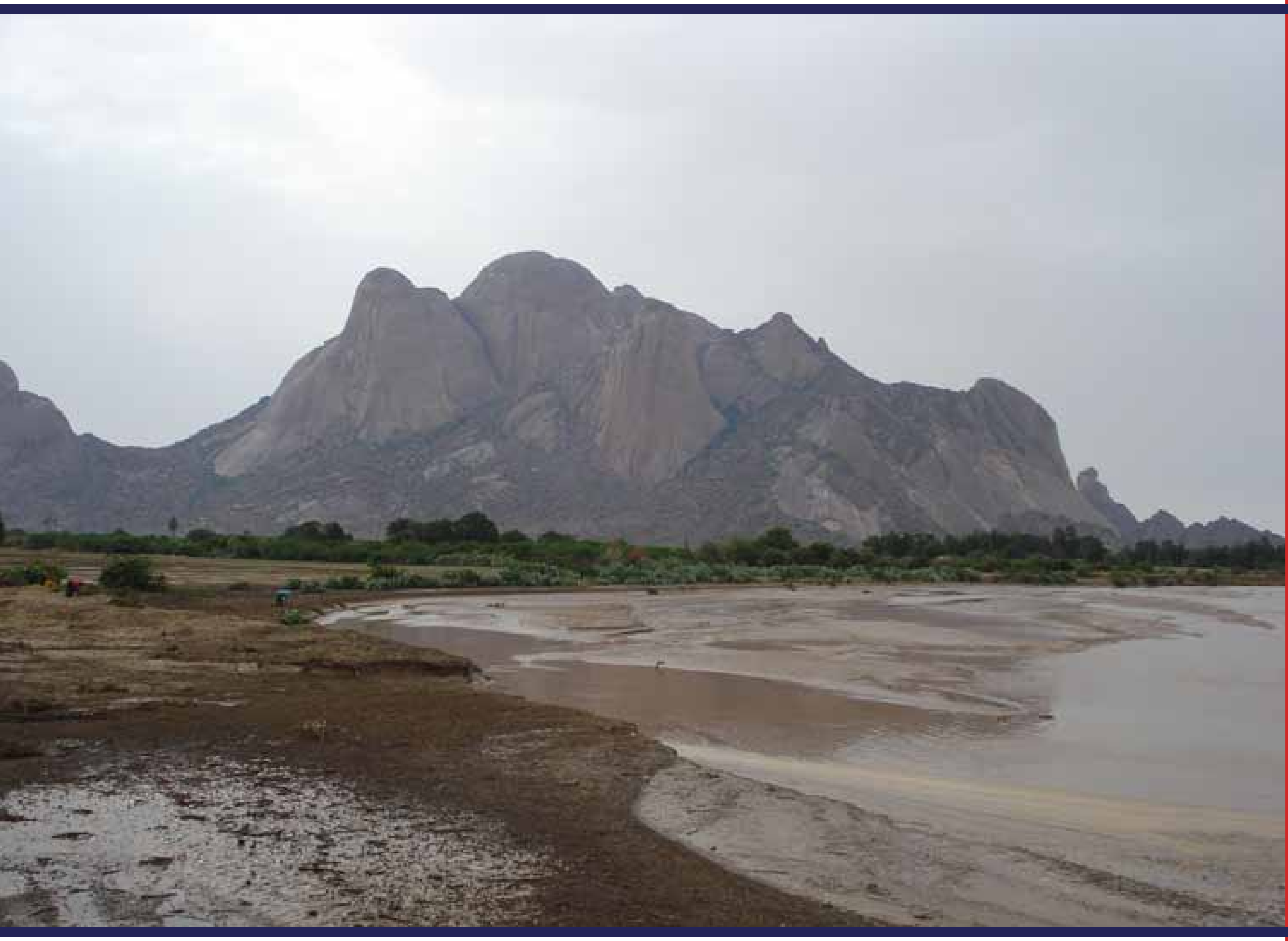
Meeting Climate Change and Food Security Challenges in Fragile States

1

Potential of Spate Irrigation for Rural Livelihoods



Practical Note Spate Irrigation

Spate Irrigation Network

Abstract

Climate change, uncertainties in water supply and food production are realities affecting especially the rural poor. Where the rural poor live in fragile states the vagaries of climate change and food insecurity may be aggravated by the lack of service provision and ineffective legal frameworks. Spate irrigation has been considered as a marginal water resource management system where high uncertainties and risks in crop failure are a given and has unfortunately often been neglected. This paper, however, argues that spate irrigation could significantly contribute to the reduction of rural poverty and enhance adaptability to climate change in areas vulnerable to droughts, but that this would a better appreciation of the potential and scope for a broad livelihood approach in spate irrigation development and management:

- *Focus on 'improving water productivity' rather than on 'improving diversion efficiency'*. In most spate irrigation systems, the spate flows no longer reach the sea or inland deltas, there is no water loss at a basin level - more efficient diversion in one place simply means less water in another are of the basin. Investment would have to better be tailored at making productive use of water within the command area through improved field water management and moisture conservation, conjunctive use and improved agronomic practices;
- *"Improving'' rather than "modernizing" traditional system*. Unlike in the 'modernization' approach, in 'improving traditional systems' the emphasis would be on river engineering rather than on controlling the flood at a single point. Strategies include splitting the flood in manageable proportions, spreading the flood over a large area thereby reducing its force and reversing the degradation of the bed level. These can, at a reasonable cost, improve reliability of the spate systems, reduced maintenance burden and keep local management intact;
- *From crop production to "integrated landscape farming system"*. Crop production is an important benefit stream, but even at its optimum level, it can not alone deliver sustainable livelihood improvement. There is more to spate flow than just crop production - it can be optimally used for horticulture, groundwater recharge, rangeland, forestry and small-scale water storage for domestic and livestock water supply and water and sediment in spate system need to be managed at landscape or sub-basin level;
- *Transforming women from non-rewarded productive labour providers to household income generators:* The death of a working husband or a divorce is a major cause of impoverishment for female-headed households. In the Gash spate irrigation system in Sudan, 4,500 of the 20,000 poorest households are female-headed. In female headed households, women have to undertake all domestic tasks along with the spate irrigation farming activities: To improve livelihood of women, a spate irrigation improvement project would have to include: income-generating activities: handicraft, petty business, backyard horticulture; low-cost technologies to reduce women's workload such as milk churners and fuel-saving stoves, and access to credit facilities;
- *Working on the bigger picture:* improving access roads to spate irrigated areas, general amenities and market facilities; and placing the development of spate systems within the framework of the entire local economy.
- *Giving a voice to spate irrigation communities*. Because of their nature and location spate irrigation areas are often invisible in national programmes and international support. As a result investment is limited and if it happens interventions are in many cases inappropriate as does not understand the management systems as practiced traditionally and effectively.

Introduction

Spate irrigation is a type of water management, unique to arid regions bordering highlands. It is a largely neglected and forgotten form of resource management, in spite of its potential to contribute to poverty alleviation, adaptation to climate change and local food security. Spate irrigation can be found in West Asia (Pakistan, Iran and Afghanistan), the Middle East (Yemen, Saudi Arabia), North Africa (Morocco, Algeria, Tunisia) and the Horn of Africa (Ethiopia, Eritrea, Sudan, Somalia) and more sporadically in other parts of Africa, South America and Central Asia.

Spate irrigation is often found in fragile states or in more sensitive and disturbed areas in general: the foothills along the Koh-I-Suleiman and Kacchi Plain in Pakistan; the Gash in Sudan; the highlands and coastal areas in Yemen Different from other They are largely farmer-operated but in various times in the pass. The role of the government has been more related to governance **(settling disputes)/////.**

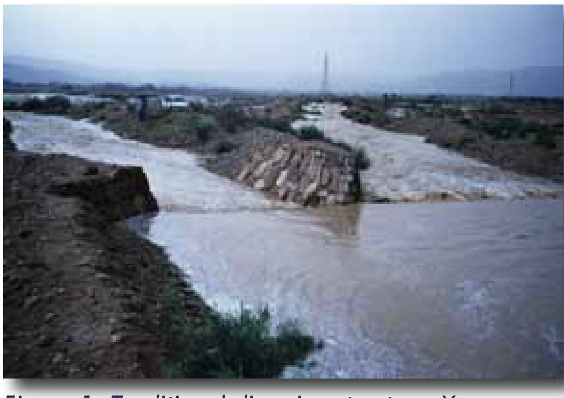


Figure 1: Traditional diversion structure, Yemen

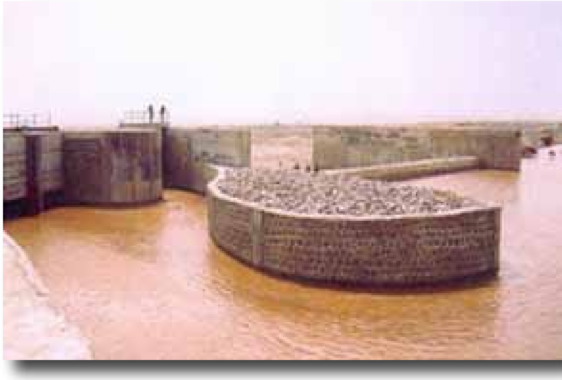


Figure 2: Modern diversion structure, Wadi Laba, Eritrea

Floods originate from episodic rainfall in macro-catchments. They are diverted from ephemeral rivers and spread over agricultural land through traditional earthen and brushwood statures or modern concrete headworks (Figures 1 and 2). After the land is inundated crops are sown, sometimes immediately, but often the moisture is stored in the soil profile and used later. Spate irrigation systems support low value farming systems, usually cereals (sorghum, millet, wheat, barley), oilseeds (mustard, castor, rapeseed), pulses (chickpea, clusterbean), but also cotton, cucurbits, tomatoes and other vegetables. Besides providing irrigation, spates recharge shallow aquifers (especially in river beds), they fill (cattle) ponds and in some areas are used to spread water for pasture or forest land.

