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Guidelines on spate irrigation

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Frank van Steenbergen - Constructing a large river diversion structure - earthworks and gabions - in Wadi Labka, Eritrea.

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Table of contents

List of figures

List of tables

List of boxes

Glossary and abbreviations

Ala'ala fala'ala	Irrigation sequence giving upstream users priority (Yemen).
Algamas	Canal entrance formed by two conical stone structures, with a circular base having a diameter of 3–4 m (Yemen).
Aqm	Earthen diversion bund constructed across a wadi bed. Also used to describe traditional diversion spurs (Yemen and Eritrea).
ARV	Annual runoff volume (m^3).
Base flow	Part of the streamflow that results from precipitation infiltrating the ground and eventually moving to the stream channel. Also defined as groundwater return flow.
Bund	Embankment constructed from soil or wadi bed sediments.
Command area	The area of the spate irrigation scheme that can be irrigated (provided that water is available) and is fit for cultivation.
D_{84}	The size of the sediment of which 84 percent of the material is finer (m).
ERR	Economic rate of return.
Floodwater diversion	The act of diverting floodwater from the seasonal channels into adjacent embanked fields for direct application or into storage.
Gannda	Earthen diversion bund (Pakistan).
Gham	Contribution of land owner to maintenance (Pakistan).
Kharif	Summer cropping season (wet season).
MAF	Mean annual flood peak discharge (m^3/s).
MAP	Mean annual precipitation (mm)
MAR	Mean annual runoff (mm).
Mekemet	A conservation tillage practice of the Sheeb area of Eritrea.
Numberwar	Rule describing an irrigation sequence (Pakistan).
Peak flow	Maximum discharge of a flood event (m^3/s).
O&M	Operation and maintenance.

Q	Discharge or runoff (m^3/s).
Rabi	Winter cropping season (dry season).
Rada'ah'	Irrigation sequence giving upstream users priority (Yemen).
Rod-Kohi or Sailaba	Form of spate irrigation practiced in Pakistan.
Saroba paina	Rule describing the irrigation sequence (Pakistan).
Seguia	Irrigation canal (Morocco).
Spate flow	Runoff regime characterized by rapid changes in the levels of discharge and large variation in the size and frequency of flood events.
Spate irrigation	An irrigation practice that uses the floodwaters of ephemeral streams (wadi) and channels guided through short, steep canals to bunded basins where cropping takes place (sometimes referred to as floodwater harvesting).
Streamflow	Flow or discharge of water that moves along a river or channel (m^3/s).
T	Return period of a flood of a given magnitude (years).
TDA	Tihama Development Authority (Yemen).
Wadi	The bed or valley of a seasonal stream in arid or semi-arid areas that is usually dry except for a short time after spate flow events (a few hours to a few days).
Wakra	A local term in Pakistan that refers to an earthen bund for diverting spate flow from a secondary canal to a field.
Waqf	Land belonging to religious trusts (Pakistan).
WUA	Water users' association.
Zakat	Religious tax (Pakistan).

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This work is dedicated to the memory and inspiration of two giants in the field of spate irrigation: Robert Camacho and Berhane Haile Ghebremariam.

Preface

Spate irrigation is an ancient practice by which floodwater is diverted from its river bed and channelled to basins where it is used to irrigate crops and feed drinking-water ponds, serve forest and grazing land and recharge local aquifers. It has evolved over the centuries and provided rural populations in arid and semi-arid regions with an ingenious way to cope with the aridity of their climate. It is thought that spate irrigation started in present-day Yemen, where it has been practised for around five thousand years.

Today, spate irrigation covers more than 3 million hectares across the world. Although its extent is relatively minor compared to other types of irrigation, it represents a unique option for the management of scarce water resources in support of agricultural production and rural livelihoods in many arid regions.

Spate irrigation has been largely neglected in the technical literature. There are no available guidelines that discuss the specificities of spate irrigation. Yet it is different from conventional irrigation in many ways and therefore needs special skills and approaches of which practitioners are not always aware. In particular, standard design approaches cannot appropriately take into account the level of uncertainty related to floods, the hydraulic challenge of guiding flood flows, the heavy sediment loads, the exceptional nature of the water rights, or the management and maintenance models that are specific to spate irrigation.

The main objective of this publication is therefore to assist planners and practitioners in designing and managing spate irrigation projects. It covers hydrology, engineering, agronomy, local organizations and rules, wadi basin management and the economics. It is designed to be both a practical guidance document and a source of information and examples based extensively on experience from around the world in areas where spate irrigation is practised.

Chapter 1
Introduction

DEFINITIONS AND CONCEPTS

Spate irrigation is a unique form of water resource management that has been practised in arid and semi-arid regions where evapotranspiration greatly exceeds rainfall. In the report of an Expert Consultation on the subject, *UNDP and FAO (1987)* have defined spate irrigation as "an ancient irrigation practice that involves the diversion of flashy spate floods running off from mountainous catchments where flood flows, usually flowing for only a few hours with appreciable discharges and with recession flows lasting for only one to a few days, are channelled through short steep canals to bunded basins, which are flooded to a certain depth". Subsistence crops, often sorghum, are typically planted only after irrigation has occurred. Crops are grown from one or more irrigations using residual moisture stored in the deep alluvial soils formed from the sediments deposited in previous irrigations.

A simpler definition of spate irrigation was given by *Mehari et al. (2007)* as "a resource system, whereby flood water is emitted through normally dry wadis and conveyed to irrigable fields". *ICID (2010)* distinguishes floodwater harvesting within streambeds, where channel flow is collected and spread through the wadi where the crops are planted, from floodwater diversion, where the floods – or spates – from the seasonal rivers are diverted into adjacent embanked fields for direct application. In all these cases, spate irrigation is characterized by the arid environment in which it takes place, the unpredictable nature of flood water to be harnessed, high sediment loads and a complex social organization.

Sedimentation is a major factor in spate irrigation. Spate systems grow their own soils, and rely on nutrients transported with sediments from upstream catchments to maintain soil fertility. High sediment loads cause command areas to rise and block intakes and channels, but sedimentation processes can be manipulated for the benefit of farming. Spate irrigation is as much about sediment management as it is about water management.

Spate irrigation is the main source of livelihood for large numbers of economically marginal people in areas as varied as the Near East, Africa, South and Central Asia and Latin America, and is mostly practised outside the formal state-managed irrigation sector. Generally, it is a subsistence activity, with low returns, generating highly variable incomes between good and bad years. It requires high inputs of labour to maintain intakes, canals and field systems and, in places where more reliable and rewarding livelihood opportunities are available, farmers tend to abandon their schemes, local management structures are undermined, and spate irrigation systems tend to decline and disappear. This has been the case in some richer countries such as Saudi Arabia. On the other hand, spate irrigation also remains at the heart of places like the bread basket of Yemen – the Tihama – and it is on the upsurge in several countries, for instance in the Horn of Africa.