The area under spate irrigation globally is substantial. It forms one of the largest, but also least known and most neglected water harvesting systems around. The most accurate estimate of the area under spate irrigation brings it around 2,100,000 ha (Table 1), but the nature of spate irrigation is such that the acreage varies from year to year depending on rainfall. The number of people dependent on spate irrigation is estimated at 9-13 Million people. There are also un-quantified areas under spate irrigation not presented in Table 1, namely in Afghanistan, Saudi Arabia, Tanzania and Kenya. In addition to these there are largely undocumented water resource systems in Central Asia, Mongolia and Latin America, whereby first floods are for instance used to fertilize and soften-up the land ('machaco'), to be followed by semi-perennial irrigation supplies.

In North Africa the area under spate irrigation reduced in the last twenty years, as a result of reservoir construction on several of the ephemeral rivers. Conversely, in the Horn of Africa the area under spate irrigation is expanding rapidly, especially in Ethiopia and Eritrea. Population pressure encourages settlement in the lowlands, which have become more habitable as malaria and trypanosomiasis are slowly being brought under control. The largest areas under spate irrigation can be found in Pakistan and Iran. In both countries spate irrigation has been neglected, regardless of the significant areas under spate irrigation and its potential to reduce poverty and contribute to food security. In Pakistan and Iran the focus has been on perennial

Table 1: Estimated area under spate irrigation

Country	Year	Area under Spate Irrigation in Ha	Source
Algeria	2008	53,000	Anonymous
Eritrea	2004	16,000	Haile (2005)
Ethiopia	2007	140,000	Alemaheyu (2008)
Iran	2008	450,000 - 800,000	Kowsar (2011)
Morocco	2008	79,000	Oudra (2011)
Pakistan	1999	640,000 - 1,280,000	NESPAK (2001), Ahmed (2008)
Somalia	1984	150,000	FAO Aquastat (www.fao.org)
Sudan	2007	132,000	UNEP (2007)
Tunisia	1991	30,000	FAO Aquastat (www.fao.org)
Yemen, Rep. of Mongolia	1999 1993	117,000 27,000	World Bank (1999) FAO Aquastat (www.fao.org)

irrigation.

The contention of this article is that spate irrigation is nowadays neglected and in engineering, development practice and education not well understood – in terms of potential in improving adaptability to climate change and contribution to poverty alleviation and food security, Improved spate irrigation – using a range of appropriate interventions - could significantly contribute to the reduction of rural poverty and enhance adaptability to climate change in some of the most fragile areas on earth. There has been a running argument that in several poor countries, especially in Africa, the reservoir capacity per capita is low. Yet in spate irrigation moisture is stored in the soil profile and in shallow aquifers. This can be done at a much lower cost than storing water in a surface reservoir. Even though spate irrigation is inherently risky, it can potentially contribute significantly to local and regional food security, which in a world of higher food prices and reduced food aid assumes large importance.

In several cases highly productive agricultural systems are sustained by spate irrigation. One example can be found in the Eastern Lowlands of Eritrea, where thanks to a sophisticated system of moisture management, sorghum yields of 4,500 kg/ha are achieved (Figure 3). This is three to six times higher than sorghum yields elsewhere. A second example is the Tihama Plains in Yemen, where the conjunctive use of spate irrigation and groundwater (recharged from spate) sustains the grain basket (and livestock basket) of the country (Figure 4). Similarly, the coastal spate and groundwater systems in Saudi Arabia have the highest water productivity in the entire country. The point to make is that spate irrigation is a complex but not necessarily marginal resource management system.
This paper first describes spate irrigation in the light of climate change adaptation and climate change. It then discusses the effect of spate irrigation on livelihood improvement and poverty alleviation. This is followed by an overview of experiences with improving spate irrigation systems and concluding remarks outlining concepts, approaches and techniques for improving productivities and enhancing economic opportunities in spate irrigated agriculture.

Climate Variability and Climate Change

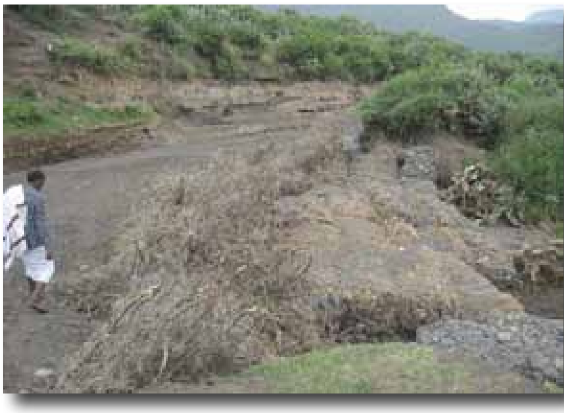
Adaptation to Climate Variability

Spate irrigation is the quintessential adaptation to climate variability. Spate irrigation depends on the availability of floods, but the number and sequence of floods vary from one year to another. Good years alternate with bad years. A bad year may be caused by a drought or by off-season floods. A bad year may also be triggered by the arrival of a very high flood that takes out diversion structures and makes it impossible to control water. If a large flood enters the command area, it leads to severe damage, destroying flood channels and creating deep gullies (Figure 5). These deep gullies may cause the depletion of soil moisture or simply make it impossible to command a sub-area. On the other hand in a good year, typified by a series of medium-sized floods, the availability of water may exceed the local capacity to prepare land and store moisture.

Another important characteristic of spate irrigation is that sediment management is as important as water management. Rivers in spate lift and deposit huge quantities of sediment (Figure 6). As a result there is constant change in bed levels, both in the river system and in the distribution network. This results in frequent

Figure 3: Eritrea, high production sorghum as a result of effective moisture conservation

Figure 4: Intercropping date-palm and forage with conjunctive use of spate and ground water



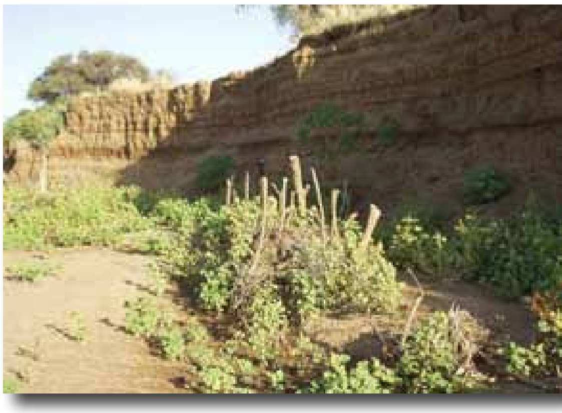


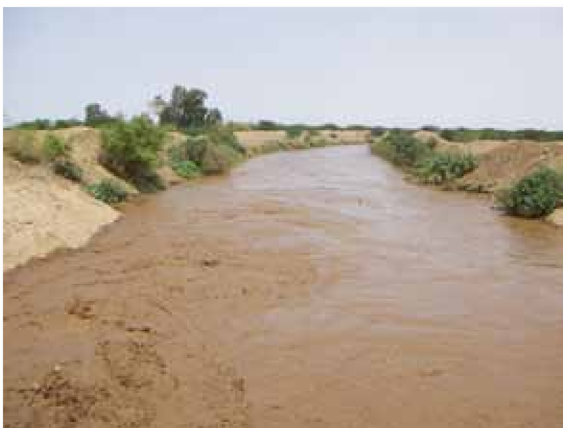
Figure 5: Ethiopia, after large flood: damaged gabion structure (left) (Kidane, 2009); huge gully formation (right)

changes and adjustments. The severity of sedimentation depends on the sediment load of the ephemeral flows. These sediment loads are related to the rainfall pattern and the geology, morphology and vegetation cover of the catchment. Despite the frequent changes, the mere existence of a functioning spate irrigation system will consolidate an ephemeral river system and prevent it from constant braiding and degradation in extreme weather events. Farmers often actively use the force of the sedimentation and scour processes. They may deepen the head reach of a flood channel in order to attract a larger flood that will further scour out the channel. In other cases farmers may block a flood channel to force the bed level to come up.

The variability and uncertainty that is inherent to spate irrigation – with the area cultivated dependent on the number of useable food diverted in a given year translated in special land tenure arrangements – as does the process of field maintenance and sedimentation. Land tenure is very important to keep a large number of people 'tied' to the land so as to be able to do the main maintenance works on diversion structures and the keep the system of field bunds in tact. The latter is essential to maintain water at field level and with this store soil moisture. In most areas this is resolved by long-term individual usefruct of the land – as owner or hereditary tenant – with penalties for instance for the neglect of field bunds. The latter would not only make it difficult to store flood water in the fields and soil profile but also could create damage to adjacent lands, when water would flow in an uncontrolled manner. Not in all system the usufruct of land is consolidated: it is a major impediment in the Gash system where land was allocated on a lottery basis and no investment in field bunds was made. Similarly in the Western Lowlands the development of field bunds is hampered by land tenure.

In all spate irrigation systems there are mechanisms in place that help adapt to climate variability, both at household level and farming system level. These mechanisms give an indication of the response that may be required in adjusting to climate change as well.

Many households in spate-irrigating communities have developed a range of livelihood strategies in order to cope with the inherent uncertainties of spate-irrigated agriculture, and occasional crop failures. The most common strategy is the



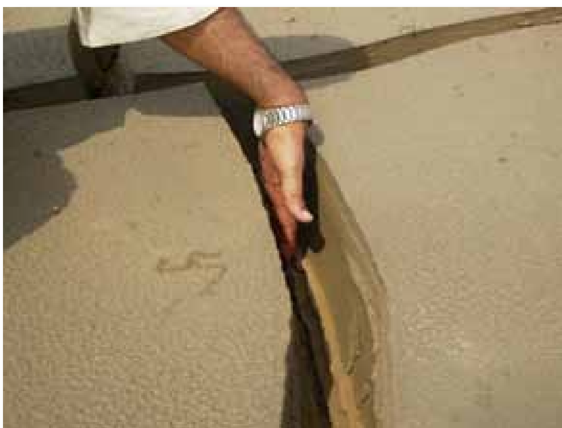


Figure 6: Large sediment laden spate flow (left) Sudan; up to 15 cm fine sediment deposit (right), Yemen

diversification of the household economy, whereby poor(er) households in spate-irrigated areas generally depend on multiple sources of income. Livestock keeping is an integral component of livelihood strategies of most households involved in the cultivation of spate-irrigated crops, providing draught power, transport, animal products for home consumption and sale, and dung used as fuel and/or construction material. In general, households in spate-irrigated areas keep oxen, cows, goats, sheep, donkeys and poultry. The number of cattle kept by farmers is often in proportion to the amount of fodder available. The ownership of at least one pair of oxen is often a good indicator of wealth. For many households it is difficult to support a pair of oxen because their farm size is too small to produce sufficient fodder to feed them in years with normal floods. In the Sheeb area in Eritrea, about 30% of the farmers do not own bullocks, whereas in the Yandafero scheme in Ethiopia only one-third of the landowners have one or two oxen. The number of animals owned by an average household varies considerable between and within countries and spate irrigation schemes, ranging from about 7 sheep in Wadi Rima in Yemen to 62 small ruminants in the Toiwar scheme in the Province of Balochistan (Pakistan).

Other strategies adopted by households in spate-irrigated areas to cope with the uncertainties inherent to spate irrigation include:

- Households having different plots of land with high and low probabilities of spate irrigation;
- Saving of grains from one year with crop surplus to bridge the gap to the following year;
- Investment in easily disposable property, such as livestock, in good years with crop surplus to be sold in a lean year;
- Wage labour and off-farm income-generating activities (i.e. handicraft, petty trade, transport);
- Exploitation of locally available natural resources, in particular trees for the sale of timber, fuel wood and charcoal;
- Migration of male household members in search of labour.

At farming system level there are also several adaptations to climate variability including:

- Using local varieties, adjusted to the peculiar local conditions of spate systems;
- Crop choice in accordance with the timing of first irrigation;
- Staggered sowing dates to control the outbreaks of pest and/or attacks by birds;
- Intercropping with two or three different crops with different water requirements and harvesting dates, so that at least one crop can be harvested in dry years;
- Low investment in agricultural inputs - minimizing the risk of financial losses if the crop fails;
- Using crops as livestock fodder as fall-back in case of crop failure. This is for instance common in Pakistan, where good yields depend on mid-season rainfall, which may not come;
- Keeping the command area relatively compact. This increases predictability of flood water supplies and with it willingness to adequately prepare land (in particular pre-irrigation ploughing) as well the likelihood of a second irrigation, that may substantially increase crop yields. Two irrigation turns (Irrigation gift of 50 cm) result in twice the yield received from one irrigation turn (Mehari et al., 2008). In Gash a distinction was made between: planned, allocated, irrigated/wetted, and actually planted and harvested crop land. It is this mix that determines the fee to be paid - following allocation and actual wetting.

Some spate irrigation systems are more susceptible to crop failure than others. Table 2 provides an overview of factors that determine this vulnerability. The most vulnerable systems are those with low rainfall, small catchments, and overstretched command areas, with no opportunities for conjunctive use and deeply incised rivers requiring the construction of relatively large diversion structures. Also remote areas with less opportunity for alternative sources of income, and areas where there is no strong link between livestock keeping and farming, are more prone to severe setbacks in times of prolonged drought. Climate change and catchment degradation is moving some systems from moderate vulnerability to high vulnerability – in particular where river morphology is disturbed by mega floods, more low rainfall years occurs and flows from semi-perennial become ephemeral.

Climate Change

In most areas there are mechanisms in place that accommodate climate variability and for several areas – with the exception of the most vulnerable spate irrigation systems - these mechanisms contribute to the robustness of spate areas.

Whereas climate variability is already at present the defining feature, climate change is likely to alter the variability as well as other parameters that affect productivity of spate irrigation

Highly vulnerable	Moderately vulnerable
Low rainfall in catchment (<200 mm), higher variability	Moderate rainfall (>200 mm) in catchment
Small catchment - chance of floods being missed	Relatively large catchment - higer probability of at least small number
High maintenance systems - diversion bunds in incised rivers	Low maintenance systems - run off the river systems
No conjunctive use - as groundwater is too deep or saline or not utilized	Conjunctive use of groundwater
Overstretched command area - most areas will have zero of one flood	Compact command areas - large chance of two to three floods
Low link with livestock keeping	Livestock as important complementary source of livelihood
Remote area - less opportunities for alternative incomes	Well connected area - activities integrated in larger economy

Table 2: Factors determinating vulnerability in spate irrigation systems

systems. In the last five years tremendous effort has gone into predictions of climate change and more progress is expected. Current predictions still have a level of generality or uncertainty, requiring considered interpretation. On the other hand, different predictions and trends observed point in the same direction, where it concerns the incidence and timing of floods, the extent of droughts or the rise in surface temperature.

Table 3 summarizes the predicted climate changes for major spate irrigated areas, prepared on the basis of the IPCC Fourth Assessment Report and other documents. Climate change will have an impact on spate irrigated areas as well as their catchments. The impact of climate change may take on different forms, such as: more floods, larger floods, later floods, longer droughts and increased risks of pests and diseases. Climate change or environmental degradation and fast population growth elsewhere may also affect spate irrigation systems as it may generate an influx of people. As the case in Gash: from 20,000 tenants to 72,000 on the books (now cleaned up to 58,000 or so). This influx nearly killed the Gash system it required land to be rotated among too many people. Current climate models are able to predict the changes on a number of these parameters - but at a ‘coarse resolution’ only, limited essentially to regions and countries, but not yet at the scale of specific areas. Table 3 provides a summarized overview of the likely change for different countries, as well as the impact on the spate systems and the required response.

Not all climate changes are negative for spate irrigation. A lot depends on the flood regimes. In most cases floods are expected to increase, an important feature of floods being their timing and size. Out of season floods generally make no contribution and in many areas are not diverted and at best, allowed to spread over outwash areas. Similarly large floods are of limited use, but can wreak havoc with local infrastructures unless carefully managed. On the other hand, more frequent moderate floods can increase returns from spate irrigation. An increase in temperature, predicted at 1.5% globally, will also have numerous effects. Temperature changes will have an impact on crop yields and on evapotranspiration. It will trigger the adaptation of new varieties or changes in cropping pattern. There will be also a greater need to optimize moisture conservation techniques.

Alleviating rural poverty and improving livellihoods

Spate irrigation is the defining characteristic of large areas in arid and semi-arid regions of the Middle East, Africa, South and Central Asia and Latin America, providing a livelihood base for 9 to 13 million economically disadvantaged households in these areas. The people inhabiting spate-irrigated areas generally belong to sedentary households (Pakistan, Yemen) or are semi-nomadic (Eritrea). However, in the Gash irrigation scheme (Sudan) and the Gareh Bygone Plain (Iran) the present inhabitants were originally nomadic pastoralist who were forced or chosen to settle.

Income Levels

Income levels in spate-irrigated areas are usually low. Per capita income in many systems is less

Possible climate change	Countries	Likely impact	Likely adjustment or effect
More frequent floods	Pakistan, Iran, Yemen, Ethiopia	This effect depends very much on the nature of the catchment and the precipitation patterns and the size of the floods	Increased production
Longer drought periods	Sudan, Eritrea, Ethiopia, Morocco, Algeria, Tunisia	Stress on livestock - undermining capacity to prepare land; Stress on population - out migration results in loss of critical mass to do maintenance work	Need for alternative livelihood sources
Temperature rise	Pakistan, Iran, Yemen, Sudan, Ethiopia, Eritrea, Morocco Algeria, Tunisia	Higher soil evaporation, crop sensitivity to temperature	May need adjustment in crop varieties, more emphasis on moisture conserevation techniques such as mulching
More larger floods	Pakistan, Iran, Yemen	Damage to diversion structures and risk of gullying and extensive damage to command area	May need to intensify use of outwash areas for rangeland and agro-forestry
Later or earlier floods	Unknown	Later floods will cause change in crops - for instance from sorghum to barley; earlier floeds may make it more difficult to store moisture	May need adjustments in the cropping pattern
Higher risk of pest and diseases such as grasshoppers	Pakistan, Irean, Yemen, Sudan, Ethiopia, Eritrea, Morocco, Algeria, Tunisia	Likely, but uncertain in which direction this effect will go	Require vigilance and back-up system in pest control

Table 3: Expected impact of weather events resulting from climate change

than US$ 1 per day. Moreover spate-irrigated areas are often situated in remote regions. Hence, spate areas are among the main poverty pockets in most countries. The net annual income for households in the Sheeb area in Eritrea was US$ 355 against US$ 300 for the Toiwar spate irrigation scheme in Pakistan and US$ 412 in the Shabwah Governorate in Yemen. In 2000, 28% of the households in Wadi Tuban (Yemen) and 35% in Wadi Zabid (Yemen) lived below the poverty line of US$ 203 per year. However, these are average figures and they mask differences in income between households in the up and downstream locations of spate-irrigated areas. On average, farm incomes differ by a factor three between up and downstream spate irrigation schemes in the Tihama region of Yemen.