This type of water management is very risk-prone and requires high levels of cooperation between farmers to divert and distribute flood flows. The uncertainty stems from the unpredictable numbers, timing and volumes of floods, the occasional very large floods that wash out diversion structures, and the frequent changes to the wadi channels from which the water is diverted. Substantial local wisdom has developed in setting up and constructing intakes, organizing water distribution and managing the flood waters and their heavy sediment loads. In some locations, large irrigation systems have developed over centuries, first with rudimentary diversions and canals providing high water diversion efficiency and a fair measure of equity between upstream and downstream water users. Command areas may range from anything between a few hectares to over 30 000 ha, and some spate schemes rank amongst the largest farmer-managed irrigation systems in the world. While spate irrigation has been primarily developed for cropping, it rarely serves only agriculture. In many instances, it also sustains rangelands and local forestry, and helps recharge groundwater, thus providing drinking water for humans and livestock.

In many arid environments, the classical approach to water management through storage of river water in reservoirs is not practical owing to the very high sediment loads transported during floods. In such regions, the useful life of reservoirs is usually very short. Spate irrigation offers more attractive development options when appropriate models can be identified. However, only a relatively small number of public programmes to develop and improve traditional spate irrigation have been carried out. One reason has been the difficulty in justifying investments in civil engineering works on systems dominated by low-value subsistence farming. A second reason is that it has been hard to identify successful interventions, as spate schemes, in spite of their apparently simple technologies, are hydraulically and socially complex.

These complexities have not always been sufficiently appreciated. In past improvement and modernization projects, with serious implications for the quality of the results. The overriding point is that the repertoire of potential improvements is often not well known. On the engineering front, for instance, interventions based on improving traditional systems are not part of standard curricula and yet it requires understanding and ingenuity to identify break-through improvements in these systems. As a result, modernization projects have too often applied design and management principles issuing from classical irrigation but not adapted to spate conditions.

Similarly, the potential scope for other contributions to improved spate irrigation – in agronomy and post-harvest technology, in rangeland management and agroforestry, in promoting recharge and reducing potential damage – is often sector-specific and not widely understood. The introduction of irrigation from shallow groundwater in spate-irrigated areas, for instance, is a recent innovation. With the availability of relatively inexpensive pump sets, this technique has become important in some areas in Pakistan, Tunisia and Yemen. In some areas, spate water and shallow groundwater are used together, but in others the introduction of shallow wells has resulted in the abandonment of the spate infrastructure and a move towards perennial cropping, sometimes of high-value cash crops.

HISTORY OF SPATE IRRIGATION

Spate irrigation has evolved and developed over a very long time period. The remains of diversion dams in ephemeral rivers dating from 3000 BC can be seen in Iran and Balochistan (Pakistan). It is thought that spate irrigation started in present-day Yemen, when the wet climate of the neolithic period became more arid, and has been practised there for around five thousand years. The famous Mar'ib dam in Yemen, which irrigated 9 600 ha with spate flows diverted from the Wadi Dhana, was first constructed during the Sabian period in the third millennium BC (see Box 1.1).

It is reported that large volumes of sediment were scoured out of the dam when it was breached. *Hehmyer (2000)* suggests that the dam builders could have constructed a permanent masonry dam but chose an earthen impounding structure that would fail when overtopped by historic floods, to prevent very large flows from damaging the irrigated area.

One can only speculate as to how the practice spread across the world. However, the intense development of trade after the Islamic period may have helped to spread innovations from the Yemen area. Yet it is likely that spate irrigation technology has

BOX 1.1

Mar'ib dam, Yemen

It is believed that construction of the Mar'ib dam commenced in about the third millennium BC, and was completed in stages over the next 500 years. The structure had very well constructed stone abutments and irrigation offtakes on both banks, which have partly survived. The dam itself was constructed from rock and soil and was breached on five or six occasions between the fourth and seventh centuries BC, when the final catastrophic breach, which is described in the Holy Koran, occurred. In its final form the dam was about 18 m high and 700 m long, and irrigated farmland supporting a population of between 30 000 and 50 000, growing maize, millet, barley and other crops. The dam was intended to divert water from spate floods, rather than to store water over long periods, as storage of flood waters would have resulted in fairly rapid sedimentation. It thus functioned more like a diversion barrage than a dam. The remains of the dam abutments and the 60 m^3/s irrigation outlets can be seen in the figure below.

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sprung up independently in several areas – particularly as it is found in areas as diverse and remote as West Africa, Arabia, Central Asia and Latin America. In some areas the interest is recent. The development of spate irrigation in Eritrea is for instance traced back to the arrival of Yemeni migrants 80-100 years ago (Haile *et al.*, 2003). In several other parts of Africa, such as Ethiopia, spate irrigation is now just emerging, in response to increased population pressure in the highlands.

In Yemen, large traditional spate systems consisting of numerous individual intakes and canals irrigating areas of up to 30 000 ha were developed in individual wadis. Sophisticated water sharing arrangements were formalized, with rules relating to water rights that exist in written records dating back at least 600 years. In Pakistan, spate irrigation has been practised for a long period and it was the basis of important agricultural production systems until the end of the nineteenth century, when the development of perennial irrigation received an important impetus under the British colonial administration – essentially by a reorganization of the water management arrangements. Spate water from about 26 wadis in the northwest coastal region of Egypt has been used for irrigation since Roman times, while spate irrigation has been practised in Morocco over a similar period. In central Tunisia, farmers have irrigated their fields with diverted spate water since the second half of the nineteenth century *(Van Mazijk, 1988)*. In Iran, spate irrigation has a history of many millennia and can be seen in many forms, often combined with groundwater drainage galleries, so-called *qanats*.

Spate irrigation practices are widespread in Iran, as illustrated by the rich terminology used in different parts of the county to describe it. *Darband,* check dams made of dry masonry are called *khooshãb* or *bãgh* in northern Baluchestan, southeast Iran, and *bandsar* in Khorasan, northeast Iran. Diverting floods from ephemeral streams and spreading the water on relatively levelled land is called *degar* in southern Baluchestan; *pal* and *bandsãr* in Khorasan; *ta, goudtak, taghal* and *gaband* in the Izadkhast Plain, Darab and southeast Iran; *goorehband* in Sistan, eastern Iran; and *korband* (silt retainer) in southern Fars, southern Iran, the Persian Gulf coast and the Qeshm Island. *Lavar*

FIGURE 1.1
Area equipped for spate irrigation in selected countries *(FAO-AQUASTAT, 2010)*