The income derived from spate-irrigated agriculture is also determined by the size of the land owned or cultivated by a household. The average landholding in spate irrigation systems tends to be small, ranging 0.5 to 2.1 ha in the Sheeb area in Eritrea, Nouael II project in Tunisia, Wadi Tuban and Wadi Zabid in Yemen. The average landholding in the Gash irrigation scheme in Sudan is less than 0.5 ha. In the Province of Balochistan in Pakistan, on the other hand, the average landholding ranged from 5 to 8 ha and extensive use is made of tenants. The distribution of land within spate irrigation schemes varies from relatively egalitarian (i.e. Eritrea and Ethiopia) to highly skewed (i.e. Pakistan, Sudan and Yemen). In the latter countries a limited number of very large landholders own large tracts of land, sometimes in the upstream parts of spate irrigation systems that have first access to spate water. In addition, there are also landless households, who usually earn an income as daily labourers. In Wadi Zabid and Wadi Tuban (Yemen), 55% and 25% respectively of all households living within the command areas of these spate irrigation schemes did not own or lease any arable land. In the Gash irrigation scheme in Sudan, at least 20,000 of the total 72,000 households are landless. In this area there were no fixed land titles and land was allocated annually, foreclosing investment in land development or field bunds.

It is common in many spate irrigation systems that a large proportion of land is cultivated by tenants and sharecroppers. In Yemen roughly 82% and 51% of the total command area in Wadi Zabid and Wadi Tuban respectively, were cultivated by sharecroppers and tenants. In large parts of the command areas of the spate irrigated areas in Pakistan a system of 'hereditary tenancy' is in place. The tenant is de-facto co-owner, with his entitlement dating back to the time that the lands were prepared for the first time. To retain his title the hereditary tenant has to continue cultivating the land. Indeed, it is rare that a non-widowed women holds a land title and exerts her rights over it (,1% in Gash Sudan). The question not raise din the paper is how Land Tenure and size/ distribution of holdings (or lottery rights) is related to rights to water. The gash was originally sold in IFAD as an irrigation project; we only found out later it was actually a LT project-which we couldn't resolve!

Benefit Streams

Investments in spate irrigation improvement ranges from USD 100 to USD 2500 per hectare (van Steenbergen et. al 2010). The costs are very much a factor of technology chosen (improved traditional techniques being more economical), the complexity of the systems (headworks, command area work, agricultural extension, farmer organizational support). The main cost factor is usually the diversion structure. Modernized structures often increase the cost per hectare but as explained later improved traditional interventions are usually more effective in diverting water.
Spate irrigation systems generate important benefits in terms of an improved economic natural resource base. First and foremost spate irrigation makes it possible to grow crops (food, feed, fibre) in hot arid and semi-arid regions where evapotranspiration greatly exceeds annual rainfall. In addition, spate irrigation – like many other water systems – is 'multiple use': households living in and around the command areas of spate irrigation schemes may enjoy one or more of the following benefits:

- (Improved) access to animal feed;
- Groundwater aquifer recharge;
- (Improved) access to water for humans and livestock; and/or
- (Improved) access to forest products
- Access to income opportunities.

Examples from spate-irrigated areas in Ethiopia, Eritrea, Pakistan, Yemen and Sudan are presented briefly in the following sections, in order to illustrate the different benefits of spate irrigation for populations whose livelihoods are based mainly on the use of diverted spate flows.

Crop production

The cropping patterns in spate-irrigated areas is dominated by the cultivation of low-value, drought-resistant subsistence crops, such as sorghum, wheat, millet, pulses and oilseeds, whereas cotton, pumpkin and melons are also grown as cash crops. In addition, the production of fodder crops to support livestock is also important in most spate irrigation systems. The selection of the crop and varieties used is mainly determined by the location within the spate irrigation system; resistance to drought, pests and diseases; fodder production; storage; and market prices.

The yields of spate-irrigated crops vary widely between and within countries, and are influenced by the spate-irrigation scheme adopted, years with good rains and floods, and years with less than normal rainfall. In Yemen, reported yields varied from 600 to 3,500 kg/ha for sorghum, 600 to 1,200 kg/ha for millet, 1,000 to 1,500 kg/ha for maize, 350 to 700 kg/ha for sesame, 5,000 to 14,100 kg/ha for melon, and 650 to 1,600 kg/ha for cotton. The reported yields in the Province of Balochistan (Pakistan) are significantly lower with only 360 to 550 kg/ha for sorghum, 150 to 350 kg/ha for oilseeds, 200 to 500 kg/ ha for pulses and 360 to 620 kg/ha for cotton. This relates to the lower rainfall and infrequent floods in Pakistan.

In the Gash Barka region in Eritrea, the average sorghum yield was 1,200 to 2,100 kg/ha in spate-irrigated areas, whereas only 450 kg/ha sorghum yield was derived from rain fed land. In Sheeb (Eritrea) sorghum yield fluctuates but in good years reached 4,500 kg/ha and in some cases even 6,000 kg/ha. In the northern part of Amhara State in Ethiopia, the sorghum yield doubled and the pepper yields were 400% higher with the availability of flood water. In the spate-irrigated areas of the D.G. Khan District in the NWFP (Pakistan), the average yield for spate-irrigated cereals is significantly higher (2,113 kg/ ha) than for rain fed grain crops (1,243 kg/ha).

The wide ranges in yields observed in different spate irrigation systems in various countries are attributed to the unreliability of irrigation, degree of control of spate flows, planting date, sensitivity to inadequate watering, crop husbandry skills, soil moisture conservation practices, crop type as well as by insect plagues and diseases. Yields also vary depending on the location within spate irrigation systems, as areas have different probabilities of irrigation. It is estimated that yields could be increased by 30 to 50% with the ownership of a pair of oxen, as ploughing and mulching could be undertaken more frequently. In the Western Lowlands of Eritrea and the Gash irrigation scheme, planting of the crops were delayed in many cases due to a high demand for a limited number of available tractors and implements.

In most spate irrigation schemes, farmers prefer the use of local cultivars as they are well adapted to the local agro-climatic conditions. In the D.G Khan District in Pakistan, yields of wheat, chickpea, millet and sorghum increased by 10 to 24% when the farmers' seeds were cleaned and graded. Improved varieties had 25 to 37% higher yields. There is minimal use of chemical and organic fertilisers as most spate-irrigated farmers believe that their soils are naturally fertilised by the fine sediments that are deposited during the floods. The use of pesticides and insecticides is also rare. High costs, limited availability and risk aversion are other factors that have limited the use of agro-chemicals. Most spate-irrigating farmers can not take the risk of losing their entire crop in a dry year by changing to higher yielding varieties that are less tolerant to drought and require application of fertilisers and other agro-chemicals. In general, the provision of agricultural extension services to farmers in spate-irrigated areas is poor, and available services often do not meet local needs and demands.

The relatively limited agricultural research that has been undertaken in spate irrigated areas suggests that large productivity increases are possible. Research by the Arid Zone Research Institute in D.I. Khan in Pakistan came up with a number of significant production increases varying from 21 to 50% for spate irrigated wheat - in response to single improved practices, such as mulching, deep ploughing, early planting, weed control. Chickpea yields increased between 24 to 60% for each improved practice in trials with early planting, seed treatment, grazing, higher seeding rates and easy use of pesticides. In Eritrea, the pre and post irrigation tillage and soil mulching (Figure 7) improved soil moisture storage by about 100 mm and is the main reason behind the high (4,500 kg/ha/year) sorghum yield (Mehari et al, 2008). Intensified agricultural extension under the Irrigation Improvement Project in the Tihama in Yemen managed to increase sorghum yield with 35-140% by introducing seed treatment, fertilizer application and new varieties. In cotton, yield increases with 30-70% with row planting, the use of high quality seeds and fertilizer as well as timely weeding.

Another source of improvement is grain storage. In Eritrea traditional grain storage causes 4-14% crop loss (Haile et al., 2003). This post-harvest loss in Pakistan was reduced from 7% to almost negligible amounts (close to zero) with the use of improved storage methods, consisting of a seed cleaning before storage and the use of adobe storage containers, placed away from living places and detached from the floors and walls of the houses (Figure 8).

Livestock

Livestock is an integral and important component of the livelihoods of resident households in most spate-irrigated areas, making access to sufficient fodder crucial. The main source for animal feed is usually crop residue and rain fed grazing lands. A second source is the cultivation of spate-irrigated fodder crops, such as (green) sorghum. In Eritrea and Sudan, ratoon sorghum is an important feed for livestock as well. The cutting of

Figure 7: Mulching is Key to Moisture Management, Eritrea

Figure 8: Improved storage facilities, Pakistan

weed in the fields and along the canals is another source of forage, whereas leaves from trees in and around the spate-irrigated fields are also used to feed animals. For instance, households in the Sheeb area in Eritrea practice 'zero-grazing' from October to May, whereby the animals are fed with cut grass from the fields, to prevent livestock from causing damage to standing crops and to economise the scarce animal feed. Farmers in the northern part of Amhara State (Ethiopia) also indicated that spate irrigation boosted the availability of animal feed due to a significant increase in biomass production. The improved availability of animal feed has improved household income generated from livestock products.