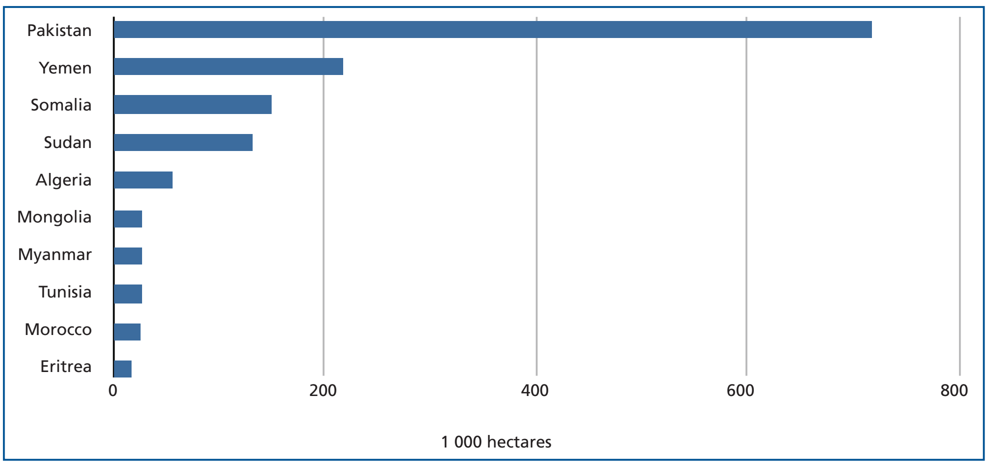
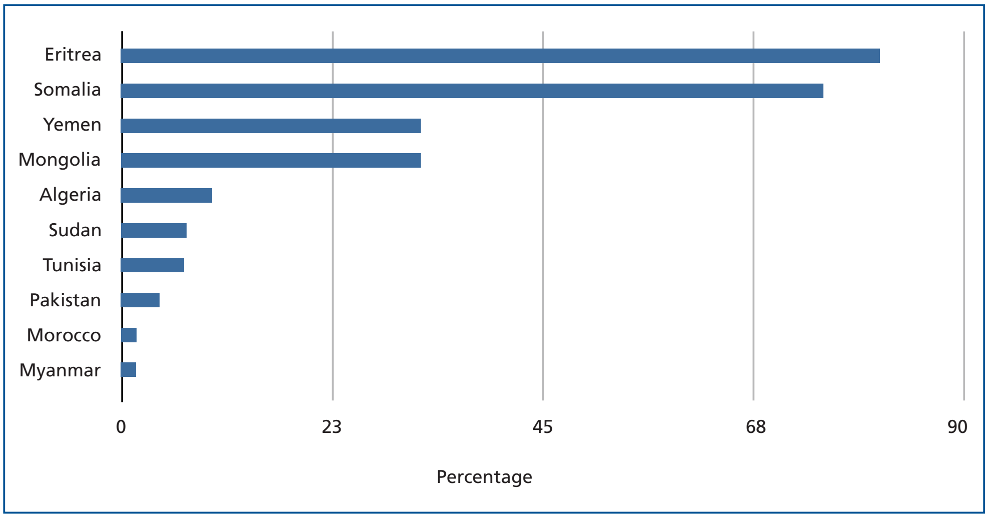


FIGURE 1.2

Spate irrigation as a percentage of total irrigation in selected countries

(FAO-AQUASTAT, 2010)



(silt bringer) is the name given to a spate-irrigated farm field in the Dorz-Sãyehbãn area in southeast Fars. Moreover, the upstream spate-irrigated fields in Mazaijohn, south of the Izadkhast Plain, Darab, are called *bonakhoo*, and those on the downstream end are called *shatmãl* (sheet irrigation) in Darab and *takhtãbi* in Khorasan.

EXTENT AND DISTRIBUTION OF SPATE IRRIGATION SCHEMES

Spate irrigation is found in West Asia, Central Asia, the Near East, North Africa, the Horn of Africa and Latin America. The country with the largest area under spate irrigation is Pakistan. In some areas – such as North Africa - the area under spate irrigation has been reduced in the last twenty years, partly as a result of reservoir construction on several of the ephemeral rivers. In contrast, however, in the Horn of Africa the area under spate irrigation is expanding rapidly, especially in Ethiopia and Eritrea, where population pressure encourages settlement in the vast lowlands which have become more habitable. Another important development is the conjunctive use of groundwater and spate irrigation, giving rise to relatively highly productive systems, where possible.

Owing to the nature of spate irrigation, a substantial level of uncertainly exists on the extent of spate irrigation across the world. The most comprehensive information on the current extent of spate irrigation comes from FAO's AQUASTAT database *(FAO-AQUASTAT, 2010)*. The database indicates that there are around 3.3 million ha under spate irrigation, spreading over 14 countries and representing 11 percent of their irrigated area, with very large areas listed in Pakistan and Kazakhstan. These data are primarily based on available statistics and do not always capture the smaller, farmer-managed, informal schemes when they are not well documented. They should be taken as indicating an order of magnitude of the importance of spate irrigation and represent probably a conservative measure of the extent of land under spate irrigation. Figures 1.1 and 1.2 illustrate some data analysis based on information available in *FAO-AQUASTAT (2010)*.

Other sources give different estimates, and the definitions adopted to describe spate irrigation vary from one country to another, making statistics difficult to establish. For example, in Pakistan, where spate irrigation is found in all four provinces, alternative estimates of the spate-irrigated areas *(Ahmed, 2000)* are more than twice that indicated in the FAO data.

In several other countries and regions, including central Asia, Afghanistan, western China and parts of Latin America, scattered reports indicate the existence of spate irrigation but no figures are available. Areas of spate irrigation located in Ethiopia, Egypt, Kenya, Mauritania and Senegal, as well as Chile and Bolivia, are not reported. It is testimony to the informal and forgotten nature of spate irrigation that, though the areas may be relatively important, there is no recent accessible reference on spate irrigation in these areas. The uncertainty about the extent of spate irrigation is illustrated in Table 1.1. The table compares the area under spate irrigation as reported in AQUASTAT with estimates provided by participants in an expert meeting organized in preparation for this publication *(FAO, 2010)*.

TABLE 1.1
Large uncertainties that exist in assessing the area under spate irrigation

	Area under spate irrigation	
	FAO-AQUASTAT	Expert meeting 2008
Algeria	56 050	56 000
Eritrea	17 490	17 000
Ethiopia	-	140 000
Iran	-	419 500
Morocco	26 000	165 000
Pakistan	720 000	640 000
Tunisia	27 000	1 000
Yemen	218 000	117 000

Sources: *FAO-AQUASTAT, 2010 and FAO, 2010.*

CLASSIFICATION OF SPATE IRRIGATION SCHEMES

There are several variants of spate irrigation and several terms are used to describe similar practices. Spate irrigation has some similarities with flood inundation and flood recession systems found along alluvial plains, where crops are grown from the residual moisture following floods. The term *water harvesting* is also used to describe the practice in which the flow discharged from a small catchment area after a storm is directed through channels to a nearby field enclosed by bunds, and soil moisture is increased by subsequent infiltration, while *runoff farming* usually refers to *in situ* collection of rainwater in the field to increase moisture in the rootzone. In all cases, the crops take up the supply of water in the soil during the dry periods that follow rainfall and they can survive longer periods without yield losses in places with deeper and heavier soils *(Touer and Humborg, 1992)*.

There are two important features that distinguish spate irrigation from these other forms of flood irrigation. The first is that, in spate irrigation, flood water is physically diverted from wadi channels via canals to bunded fields that may be located at some distance from the water course. The second is that spate irrigation is carried out on a large scale, by groups of farmers rather than individuals, who need to work closely together to divert and distribute flood waters and maintain their intakes and canals. Spate irrigation is also distinct from semi-perennial irrigation, as it depends on short-duration floods, whereas semi-perennial irrigation makes use of flows lasting weeks, even months. In all cases, however, the dividing line is thin.