Currently less common but potentially important source of fodder is spate-irrigated grazing land. In the Gash flood plains, a substantial area is covered with a large variety of annual and perennial grasses due to seasonal flooding with excess flood water from the Gash River. According to traditional water governance practices, the first flood in the river would be diverted to the periphery of the scheme in order to stock drinking water for livestock and to irrigate the grazing lands, so that animals would be kept away from the planted crops. In DG Khan, Pakistan, spate flows, at other than normal cultivation timings are purposely diverted to rangelands and common property in order to get optimal benefits in the form of pasture, timber and fuel production (Figure 9). Local farmers and nomad groups equally enjoy grazing livestock, collection of fuel wood, medicinal plants, mushrooms, honey and other similar products from these common lands.

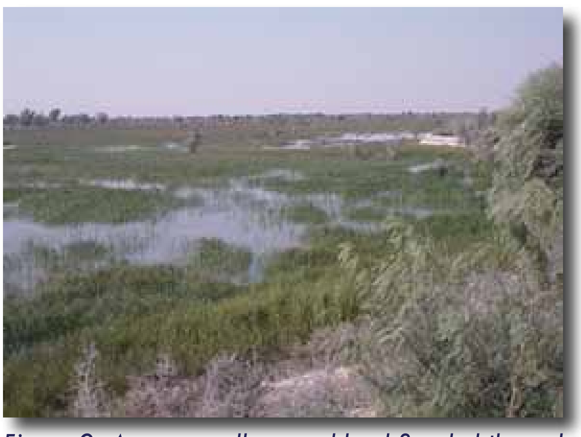
Groundwater recharge

Groundwater is saline in most spate-irrigated areas in Pakistan, Tunisia and Eritrea, and hence the conjunctive use of groundwater and spate water for irrigation is not an option. In the coastal areas of Yemen, however, the quality of the groundwater is good enough for irrigation. Since the 1970s, there has been a rapid increase in the number of installed (shallow) wells and the cropping pattern has changed dramatically towards the cultivation of high value crops, including bananas, mangoes and vegetables. This was a result of the conjunctive use of spate flows and groundwater. Consequently, the area under banana cultivation in Wadi Zabid has increased from only 20 ha in 1980 to more than 3,500 ha in 2000, while about 2,300 ha are cultivated with vegetables in Wadi Tuban. Groundwater is also used for the cultivation of green sorghum that is sold as a high value fodder crop in Wadi Zabid. In the Gash flood plain in Sudan, groundwater from shallow wells is used for the cultivation of horticultural crops (i.e. bananas and onions), which has become the foundation of the regional economy and has generated a significant demand for wage labour. Groundwater is also the major source of water for livestock in the tail reach of the Gash irrigation scheme.

In Wadi Al'Ain/Harib (Yemen), spate water only reached the tail-end during large floods following the construction of two weirs in 1980, many farmers have developed wells in the downstream reaches in order to become less dependent upon spate water. In the central region of Shabwah Governorate in Yemen, about 20% of the households have installed wells in order to reduce the risk of crop failure. Households with access to pump irrigation obtained net annual revenues that are at least twice as much as for households depending exclusively on spate irrigation.

Access to Water for Domestic Use and Livestock

The access to reliable sources of (ground)water



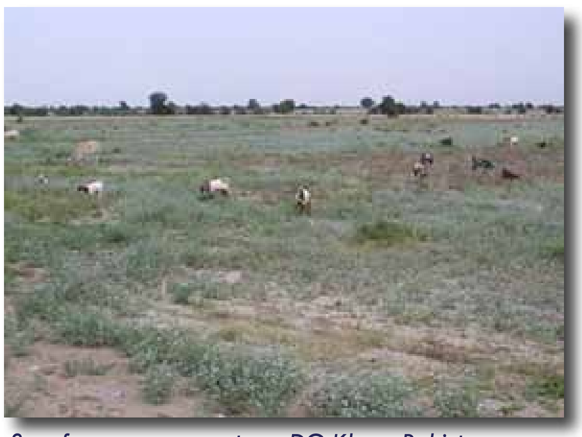


Figure 9: A communally owned land flooded through spate flow for common pasture, DG Khan, Pakistan

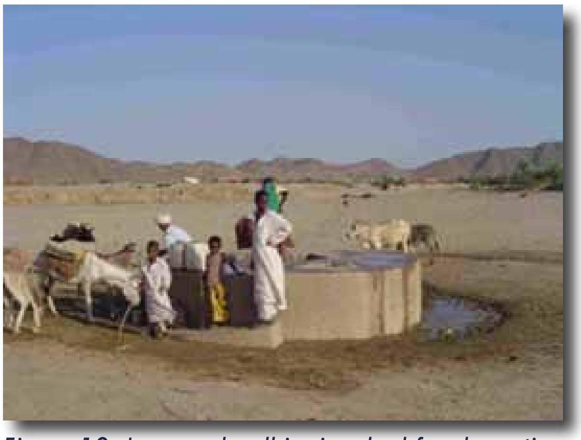


Figure 10: Improved well in river bed for domestic water supply, Eritrea

Figure 11: Renovated ponds for domestic and livestock water supply, Pakistan

for potable and domestic purposes throughout the year is a precondition for the permanent settlement of people in an area. In a number of spate-irrigated areas, however, (ground) water is not available permanently and the local population does not have another choice than to leave their villages in search of water for themselves and their animals. For instance, the majority of the local population in the Sheeb area (Eritrea), the Kachhi Plain in Balochistan (Pakistan) migrates each year for a number of months, because there is not sufficient water to satisfy the water requirements of the local population and their livestock for the entire year. There has been concerted effforts in Sheeb, Eritrea to identify locations in the river bed where relatively less saline water can be drilled for domestic purposes (Figure 10).

In spate-irrigated areas of D.G. Khan District (Pakistan), earthen ponds were renovated and new ones were constructed (Figure 11). Improvements consisting of lining the reservoirs, ensuring adequate depth (1.5-2.5 meter) to reduce evaporation and constructing hand pumps and sand filters. In addition fencing ponds and protecting the inflow through sand traps and vegetative measures can make a large difference in water availability and water quality.

In the Gash irrigation scheme 13 reservoirs (locally known as *hafir*) were excavated having a total design capacity of 375,000 m3. These were located outside the cultivated area in vast rangeland constituting the grazing ground for nomadic tribes. These reservoirs are filled with the early flood water, so that silt would not be deposited in the canal systems. The Gash irrigation scheme used to excavate the *hafirs* annually to ensure their water-holding capacity, but the annual maintenance was abandoned at one stage due to the collapse of scheme management. In addition, there are also underground cisterns, locally known as hod, and they are filled with either outflow from irrigation canals or rainfall runoff.

In the northern part of Amhara State in Ethiopia, farmers divert flood water from the Gobu River to excavated ponds (called *haroyee*) for supplying water to livestock. These ponds are usually constructed along the lower reaches of the main flood diversion canal and on the edge of the crop fields in order to keep animals off the cropped fields and to utilise only the excess runoff after irrigating the fields. If there is a scarcity of water for livestock, a traditional water management committee (locally known as *Aba-hagga*) may order farmers not to irrigate their fields with flood water until the animal drinking pond has been filled. In the Aba'ala Wereda in Afar Regional State (Ethiopia), the shallow ponds are used for watering animals and fetching water for domestic use.

Access to forest products

In the Shabwah Governorate in Yemen, each household has between 25 to 50 *Ziziphus spp* trees in and around their spate-irrigated fields for bee-keeping, fodder, fruits, timber, fuel wood and medicinal uses, whereas spate-irrigating farmers in the Tihama region earn an additional income from the sale of fuel wood and/or charcoal. In the Tihama in Yemen tree coverage has increased with many important multifunctional indigenous trees. The most important ones are *Zizyphus Spina Christa*, for high quality honey forage, timber wood, fruit, detergent (from the dry leaves) and camel fodder; *Salvadora Persica*, used to produce toothbrushes (from the roots), food condiments (fruits); *Balanites Aegyptica* for shelter, camel feed and fruits and also used to stabilise sand dunes;



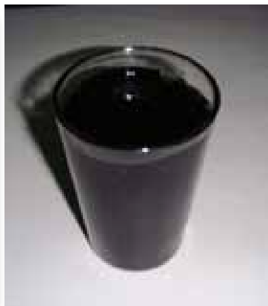


Figure 12: Yemen, Tihama, Balanites Aegyptica *for sand dune stabilisation (left),* Acadia Eherenbergiana, *best quality charcoal (middle) and* keteran *(right)*

and *Acacia Eherenbergiana*, providing premier quality honey forage, goat fodder and charcoal wood. The moisture captured from the acacia charcoal (*keteran*) is used for skin treatment of livestock (Mehari and Al-Jeffri 2008). Figure 12 portrays some of the advantages of indigenous trees in Tihama region, Yemen.