Common features of most spate irrigation schemes are:

- *ingenious diversion systems*, built to capture short floods but also designed to keep out the larger and most destructive water flows;
- *sediment management*, as the flood water has high sediment loads that would otherwise fill reservoirs and clog intake structures and distribution canals; these sediments are used to build up soil and level the land but can also result in excessive rising of land and loss of command;
- the importance of *soil moisture conservation*, especially as floods often come ahead of the sowing season;
- a sophisticated *social organization* to manage the sometimes complex system, ensure timely maintenance of the structures and channels and oversee the fair distribution of the flood water, even though it comes in unknown quantities at unpredictable times.

Schemes are usually designed for a given purpose and several classifications of the various types are possible. Table 1.2 presents classifications based on size, infrastructure, management or hydrological regime and source of water. Other classifications are possible, based on the range of crops that are grown or on the way water is distributed.

In these guidelines, scheme size and management arrangements have been used as main classification criteria, as different approaches are required for the different categories of systems. Below four main categories of spate irrigation systems are considered, to which these guidelines refer, together with a short summary of the most common improvement options, which are discussed in detail in the rest of the report.

- **Small schemes under farmer management using traditional diversion practices.**

  These schemes are usually found on small wadis where the flood flows can, for the most part, be easily handled by farmers using relatively simple diversions. For these types of schemes, the main improvement option consists in reducing the amount of labour involved in re-building diversion spurs and bunds.

- **Medium-scale/large-scale schemes under farmer management using traditional diversion practices.**

  These schemes are constructed in larger wadis carrying much larger flood flows. Typically they have numerous intakes ranging from simple deflectors in the upstream part of a wadi to diversion bunds in the lower reaches. Treating these schemes as a series of independent, small systems and providing each independent system with simple, un-gated diversions constructed from gabions, rubble masonry or concrete is to be one of the major improvement options.

TABLE 1.2
Possible classifications of spate irrigation schemes

Characteristic	Class	Description
Size of scheme	**Small**	Range from a few hectares, usually located on tributary wadis in mountain regions, or in plains supplied by small wadis, with areas not exceeding 1 000 ha.
	Medium	Schemes located mostly in plains supplied from small/medium wadis. Command areas ranging from a few hundred up to 5 000 ha. Often a single tribe or social group manages these schemes.
	Large	Substantial systems that may have numerous offtakes irrigating land areas of up to 20 000-30 000 ha. Complex water sharing rules have developed in some cases to control the distribution of flows between intakes operated by different tribes, villages or social groups.
Infrastructure	**Traditional intakes and canals**	Traditional diversions consisting of deflecting spurs or, in flatter plains areas, bunds that are constructed right across the flood channel. Canals are usually short and rarely include a secondary distribution system. Water is usually passed from field to field by breaking field bunds when the ponded water reaches a predetermined depth. In Pakistan, spate-system fields often have their own supply channels.
	Improved traditional systems	Farmer-implemented improvements could include flow throttling structures and rejection spillways near canal heads and drop structures and flow division structures in main canals. In some areas farmers may hire bulldozers to construct diversion bunds. When outside agencies support improvements, bulldozers may be provided at subsidized rates, and simple gabion or rubble masonry structures may be used at diversions. Improved water control structures may also be incorporated in the canal and field systems.
	Modernized and new systems	In large systems, numerous traditional intakes are replaced with concrete diversion weirs, with sediment sluices. Owing to the high costs of permanent structures a single permanent weir often replaces many traditional intakes. In newer schemes, steep canals and sediment management structures are provided to minimize sedimentation. In new schemes, where farmers may not have the traditional skills needed to manage spate flows, a range of diversion types, including large semi-permanent soil bunds and small, simple diversion weirs, are used.
Operation and maintenance	**Traditionally managed**	Farmers manage systems without assistance from outside agencies.
	Managed by farmers with support from outside agencies	In some schemes varying levels of support from government or NGOs is provided to assist in construction and maintenance of intakes, although operation is usually left in the hands of the farmers.
	Agency-managed	In some large, formally farmer-managed systems that have been modernized, the intakes and main canal systems are operated and maintained by irrigation agencies. In Yemen some of these systems are now being handed back to the farmers as part of irrigation management transfer efforts.
Wadi flow regimes and use of groundwater	**Schemes that have access only to spate flows**	At locations where only spates occur, it is necessary to divert water at high discharges if a reasonable proportion of the annual runoff is to be diverted.
	Schemes that have access to significant base flows	High water diversion efficiency can be obtained in wadis where (a) there are small base flows for some months during and following the rainy season; (b) there are large numbers of small and medium floods; or (c) the offtakes are located in flat plains areas where the floods have lost momentum and may last for long periods. In these cases, irrigation of areas located at the head of systems is reasonably assured, and irrigation practices resemble perennial irrigation. Spate irrigation from flood flows is carried out in the middle and lower reaches of the wadi.
	Conjunctive use of spate and shallow groundwater	Where possible, access to groundwater substantially reduces the uncertainty inherent in spate irrigation and allows cropping of cash crops that cannot survive for long periods between watering. Spates are still diverted for irrigation, albeit at unpredictable intervals and volumes. Spate flows enhance the recharge of the shallow aquifers.

- **Large and technically complex schemes.**

  Larger and technically complex systems are only feasible with an element of external management, ranging from full agency management to backstopping and technical support provided by local irrigation or agriculture departments. Where high development costs can be justified economically, permanent diversion and water control structures can be considered. Such schemes may considerably modify the hydrology of the wadi and must therefore be considered against the possible negative effects on downstream water users. There is also the requirement to ensure the funding of adequate levels of maintenance in agency-managed schemes and to avoid potential technical problems related to poorly engineered spate diversion structures.

- **Schemes with access to sufficient shallow groundwater or base flows.**

  Access to groundwater reduces much of the insecurity associated with spate irrigation and allows production of crops that cannot survive long periods between irrigations. In such cases, the provision of incentives or authorizations to allow farmers to dig wells and purchase pumps should be regulated to prevent over-exploitation of groundwater and, in coastal areas, saline intrusion and the destruction of aquifers, and the establishment of community-based groundwater monitoring and management systems may be required. The provision of communal wells to enable poorer farmers to benefit from groundwater irrigation could be considered. Properly conducted regional water balance studies are needed before shallow well irrigation is actively promoted in spate areas.

Aside from these differences, there are common possibilities for improvements in all spate irrigation systems, including stronger management in general, better moisture conservation, improvement in crop varieties and changes in cropping patterns. These improvements are discussed in the different chapters of this publication.

PURPOSE AND SCOPE: HOW TO READ THESE GUIDELINES

Although its importance is relatively marginal in absolute terms, spate irrigation offers scope as a water resources management option in support of agricultural production in many arid countries and represents therefore a viable option to enhance the livelihoods of the rural communities in these regions. Experience from past interventions has shown that improvement of spate irrigation schemes is possible when it is based on the combination of experience and knowledge accumulated by farmers over the years and on ingenious and well adapted design and management solutions.

However, spate irrigation is unquestionably different from conventional irrigation systems and therefore needs special skills and approaches, of which engineers are not always aware. In particular, the use of standard irrigation design approaches that do not take into account the level of uncertainty related to floods, their exceptional nature, and the sediment load challenge is not appropriate. Similarly, management models based on traditional irrigation are unlikely, in most cases, to be adapted to spate irrigation.

Spate irrigation has unfortunately been largely neglected. There are no available guidelines or teaching materials that focus on and discuss the specificities of spate irrigation. The main objective of this publication is therefore to provide insight and guidance, based on the experience gathered in many spate irrigation projects, about potential improvements of traditional spate irrigation systems, while it also highlights their complexity and the inter-connectedness of the different issues to be addressed.

These guidelines are designed to be both a practical guidance document, and a source of information and examples based extensively on experience from across the world where spate irrigation is practised. While it is meant to propose practical ways of designing and organizing the management of spate irrigation, the report also highlights past failures and successes in spate irrigation modernization which have been instructive for project improvement.

The guidelines cover all aspects of spate irrigation design and management: social settings and tenure issues (including water rights), hydrology, engineering design, water and soil management, crop production, farmers' organization, economics and environmental issues. They do not replace standard textbooks in all these disciplines but complement them by providing specific considerations in all these fields that apply to spate irrigation situations.

Each chapter covers one of the above subjects. A summary of the main guiding principles is presented at the beginning of the chapter and outlines the most important features of the subject. The rest of the chapter provides more detailed information and guidance, illustrated by numerous examples from existing spate irrigation schemes.

Chapter 2
The social setting

SUMMARY

An understanding of the socio-economic context in which farmers operate is essential to ensure effective and sustainable improvements in spate irrigation systems. A socio-economic analysis must be performed at an early stage in the design of spate projects, through an in-depth consultation process that covers all livelihood situations in the project area. It will help set the right priorities and avoid unintended negative consequences of spate irrigation improvement interventions.

Of primary importance is the way farmers deal with uncertainty in spate irrigation: with low crop returns and the possibility of crop failures always in the background, farming households adopt a number of strategies to cope with uncertainty that are based primarily on the diversification of the household economy. They include generating additional household income through wage labour, livestock keeping and off-farm activities; the systematic saving of surplus grains from one year to the next; the cultivation of low-yield, drought-resistant traditional crops, such as sorghum, which produce at least some fodder in drought years; and investment in easily disposable property, such as livestock and draught animals in particular, in good years when there is a crop surplus. Understanding and integrating these strategies into spate irrigation improvement projects will help set the right priorities, ensure the relevance of the interventions and avoid unintended negative consequences, as many past spate irrigation improvement projects have demonstrated.

Land tenure in spate irrigation areas varies extensively from one country to another, but it often reflects the complexity of the management of risk associated with spate irrigation. Societies have developed tenure systems that ensure the optimization of return on water, often at the expense of apparent equity in access to the resource. Projects must acknowledge and understand existing tenure systems and consider the implications of any possible intervention on tenure rights and arrangements, both in terms of management and in terms of distribution of benefits. Any changes that would have implications in terms of tenure must be negotiated with the beneficiaries at the outset. In particular, it should be considered that sharecropping is among the most common arrangements in spate irrigation systems. The impact of proposed improvements on the distribution of tasks and benefits between landlords and sharecroppers must be anticipated and agreed upon by all parties.

Careful attention must be given to equity considerations. Spate irrigation improvement projects should be designed and implemented so that poor households can have the chance to increase their incomes. In particular, it is essential that improvements in spate irrigation projects do not increase inequalities and inequitable access to the resources among social groups. While not all projects will have components covering the entire range of livelihood situations, all situations should be considered when projects are being planned and projects need to be screened for their impact on the different groups to ensure that unintended negative consequences are not introduced.

A 'pro-poor' approach will seek specific targeting of unprivileged groups. In several spate-irrigated areas there is considerable inequity and groups of 'have nots' may exist. These include: farmers who are too poor to farm and have no access to family labour or draught animals to use the water when it comes; people in areas with no, or saline, groundwater and thus without a local drinking water supply; tail-enders who depend on very unreliable spate flow with farming systems at risk of collapse; people living in low-lying areas or on exposed river banks who are in danger of losing all in floods; and the special outcast groups, for instance the Akhdam in Yemen, descendants of very early African migrants who have a long history of an extremely marginal socio-economic position. Poverty alleviation means not only making the local economy work in the remote areas where spate irrigation normally occurs but also making sure the benefits spread far and wide.

Such considerations also apply for the situation within the household. Understanding the distribution of tasks and power balance within the household is an important element of spate improvement projects. While there are major differences between regions, the distribution of tasks and responsibilities between men and women is usually well established, with men often in charge of maintenance of irrigation canals and terraces, and women often responsible for agricultural and harvesting activities, in addition to domestic tasks. It is therefore important that any proposed improvement be assessed in terms of their implications for both men and women and that the benefits of proposed improvements be shared by all. Of particular relevance is the issue of drinking water supply and the implications spate improvement can have on access to a safe source of water for domestic uses. Early consultation processes must ensure that the specific needs and requirements of women are understood and taken into account in the design of spate improvement projects.

Finally, spate irrigation improvement should not be programmed in isolation. To alleviate poverty in spate-irrigated areas, it is not sufficient to focus only on the improvement of spate irrigation. In a situation of a highly diversified household economy, successful alleviation of poverty among poor households in spate-irrigated areas will also depend upon:

- improvement of access to inputs of extension services, credit and marketing for spate-irrigated crops;
- improvement of the productivity of livestock and the processing and marketing of livestock products;
- creation of opportunities for wage labour and off-farm income, in particular for landless households;
- access to credit for well drilling and groundwater pumping or installation of communal wells with pumps, where groundwater development is possible;
- addressing the need for basic amenities – in particular, safe drinking water.

Poverty alleviation will also depend on a good understanding of the threats which spate irrigation systems face and which include their lack of attraction because of high-risk, very labour-intensive work, the excessive burden of maintenance on farming households, the reduced size of landholdings, and, in some cases, the lowering of the water table. When they become too pressing, these threats lead to the abandonment of infrastructure and emigration. It is therefore important that spate improvement projects assess and value these threats and address them to ensure a successful and sustainable impact of projects on people's livelihoods.

INTRODUCTION

Spate-irrigating communities have developed a range of livelihood strategies to cope with the large and unpredictable seasonal and inter-annual variations in water supply and crop production which are inherent in spate irrigation. An understanding of the socio-economic circumstances of farmers and the coping strategies that they adopt is needed if effective and sustainable improvements to traditional spate irrigation systems are to be developed.

This chapter presents a summary of the socio-economic background of farmers in spate systems, based on information from spate schemes in Yemen, Pakistan and Eritrea. Livelihood and coping strategies adopted by spate farmers vary within and between schemes, regions and cultures.

Most households in spate-irrigated areas are poor, with a per capita income of generally less than US$1 per day. Estimated net household revenues derived from some spate-irrigated systems in Eritrea, Yemen and Pakistan are given in Table 2.1. In most areas economic poverty is amplified by remoteness and lack of access to basic amenities.