Under the Project for Supporting Implementation of IWRM Policy in Balochistan (Pakistan), the development of tree plantations in spate-irrigated areas is promoted as it would enhance the sustainability of spate-irrigated farming systems by producing bio-diesel, timber, fuel wood, fruit and nuts. The proposed trees could survive drought years as they can extract groundwater from greater depths and they are tolerant to ponding of excess flood water. In DI Khan agroforestry plantations were laid out in the outwash areas. Fields were prepared in order to concentrate run-off and spate releases to the tree plantations.

The way forward

Improving livelihoods

The livelihoods of households in spate-irrigated areas, which are based on the cultivation of spate-irrigated crops in combination with additional incomes from livestock, off-farm activities, wage labour and/or migration, are under threat by the following developments:

- Average size of landholdings decreases due to further sub-division through inheritance and/or settlement/migration of households from elsewhere (i.e. Gash irrigation scheme: number of tenants increased from 22,000 in 1988 to 72,000 in 2008;
- Capacity to maintain spate irrigation infrastructure diminishes due to (permanent) migration and installation of wells, so that remaining farmers are unable to mobilise sufficient labour and draught animals;
- Modernisation of spate irrigation systems can have a detrimental impact for farmers in the middle and tail sections as it has become easier for upstream water users to divert more if not all spate water to their fields despite existing rules regarding the allocation and distribution of spate water;
- Occasional changes in the riverbed, which could be accelerated by deforestation and overgrazing in the upper catchments as well as in and along the riverbed or caused by freak flood events may prevent farmers from diverting spate water to their fields as they are unable to build diversion structures that are high and/or long enough;
- Invasion of alien tree species, mesquite in particular can 'suffocate' flood channels and make land unusable; and
- Degradation of surrounding rangeland undermines incomes from livestock keeping and also triggers sand dune movement, as reported from Morocco for instance.

An understanding of the socio-economic circumstances and existing livelihoods of spate irrigation communities, including the adopted risk-coping strategies, is essential for the development of effective, sustainable and pro-poor interventions aimed at improving (traditional) spate irrigation systems. Although the cultivation of spate-irrigated crops is an important economic activity for most households in spate-irrigated areas, spate water is or could be used for other purposes as well, which may be more beneficial for the local population in financial and social terms. Therefore, it is crucial that any approach aimed at poverty reduction and economic development in spate-irrigated areas is based on "integrated land use" (crop-livestock-plantation farming systems), whereby diverted spate water is optimally used for crop production, horticulture, groundwater recharge, fodder/pastures, forestry and/or small-scale water storage.

An area of special concern is improving the position of women. The death of a working husband or a divorce is a major cause of impoverishment for female-headed households. In the Gash irrigation scheme in Sudan, some 4,500 of the 20,000 poorest households are female-headed, who do not own (spate-irrigated) land and livestock, and they are fully dependent on earnings from daily labour and sale of fuel wood and charcoal.

All domestic tasks are usually the exclusive responsibilities of the female household members, including the fetching of potable water and fuel wood. Even though the role of women in spate-irrigated agriculture and other economic activities varies between regions and cultures, the role of women in the livelihood strategies of households in spate-irrigated areas should not be under-estimated and under-valued as they are important actors in agricultural activities (i.e. sowing, weeding, harvesting, threshing and processing) and rearing livestock, including the processing of livestock products. In general, men are responsible for irrigation and cleaning of canals, but women may assist with infield irrigation. In poorer households, women are often engaged as wage labourers as well or involved in handicraft, petty trade and sale of fuel wood.

Although women are usually entitled to inherit land, socio-cultural practices in (mostly Islamic) countries prevent women from cultivating their lands themselves. As a result, these lands are either cultivated by male relatives of the female landowners or by tenants/sharecroppers. Lack of oxen and insufficient household labour are additional constraints that make it difficult for female-headed households to crop their own fields.

In order to improve the position of women in general, particularly (poor) female-headed households, in spate-irrigated areas, a spate irrigation improvement project should assess the need to develop and implement interventions aimed at improving access to:

- Financial service facilities (i.e. micro-finance/credit, saving and credit groups, insurances);
- Draught power;
- Extension and training services, (incl. improved health and nutrition programmes focusing on women);
- (Drinking) water supply (i.e. wells, ponds, cisterns) and sanitation (education);
- Fodder and water for animals (i.e. ponds and reservoirs);
- Special training in vaccination and health care for small ruminants;
- Energy sources (i.e. (re)forestation, tree plantations, fuel-saving stoves);
- Appropriate, low-cost technologies to reduce women's workload (i.e. milk churners); and
- Income-generating activities (i.e. handicraft, petty business, horticulture)
- Special information services – even in isolated areas women have access to mobile phones..

Improving spate irrigation systems

Large spate irrigation areas have been neglected and external support has been minimal. Over the past three decades spate irrigation development has been supported under a range of national and international programs in some areas. Even so, the vast majority of spate irrigation programs are 'untouched'. This section summarizes the experience with different types of external support given to spate irrigation system world-wide.

Improving Water Diversion

The most 'high profile' external investments in the last 25 years in spate irrigation have consisted of improving the diversion of spate flows. In improving diversion three very different approaches have been followed:

- 'Modernization';
- Improving traditional systems; and closely related:
- Making earth moving equipment available.

Modernization

Under the guise of 'modernization' extensive civil engineering investments have been made in the headworks of spate irrigation systems in Yemen and to a lesser degree in Morocco, Pakistan, Eritrea and Ethiopia. Characteristically, traditional intakes were replaced by civil headworks, typically a weir, an off-take gate and a sluice gate (see Figure 2). In some cases a breaching bund was provided, to save on construction costs and to provide the means to handle very large floods. Also in some systems a sedimentation pond was part of the headworks, designed to avoid coarse sediments going into the command area. Because such modernized headworks are costly, in many cases, a traditional system with multiple off-takes from the river was replaced by a single diversion structures supplying a newly-built long flood channel.

In the Tihama plains in Yemen several large spate irrigation systems (5,000 ha or more) were 'modernized' along these lines in the 1980s (i.e.

Wadi Zabid, Wadi Rima and Wadi Mawr) using World Bank funding (Figure 13). Major investment in the Tihama continued until 2003, when Wadi Siham was modernized with EU financing. Similarly, large civil works have been undertaken in the large spate systems in South Yemen in the eighties with Soviet support. Since then, the focus on new developments in Yemen has shifted to smaller systems (i.e. in Hadramawt), usually as part of larger rural infrastructure projects funded by World Bank or Arab Funds. Recently under the Irrigation Improvement Project (World Bank) two of the systems modernized earlier are being rehabilitated and brought under farmer management.

In some cases (in Pakistan) investments have been made on flow division and regulation structures in ephemeral rivers, but the main focus has been on diversion structures. Under a number of programs in Balochistan Province new spate headworks have been constructed. In the early days these investments were strongly inspired by perennial systems and were not able to cope with the heavy sedimentation process or violent peak floods. An evaluation of 47 relatively minor spate systems built from 1960 up to 1990, established that as little as 16 were still operational.

The track record of such civil engineering investments then is mixed: a large number of disappointments with a few real success stories:

- Investments in flow division and regulation rather than diversion have performed reasonably well. Examples are the Gaj Nai in Sindh and the Mitaj in Balochistan (both in Pakistan);
- Modern flow diversion structures on relatively large systems (1,000 ha and more). All spate projects developed under the Balochistan Community Irrigation Project, implemented from 1995-2002 suffered from operational or social problems. Similarly the Mithawan system developed with JICA funding in Punjab has failed because of inadequate sediment management arrangements. In the Tihama plains of Yemen the designs of the modernized systems became more sophisticated over time, but in many cases suffered from inadequate sediment handling. The Wadi Siham works, in particular suffered seriously from poor design: the traditional flood channels were dissected by a new canal from the civil headworks, which had a far lower capacity. There was substantial damage to the culvert and flood protection, because the effects of scour and sheer were underestimated. Moreover, serious social problems persist in Yemen. These are related to the increased capacity of upstream landowners to control spate flows after the civil works investments. In the past the inherently weak nature of traditional diversion structures made such full control difficult. For instance, in violation of written rules the local elite in Wadi Mawr diverted water to another catchment. Similarly in Wadi Siham and Wadi Zabid powerful upstream farmers created new diversions and deprived downstream water users;
- In contrast small civil engineering works on smaller flood systems (less than 500 ha) have generally performed better. The investments have in these cases usually been straight forward (serving one bank at a time; no complication with distribution of water; no long flood channels; selection of sites with attenuated flows);
- Leaving aside effectiveness of modernization programmes, there are many areas where the modernization approach, even if desired, is not feasible, because of the elevation of the land, the width of the rivers or other reasons.

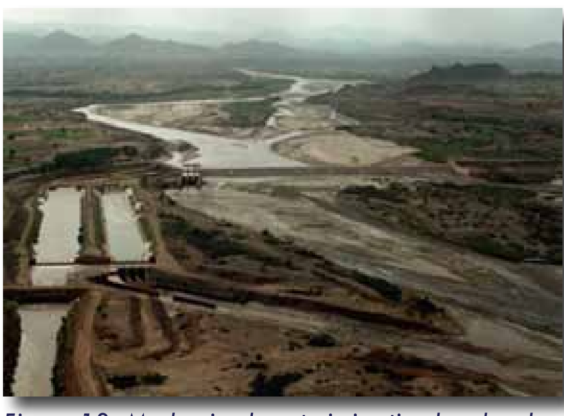


Figure 13: Modernized spate irrigation headwork with settling basin and breaching band, Yemen

Improving traditional systems

Most spate-irrigated systems remain 'traditional'. The traditional structures can be spectacular, with high earthen bunds spanning a river, guide bunds measuring several kilometres or extensive spurs made of brushwood and stones. Often the traditionally designed systems are the most appropriate interventions: they have fewer problems with handling peak floods and excessive sedimentation. Spurs and bunds are generally built in such a way that the main diversion structures in the river break when floods are too big. The breaking of diversion structures also serves to maintain the floodwater entitlements of downstream land users. The capacity to divert water in traditional off-takes is less reliable and the work of reconstructing them can be a considerable burden, and can exceed the capacity of the local community, resulting in the systems being abandoned.