TABLE 2.1
Net annual revenues from selected spate irrigation areas

Country	Location	Household net annual revenue (US$)	Note
Eritrea	Sheeb	355	A further US$165 from livestock products giving income of US$520 in a 'good' year.
Pakistan	Toiwar	300	Two-thirds from crop production and one-third from livestock.
Yemen	Shabwah	412	Increases to between US$765–1 000 for households with access to pump irrigation.

Source: Hadera (2000), Halcrow (1993a, 1997, 1998)

These figures are averages and mask large fluctuations between households. For example, farm incomes were reported to vary by a factor of three between upstream and downstream locations in traditional spate-irrigated areas of the Tihama in Yemen, reflecting the farmers' relative access to water *(Tihama Development Authority, 1987)*. While a few favoured landowners located at the head of some schemes generate high incomes from commercial-scale farming, most spate irrigators further downstream are poor subsistence farmers, who lack basic amenities such as potable water and sanitation, electricity and health care. High infant mortality due to malnutrition among children and pregnant women is evident in many locations, as well as anaemia, malaria and other health problems.

LAND TENURE

Spate irrigation systems are used by sharecroppers and tenants as well as by landowners, but there are wide variations in the pattern of tenure. Statistics from selected spate irrigation systems show that the proportion of spate-irrigated land cultivated by landowners may vary from zero to 100 percent (see Table 2.2).

TABLE 2.2
Irrigated areas farmed by landowners, tenants or sharecroppers

Scheme	Percentage of irrigated area farmed by landowner
Kharan District, Balochistan, Pakistan	0
Nal Dat, Balochistan, Pakistan	27
Toiwar, Balochistan, Pakitan	100
Wadi Zabid, Yemen	18
Wadi Tuban, Yemen	49
Wadi Rima, Yemen	50

Source: World Bank (2000a), Makin (1977a), Halcrow (1993, 1994e, 1998)

A common arrangement in many spate-irrigated areas in Pakistan is that of hereditary tenancy. The tenant has a hereditary right to the land but this is contingent on his cultivation of the land. In several places the tenant is called *lathband*, meaning that his responsibility is the maintenance of the field bunds. This shows the importance of field bunds in moisture conservation and at the same time it is an arrangement to tie labour to the land and keep the critical mass required to maintain the systems. In the Anambar Plains in Balochistan, Pakistan, even in the 1990s landowners were actively trying to bond farm labour, for instance by offering farmers loans for bride prices.

An exceptional land tenure situation applies to the main spate irrigation systems in Sudan, the Gash and Tokar. In both systems, land tenure in most of the area is uncertain and land is allocated on an annual basis by the local government. This serves as a severe disincentive for land improvement. Both areas, moreover, suffer from the invasion of mesquite (*Prosopis juliflora*), making land difficult to cultivate and causing the obstruction of flood paths and changes in river morphology.

In some countries, for example Ethiopia, Eritrea and Sudan, all agricultural land is formally owned by the government, while in others, for example Pakistan, individuals' land rights are formally recognized and registered in government-administered cadastral records. In Balochistan (Pakistan), the hereditary tenants acquire partial ownership rights as compensation for developing the land for the original landowners.

Land reforms initiated by the Eritrean People's Liberation Front (EPLF) in the latter half of the 1970s and early 1980s have significantly changed land ownership in Eritrea by allocating small plots of land (0.5–1 ha) to poor families. At present, all land is government-owned, but the farmers have the continuous right to use spate-irrigated land. When the user of the land dies the usufruct right is transferred to the oldest son. Younger sons are allocated their own plots of land by the local administration when they marry.

In Yemen, land can be owned by individuals, government or trusts. In Wadi Zabid, 54 percent of the total command area is privately owned, with the remaining 46 percent belonging to religious trusts. In Wadi Tuban, 20 percent of the total command area is government-owned land, and 10 percent belongs to religious trusts (*waqf* land). Following the independence of South Yemen in 1967, large landholdings were redistributed among new farmers and tenants. After the unification of North and South Yemen in 1991, the farmers working these lands formally lost their legal entitlements to use the land, but the Government has not enforced this change as it would make many households landless.

In general, as indicated in Table 2.3, the average landholdings in spate irrigation systems are rather small. The main exception is in Pakistan, where holdings are generally larger but where command areas are usually overstretched and much of the land has little probability of being irrigated.

TABLE 2.3
Average landholding in selected spate irrigation schemes

Scheme	Average landholding (ha)
Wadi Tuban, Yemen	1.4
Wadi Zabid, Yemen	2.1
Shabwah Governorate, Yemen	2.5–5
Sheeb Eritrea	0.5-1
Balochistan Pakistan	5.4–7.8
Nouael II project Tunisia	1.1
Morocco	1.0

The distribution of land within schemes varies from a relatively egalitarian to a highly skewed distribution, in which a few rich landowners own large tracts in the favoured upstream parts of systems that have first access to water. Only 25 families own 53 percent of the privately owned land in the modernized Wadi Zabid system in Yemen, and their land is mostly located in the upstream areas of the scheme. Another 31 percent of the total command area belongs to family trusts that are often managed by the large landholding families. Only 33 percent of irrigated land is owned by small scale landholders who often have less than one hectare of land, usually located toward the tail of the scheme where irrigation is less reliable.

Land distribution in Wadi Tuban (Yemen) is less skewed, as only 7 percent of the total command area belongs to landlords with more than 5 ha of land, and 49 percent of the total command area is owned by small scale farmers with less than one hectare. Around 55 percent (Wadi Zabid) and 25 percent (Wadi Tuban) of the households living in the spate-irrigated areas do not own or lease any arable land. These landless households usually earn an income as agricultural labourers. Further examples of the unequal distribution of spate-irrigated land, occurring in Balochistan (Pakistan), are shown in Table 2.4.

TABLE 2.4
Distribution of spate-irrigated land in Balochistan (Pakistan)

Scheme	Percent of land area owned by the 25 percent of landowners with the largest holdings
Nal Dat	75
Chandia	55
Marufzai	48

Data cited in Verheijen (2003)

Inheritance and sales usually lead to landholding fragmentation. Inversely, fragmented land-holdings are sometimes amalgamated or enlarged by marriage, inheritance or the purchase of land with remittances from migrants. Land fragmentation may be advantageous when different parts of the farms are irrigated and cultivated at different times, by spreading labour and management demands. Strategies for land distribution to minimize risk in Pakistan, Tunisia and Eritrea are given in Box 2.1.

BOX 2.1
Spatial distribution of land to minimize risk

To cope with the different probabilities of receiving spate water, it is common in small spate irrigation systems in Pakistan for each household to farm different plots of land, with high and low probabilities of irrigation. For instance, most landowners in the Chandia system have plots in different parts of the command area in order to reduce the risk of not receiving any flood water, as this prevents stratification and friction between upstream and downstream users. A similar strategy existed in central Tunisia, where the command areas were divided into three or four sections and each landowner had a plot of land in each section. In this way, each household had access to spate water even if a small flood did not reach further than the first section of the command area. In the 1980s, however, it was no longer possible to allocate a plot of land to each household in each section as some plots had become very small, less than 0.1 ha, because of rapid population growth. (Van Mazijk, 1988).

Another strategy was followed for a period in Eritrea, where the community reallocated land at regular intervals, so as to equalize the probabilities of receiving spate flows over time. The difficulty with this was that farmers were not prepared to invest time in developing and maintaining canals and field bunds when they were shortly to be moved to other plots.

TENANCY AND SHARECROPPING

Landowners engage tenants or sharecroppers to cultivate their lands if they are too old or too ill to cultivate the land themselves or if they are not resident locally. Larger landlords also hire the services of tenants or sharecroppers when they do not have a sufficient labour force to cultivate the fields themselves. Female landowners, such as divorcees and widows, often find it difficult or impossible to cultivate their fields themselves owing to lack of labour and draught animals, as well as cultural or religious constraints. Some landholders may be "too poor to farm" as they do not own draught animals or have access to a tractor for the preparation and repair of the bunds. Furthermore they cannot afford inputs such as seeds to grow crops themselves. As a result, they are forced to rent out their land to tenants or sharecroppers.

Sharecropping is the most common arrangement in spate irrigation systems, but the contractual arrangements between the landowners and the sharecroppers vary considerably, as shown in the examples listed in Table 2.5.

Hereditary tenancy is very common in Balochistan (Pakistan). In the past, owners of large tracts of land used to give plots of land to other persons to develop. As compensation, the developer became a hereditary tenant. As per the customary law, the hereditary tenant loses his rights if he fails to cultivate the land and to maintain the field bunds. Landowners receive between 18 to 25 percent of the harvested crops as rent for the use of the land. The hereditary tenant is responsible for providing all inputs and labour, including the maintenance and repair of field bunds, canals and diversion structures.

TABLE 2.5
Sharecropping arrangements in some spate irrigation schemes

Location	Sharecropping arrangement
Balochistan, Pakistan	Sharecroppers are entitled to 50 percent of the harvested crop and straw if they provide the bullocks for land preparation and labour for planting, weeding and harvesting. Seeds are provided either by the landlords or by sharecroppers. Sharecroppers are responsible for maintenance of field bunds and, in some cases, reconstruction of diversion structures. In areas where it is difficult to find sharecroppers, landlords may provide substantial loans. In some regions this has evolved to a form of debt-bonding, under which sharecroppers have to work for the same landlord until the loan is repaid, with interest.
Wadi Rima and Wadi Zabid, Yemen	Sharecroppers receive one-third of the total output after they have paid 10 percent of the total output as a religious tax (Zakat) and 5 percent to the canal master. The sharecropper contributes proportionally to agricultural inputs and the maintenance of canals, but has to provide all labour, including payment for any wage labour. If major repair works are required, then the landowner and the sharecropper each pay 50 percent of the costs.
Wadi Tuban, Yemen	The sharecroppers' share is 70–75 percent of the harvest, but they have to provide all inputs, irrigation fees and maintenance costs.

Tenancy is also common in Yemen, where substantial spate-irrigated areas are owned by the State and trusts. In Wadi Zabid, some 5 000 tenants cultivate about 46 percent of the total command area, while 1 266 tenants farm 10 percent of the command area in Wadi Tuban. Annual rents may be paid in cash (US$10 to US$15 per hectare) or in kind (5–10 percent of the crop). In Wadi Tuban and Wadi Zabid, the Government and religious trusts lease land to leading community leaders, who then sublease these lands to tenants and sharecroppers for significantly higher rents.

LIVELIHOOD STRATEGIES

With low crop returns even in good years and the possibility of crop failures always in the background, spate-irrigated agriculture makes a precarious living. Farming households adopt a number of livelihood strategies to cope with these uncertainties. The most common is the diversification of the household economy and households in spate-irrigated areas generally depend on multiple sources of income. The coexistence of livestock keeping and spate irrigation is almost universal. Small ruminants in particular are an integral component of the household production system. Other strategies include saving surplus grains from one year to the next, investing in easily disposable property, such as livestock and draught animals in particular, in good years when there is a crop surplus, and earning additional household income through wage labour and off-farm activities.

In spate communities, failed flood seasons often trigger migration of able-bodied male family members in search of labour. Traditional mechanisms of solidarity and mutual assistance also play an important role in such communities. Money, for example, is borrowed from other family members or local moneylenders after a poor season in order to purchase additional food items or to obtain seeds for the next cropping season.

Strategies for coping with risks are summarized in Box 2.2 and discussed more in detail below. An understanding of these coping strategies is essential when spate improvement projects are being planned, to ensure that the proposed interventions are appropriate and do not have unintended negative impacts on aspects of farmers' incomes that are not directly concerned with the spate-irrigated crop production.

BOX 2.2

Strategies for coping with risks in spate irrigation

To reduce the risks of uncertainties in spate irrigation, farmers have adopted a number of strategies:

- Diversification of the household economy: in addition to a highly variable income from spate-irrigated agriculture, households may also have income from livestock keeping and wage labour and to a lesser extent from the sale of handicraft products.
- Spate-irrigated fields may be redistributed annually among all households with land rights.
- Households may have different plots of land with high and low probabilities of spate irrigation.
- Cultivation of drought-resistant traditional crops, such as sorghum, which produce at least some fodder in dry years.
- Practising crop rotation: fields are left fallow during one season in order to reduce the loss of soil fertility.
- Changing of sowing dates to control the outbreaks of pests and attacks by birds.
- Intercropping, whereby two or three different crops with different water requirements and harvesting dates are planted in the same field, so that at least one crop can be harvested in a dry year.
- Linking crop choice with the timing of the first irrigation.
- Use of groundwater as an alternative source for irrigation.

Livestock

Livestock keeping is an integral component of the livelihood strategies of most households involved in the cultivation of spate-irrigated crops (see Figure 2.1). It contributes to households through the provision of:

- Draught power: oxen, and to a lesser extent camels, are traditionally used for the preparation of the fields and the maintenance of the field bunds as well as the reconstruction of the diversion structures in the watercourse beds and the cleaning of the flood canals.
- Transportation: camels and donkeys are used for the transport of crop produce, drinking water and people.
- Food production: cows, goats, sheep and poultry are raised as a source of food. Milk, dairy products, eggs, meat, wool and skins are the main livestock products, mainly used for home consumption but also sold to raise cash.
- Savings: small ruminants, such as goats and sheep, have high reproductive rates and a high degree of resilience to drought conditions. They are an important form of 'saving' and can be sold in crisis situations. Oxen are also sold to bridge adverse years.
- Energy: cattle (oxen and bullocks), donkeys and camels provide dung, which farm families use as fuel by making dung cakes and as a building material by mixing it with earth and straw.

The ownership of at least one pair of oxen is a good indicator of wealth. In many households it is difficult to support a pair of oxen because the farm size is too small to produce sufficient fodder to feed them in years with normal floods. At times of drought, oxen and other large ruminants are at risk, and many households do not have any choice other than to sell them, or to move them to areas where fodder is available.