Supporting traditional systems is done to improve their reliability and reduce the maintenance burden. In some cases they make it possible to guide floods where this was not possible earlier. Recently the Government of Eritrea launched an impressive campaign whereby the head reaches of the traditional diversion bunds are replaced by gabions and bulldozered bunds, with farmers providing the labour for filling the gabion crates (Figure 14). One area where this approach was implemented was Wadi Labka, where 1,200 meters of guide bunds were reinforced, and positioned at different places in the wide river bed. The different diversion bunds serve to split the floods in the Labka River to manageable portions in harmony with traditional water rights, and guide the flows to the command area.

Another example of improved traditional systems approach is the Rehanzai Bund (Balochistan, Pakistan), where farmers used external financial support to construct a very large new soil bund on the offshoots of two ephemeral rivers, in order to spread floodwater to more than 15,000 ha of land. In the same area the construction of gabion bed stabilizers was contemplated on the Korasan River. As the Korasan River was degrading, the inexpensive bed stabilizers were to reverse this development and raise the bed level of the river. This would allow farmers to build earthen bunds in the deeply incised river, causing the bed level to rise further. By raising the bed level, natural depressions would start functioning as natural spillways again, in case of very large floods.

A fundamental difference with the 'modernization' approach is that in improving traditional systems the emphasis has been on river engineering rather than on controlling the flood at a single point. Strategies used have been to split the flood in manageable proportions (Wadi Labka), to spread the flood over a large area and reduce its force (Rehanzai) or to stabilize riverbeds and reverse the degradation of the bed level (Korasan) and to avoid water going to low flow areas (Ala'Aba). The advantages of such programs have been that at reasonable cost they have improved reliability of the systems, reduced maintenance burden and kept local management intact.

In many cases intense use has been made of gabion structures. The experience with gabions has not always been positive. In some countries

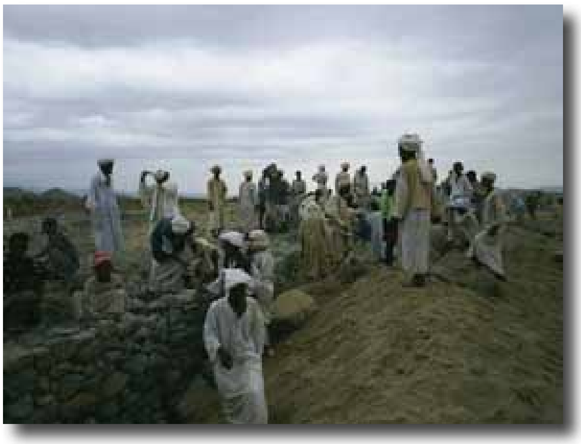


Figure 14: Re-enforcing traditional guide bands with gabions, Wadi Labka, Eritrea

the use of substandard wire crating has been problematic. In the Wadi Beihan Project in Yemen it was found that gabions were only marginally cheaper than the local reinforced structures, but the capacity to repair the gabions did not exist in the area and supply of new gabion crates or even meshwire was difficult. In the end in the Wadi Beihan project traditional stone abutments were preferred over the gabion diversions.

A closely related support strategy to the improvement of traditional structures has been the provision of earth moving equipment. In such programs bulldozers and front loaders are made available at rates that typically cover part of the running costs but none of the capital expenses. Such earthmoving equipment was often made available by aid-in-kind programs. In Eritrea, Iran, Pakistan and Morocco the Ministry of Agriculture has been supplying bulldozer services.

With 'bulldozer' programs farmers are given new means to build or restore diversion work (especially earth bunds), or improve command areas, ranging from gully plugging and repairing canal bunds to making new flood channels (Figure 15). In countries where bulldozer programs are in place they tend to be uniformly popular and have developed into the lifeline for spate irrigation. The downside of the bulldozer programs is that traditional water distribution systems were sometimes upset, because upstream farmers were now able to build bigger bunds. This happened in the Kacchi Plains in Balochistan (Pakistan). Also the issue of restocking bulldozer fleet is there. In all Provinces of Pakistan bulldozers and frontloaders were donated by the Government of Japan in the earlier eighties. Thirty years later many of these bulldozers are – amazingly – still operational, even where they have clocked more than 30,0000 hours – more than double the normal lifetime. Much efforts is done to keep the

Figure 15: Field and canal bund maintenance using bulldozers in Pakistan.

equipment running by famers and government alike, including the cannibalization of broken down bulldozers.

Another issue has been the sustainability. The prime example is again Pakistan, where a vacuum was created after bulldozers had outlived their economic life: the traditional means and organization of the repairing bunds with bullocks had withered away and the number of bulldozers in operation was insufficient. The challenge of the bulldozer programs is to create a situation whereby the rental price covers all running costs of the bulldozers, and to stimulate local entrepreneurs renting out earthmoving equipment.

Organized farmers, better governance

Being located in remote areas – some with a history of insecurity, governance in spate irrigation differs from conventional irrigation. Two major differences are that much of the work is self-organized often through a hierarchy of local leaders and functionaries and that water rights are not based on entitlements (as in perennial irrigation) and quantities but are 'reactive' – responding to the flood water availability in a given time (Mehari et al, 2005). Particular in larger systems with a presence of larger powerful landowners there is the risk that the more 'loose' water management systems translate in the capture of water by making a new diversion or canal. Wadi Zabid and Wadi Mawr in Yemen are prime examples here. This has a number of implications. First is that forming Water Users Associations as part of improving a spate systems should be done carefully and not mechanically? The development of WUAs in the Tihama in Yemen was welcomed as a way to counterbalance the strong grip of large land owners on the water distribution. To avoid that the same leading persons would re-emerge as leaders of the Water Users Association blind balloting was used – with in many areas surprising outcomes that deviated from the status quo. A second implication concerns the water rights – not only within but also between systems along the same ephemeral river. The improvement of upstream systems can often upset a delicate balance in water use that cannot be resolved between farmers of the different systems. There are however good examples where a complementary role of local government organizations in resolving such disputes and coordinating the work on the main rivers (plugging breaches, ensuring distance between off-takes) is a major factor in the operation of the systems.

Concluding remarks: Improving productivity and economic opportunities

Diverting flood water from the ephemeral rivers has often been the main intervention in spate investment programmes, but there is much more to these resource systems than that. In several spate irrigated areas the rivers no longer reach the sea or inland basin. Water is exploited intensively and some basins are effectively 'closed'. This is the case in several parts of Yemen for instance. More efficient diversion in one place means less water in another place. The way forward in improving water productivity lies in making better use of water within the command area. Major advantages can still be experienced here with improved field moisture management, conjunctive use and in improved agronomic practices. The second argument is that there is more to spate irrigation than agriculture. The systems may or may not effectively recharge groundwater, fill drinking water ponds, serve range and local forest areas. The exclusive focus on diversion is often at the cost of supporting different multifunctional uses. Lastly, it is not sufficient to focus only on the spate irrigation per se, but look at the entire local economy. As the livelihoods of many poor households in spate-irrigated areas only rely in part on incomes generated by spate-irrigated agriculture, any spate irrigation improvement project aimed at poverty alleviation in an effective and sustainable manner should also develop and implement activities that create the basis for local sustainable development in general.

There are several ways of improving spate irrigation beyond focusing on diversion works only. A broader spectrum may be chosen/ to improve livelihoods and local food security, especially for the poorer segments of the population. The most promising interventions are:

- Improving water productivity and soil moisture management. There are several ways to achieve this. First is the use of improved field-to-field structures (inlets and overflow structures), allowing more regulated inflows and outflows during the hectic of spate irrigation. Another strategy is to ensure that animal traction power is adequate to plough and mulch so as to conserve soil moisture after irrigation. A final strategy is to concentrate flows on a relatively compact command area, thus increasing the probability of land being irrigated, making it less risky for farmers to prepare their land prior to irrigation, and increasing the capacity to absorb water. More compact command areas also increase the chances of a second and third irrigation, taking crops out of the 'stress zone';
- Agronomic improvements in field preparations, seed treatment, use of improved seeds, early planting, targeted usage of agro-chemicals;
- Introducing of new crops - vegetables, cucurbits, pulses, oilseeds. Also invest in post-harvest technology, such as seed cleaning and improved storage, which have reduced grain losses from 7% to 0% in the DI Khan in Pakistan;
- Enhance the productivity of livestock, including improved access to animal feed (i.e. fodder crops and spate-irrigated pastures), watering points and veterinary services, as well as the processing and marketing of livestock products;
- Promote local agroforestry, particularly of indigenous trees that serve to stabilize surrounding areas and provide fuel wood, timber, medicine and/or bee forage. Often this has to be accompanied by improvement in the governance of local forestry;
- Improve drinking water facilities in the spate areas. These are often meagre and unreliable, i.e. unprotected open ponds - but can be improved by a range of technical and institutional improvements;
- Where possible, the development of conjunctive use of groundwater and spate water, including the construction of infrastructure for artificial groundwater recharge and improved access to credit facilities for installation of wells and pumps;
- Improved land and water tenure, issuing individual titles, where they do not exist and codifying or reviewing water rights, in order to minimize conflicts and also to accommodate new realities, such as the intense use of groundwater and need for recharge;
- Working on the bigger picture - improving access roads to spate irrigated areas, general amenities and market facilities
- In general, the development of opportunities for wage labour and off-farm income, in particular for landless (female-headed) households.

References

AIACC, 2007. A Stitch in Time: Lessons for Climate Change Adaptation from the AIACC Project, AIACC Working Paper No. 48. The AIACC Project Office International START Secretariat 2000 Florida Avenue, NW Washington, DC 20009 USA www.aiaccproject.org.

Ahmad, S. Spate Irrigation Profile of Pakistan (ftp://ext-ftp.fao.org/AG/Data/agl/aglw/Spate/Profiles/Pakistan/Profile-MS-CG%20Pakistan.pdf).

Alamerew, E., B. Fentaw and Seid Ali.Traditional Rainwater Harvesting Systems for Food Production: the Case of Kobo Wereda, Northern Ethiopia. Addis Abeba: ERHA.

Cleveringa, R. Audrey Nepveu de Villemarceau, Ali M. Adeeb, 2006. Local governance to secure access to land and water in the lower Gash watershed. Rome: IFAD.

Egemi, O. Assessment of the Land Tenancy Reform Process – Gash Sustainable Livelihoods Regeneration Project. Rome IFAD.

Fars research Centre for Agriculture and Natural Resources, 2003. Assessment Methodology, prepared for Second Project Workshop "Sustainable Management of Marginal Drylands (SUMAMAD)".

Ghebremariam, B.H., 1998. Community Spate Irrigation in Bada (Eritrea). MSc Thesis Wageningen University.

Government of Balochistan, Asian Development Bank and Royal Government of Netherlands, 2007. TA-4560 (PAK) project for "Supporting Implementation of IWRM Policy in Balochistan", Water for Balochistan Policy Briefings, Volume 3, No.10.

Haile Ghebremariam, B. and F. van Steenbergen, 2006. Agricultural Water Management in Ephemeral Rivers: Community Management in Spate Irrigation in Eritrea. African Water Journal, 1, 1, pg 54-71.

Haile, A. M, B. Schultz and H. Depeweg, 2003. Water Sharing and Conflicts in the Wadi Laba Spate Irrigation System, Eritrea. Sponsored by the Netherlands Government within the NUFFIC-MHO programme; co-operation between the University of Asmara, Eritrea and the Wageningen University: ref. MHO/UoA/WU Agricultural Science II project nr. ERI/624A and ERI/625B).

Haile Kindane, 2009. Community Spate Irrigation in Raya Valley: The Case of Three Spate Irrigation Systems. (MSc Thesis). Addis Ababa University, Ethiopia.

Hussain, S. S. and M. Mudasser, 2007. Prospects for wheat production under changing climate in mountain areas of Pakistan – An econometric analysis. Agricultural Systems 94 494–501.

IFAD, 2003. Gash Sustainable Livelihoods Regeneration Project; Target Group and Project Description, Volume 1 of Appraisal Report 1462-SD.

IFAD, 2004. Local Governance to Secure Access to Land and Water in the Lower Gash Watershed, the Sudan; Land and Water Governance Case Study – Gash Sustainable Livelihoods Regeneration Project.

Iqbal, F. History of Daraban Zam. DI Khan: Veer.

IPCC, 1998. IPCC Special Reports to the Regional Impacts of Climate Change – An Assessment of Vulnerability. Edited by Watson, R. T., M. C. Zinyowera, R. H. Moss and D. J. Dokken. Cambridge University Press.

IPCC, 2007a. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Published for the Intergovernmental Panel on Climate Change. Cambridge University Press.

IPCC, 2007b. Climate change 2007 - The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Published for the Intergovernmental Panel on Climate Change. Cambridge University Press.

Kowsar, Ahang. 2011. . Spate Irrigation in Iran. Overview Note. 's-Hertogenbosch: Spate Irrigation Network

McKee, J., 2007. Ethiopia Country Environmental Profile. EC Delegation, Addis Abeba.

Mehari A. H., 2007. A tradition in transition: water management reforms and indigenous spate irrigation systems in Eritrea. Leiden: Taylor and Francis/Balkema.

Mehari Haile, A., F. van Steenbergen and B. Schultz, 2005. Water rules and rights and management in spate irrigation systems. In: B. van Koppen, J. Buttersworth and I.J. Juma (eds), African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa: Proceedings of Workshop, Johannesburg 26028 January. Pretoria: IWMI, page 23-1-15.

Ministry of Agriculture, 2007. Spate Irrigation Agriculture Baseline Study for Villagers in Gash Barka Region, Eritrea.

Mitiku, H. and Diress Tsegaye. Water Harvesting for Crop Production in Semi-Arid Areas of North-Eastern Ethiopia: Case Study of Floodwater Diversion in Aba'ala Agro-Pastoral Area.

Nawaz, K. and M. U. Qazi. Community Spate Irrigation – Spate Irrigation in Pakistan: Problems and Prospects (www.spate-irrigation.org/librar/spate-pakistan.htm).

Nepvue de Villemarceau, A., 2006. Back-to-Office Report – Mission to Gash, Sudan. Rome, IFAD.

Ogba-Michael, B. The State of Eritrea: Agronomy in Spate Irrigated Areas of Eritrea. Ministry of Agriculture, Department of Regulatory Services, Plant Health Division (http://www.spate-irrigation.org/librar/documents/AgronomyinSpateIrrigatedAreasofEritrea_000.pdf).

Oudra, Ismail, 2011. Spate Irrigation in Morocco. Overview Note. 's-Hertogenbosch: Spate Irrigation Network.

Ragab, R. and C. Prudhomme, 2002. Climate Change and Water Resources Management in Arid and Semi-arid Regions: Prospective and Challenges for the 21st Century. Biosystems Engineering 81 (1), 3-34.

Saleh, S. A. A., 2008. Spate Irrigation in Yemen. College of Engineering – Sana'a University, Yemen.

Shahid Ahmad and Abdul Ghaffar Khan, 2007. Sailaba and Khushkaba Farming Systems of Balochistan – Policy Support for Changing Land Use and to Avoid Infrastructure Damages Caused by Flash Floods. Water for Balochistan Policy Briefing (3, 10). Quetta: ADB.

Simms, A. and H. Reid, 2005. Africa – Up in smoke? The second report from the Working Group on Climate Change and Development, nef Publishers.

SOS Faim, 2006. Improving Spate Irrigation – the Experience of Farmers' Communities in Western Lowlands of Eritrea, Farming Dynamics Number 11/12.

Thomas, R. J., in press. Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change, Agric Ecosyst Environ (2008).

Thornton, P. K., P. G. Jones, T. Owiyo, R. L. Kruska, M. Herrero, P. Kristjanson, A. Notenbaert, N. Bekele and A. Omolo, with contributions from V. Orindi, B. Otiende, A. Ochieng, S. Bhadwal, K. Anantram, S. Nair, V. Kumar and U. Kulkar, 2006. Mapping climate vulnerability and poverty in Africa. Report to the Department for International Development, ILRI, PO Box 30709, Nairobi 00100, Kenya. Pp 171.

UNEP, 2007. Sudan: Post-Conflict Environmental Assessment. United Nations Environmental Programme, P.O. Box 30552, Nairobi, Kenya.

UNFCCC, 2007. Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. United Nations Framework Convention on Climate Change. Climate Change Secretariat (UNFCCC) Martin-Luther-King-Strasse 8 53175 Bonn, Germany.

UNHCR, 2002. Assessing the Potential of Spate Irrigation Schemes for the Gash Barka Zoba, Proposal for Pilot Spate Irrigation Scheme.

UNOPS, 2004. Gash Sustainable Livelihoods Regeneration Project IFAD Loan 630-SD/UNOPS project SUD/03/F01, UNOPS Supervision Mission – Aide Memoir.

Van Steenbergen, F., P. Lawrence, A. Mehari Haile, J.M. Faures and M. Salman. 2010. Guidelines for spate irrigation. Irrigation and Drainage Paper 65. Rome: FAO.

Water Resources Research Institute & National Agricultural Research Centre, 2001. Rod-Kohi System Development and Management in Pakistan – a National Project.

World Bank, 2002. BCIAP Completion Report.

Zaki, El Sayed A.A. and A. Nepveu de Villemarceau, 2006. Gash Sustainable Livelihood Regeneration Project – Follow-Up Mission November 2006.

Practical Note #1

Colofon

This note was prepared by Abraham Mehari[1], Frank Van Steenbergen[2] and Rudolph Cleveringa[3].

1. Corresponding author: Senior Lecturer and Researcher in Integrated Land and Water Development, UNESCO-IHE, the Netherlands; Secretary Spate Irrigation Network, (a.meharihaile@unesco-ihe.org)
2. Convenor Spate Irrigation Network and Director, MetaMeta, Research 's-Hertogenbosch, the Netherlands (fvansteenbergen@metameta.nl)
3. Senior Technical Advisor, International Fund for Agricultural Development, Rome, Italy (r.cleveringa@ifad.org)

For more information: www.spate-irrigation.org.

June 2012