FIGURE 2.1
Bullocks in a spate irrigated area, Ethiopia

Owing to increasing farm mechanization, the number of draught animals in spate-irrigated areas, such as areas in Balochistan (Pakistan) and some other spate-irrigated regions, has diminished significantly, which has had consequences for the livelihoods of many households, and the social organization of the spate-irrigated communities. The sale of bullocks has lost its importance as a mechanism to cope with a crop failure or other crisis. The replacement of bullocks by tractors has in some cases undermined the traditional organization of system maintenance, where every household contributed labour and animals for the reconstruction of the diversion structure and cleaning of the canal system. Some statistics on the ownership of livestock in spate-irrigated areas are shown in Table 2.6.

Sharecropping is also practised in the livestock sector, with owners placing animals in the care of others in return for a proportion of the produce. Small ruminants are usually grazed on rangelands, whereas large ruminants are fed with green fodder and crop residue (i.e. straw and stalks) that are collected from the fields.

Most households use their livestock products for home consumption, although some items may be sold locally to raise cash income. In addition to spate-irrigated agriculture and livestock, beekeeping may be another important source of income. Many households in the Shabwah Governorate in Yemen are engaged in beekeeping, which is also an important secondary source of income among households involved in spate-irrigated agriculture in Konso in Ethiopia.

Wage labour and off-farm incomes

Many households in spate-irrigated areas earn an additional income as agricultural labourers or from other off-farm activities. Most households also have to hire additional labour at critical times, such as harvesting, when family labour is insufficient to carry out all the field activities. The pool of wage labourers may comprise members of landless households, households with landholdings that are too small to sustain the household throughout the entire year, as well as landholding households whose fields could not be irrigated during the last flood season. Nomadic tribes and temporary migrants may also move to spate-irrigated areas during harvest time in search of wage labour.

TABLE 2.6
Livestock ownership in spate-irrigated areas

Country	Scheme/Area	Livestock owned by a typical family (there are wide variations within and across schemes)
Eritrea	Sheeb	On average, a typical household has 1.5–2.7 dairy cattle and 1–2 draught animals. About 30 percent of the farmers do not own bullocks.
Ethiopia	Konso	Thirty-one percent of the landowners in the Yandafero scheme have 1 or 2 oxen.
Pakistan	Chandia, Barag, Nal Dat and Marufzai	An average household owns 3–6 sheep, 5–9 goats, 1.5–3.5 cattle and 1–4 chickens. One-third of the farmers in Chandia possess bullocks and a few households in Barag and Nal Dat have a camel.
	Toiwar	Ninety percent of the households have on average 62 small ruminants and 2 cows.
Yemen	Shabwah Governorate	An average household owns 10–20 small ruminants, 5–10 camels and some poultry, whereas a typical household in the central region possesses 20–30 small ruminants and some poultry.
	Wadi Zabid	An average household has 2 cows, 2 calves, 5 goats and 4 sheep, while a minority of households own 2 oxen.
	Wadi Rima	An average household has 1.5 cows, 7.2 sheep, 1.5 donkeys and 6.4 hens, while about a quarter of the households have 2.1 oxen and about 40 percent have 3.4 goats.

Wage labourers are often paid in kind, receiving a fixed portion of the harvested crop. At Nal Dat, in Balochistan (Pakistan) for example, wage labourers receive one-twentieth of the crop for harvesting, while they get one-tenth of the grain with chaff or one-eighth without chaff for threshing *(Halcrow, 1993e and 1998)*. A majority of households in the Chandia spate-irrigated area in Balochistan have one or more household members in the civil service with low-ranking jobs, such as messengers and workers *(Halcrow, 1993b)*. In the Sheeb area in Eritrea, a typical household accrues 25–50 percent of its average annual income from wage labour *(Halcrow, 1997)*.

Wealthier households may also be engaged in business, trade and transport, whereas poorer households in Eritrea, Pakistan and Yemen generate an income from the production and sale of handicraft products, such as pottery, mats, baskets and sandals *(Makin, 1977; Hadera, 2001; and Nawaz, 2003)*.

Migration

Migration may be needed to move livestock to areas where fodder and water can be found and it may take place annually, or in other cases only in dry years. In the Sheeb area in Eritrea, most of the population migrates every year to the highlands during the summer months in search of fodder and water and to escape the hot climate in the lowlands. Only the male members of each household remain behind to divert the floods in July and August and to plant their fields in September. Although this strategy exploits different agro-ecological zones for acquiring water, food and animal feed, important activities, such as the emergency repairs of the irrigation structures, are usually not undertaken at the right time owing to shortage of labour. In addition, the annual costs of the seasonal migration, both in cash and labour, are substantial and could be as high as a quarter of the annual income of a typical household. A second reason for migration is the search for wage labour by male household members.

Normally seasonal migrants return to their communities before the start of the flood or cropping season to assist in the irrigation and the preparation and planting. Small scale landowners, with land that has a low probability of irrigation, migrate each year, as their landholdings cannot support their households throughout the entire year. Other landowners only have to migrate in search of labour in dry years, as their landholdings produce enough in normal years to sustain their households. In the spate-irrigated areas of Dera Ghazi Khan and Balochistan (Pakistan), seasonal migration is common.

Farmers having spate-irrigated land may also decide to migrate permanently if they can find permanent employment elsewhere. In Pakistan, the existing spate irrigation systems often cannot support entire communities. For example, more than half the landholding households in Marufzai have migrated permanently to other spate irrigation systems in the Anambar valley, where they work as casual labourers, or in some cases as bonded tenants *(Halcrow, 1993b and 1993e).*

Migration abroad, often to Saudi Arabia, was very common in spate-irrigated areas in Yemen until the first Gulf war, when most Yemenis were forced to return. In the Shabwah Governorate, up to 25 percent of extended households had a family member working in the Gulf States in 2002 *(KIT, 2002)*.

Depopulation is a general trend in many traditional spate-irrigated areas and a threat to the survival of the systems, as the labour needed to maintain canals cannot be sustained. Ultimately, the remaining farmers may have to abandon the entire spate irrigation system, as has occurred in a number of areas in the Las Bela plains in the South of Balochistan. Migration of adult males and the difficulty in sustaining the traditional systems are cited as one of the justifications for the modernization of the large spate systems located along the Red Sea coastal plain in Yemen.

Credit facilities

Indebtedness is common in spate-irrigated areas as many farmers encounter serious cash deficits during the year, or have to take on debts to survive an adverse year. Friends and relatives are usually the first source of credit. Shopkeepers and traders are another important source as many small scale farmers obtain seeds on credit at the start of the cropping season. The interest charged is often very high, which reflects the risks associated with spate irrigation. In the Chandia system in Pakistan farmers take loans for seeds from shopkeepers at a monthly interest rate of 5–10 percent. Farmers in Barag (Pakistan) purchase seed on credit and pay an 80 percent mark-up. Farmers may also be obliged to sell their produce at low prices to traders, from whom they borrowed money or products *(Halcrow, 1993b and c; Hadera, 2001).*

In the Tihama region in Yemen, the most common form of credit is the traditional system of delayed payment, practised by most merchants, traders and shopkeepers. Interest is not officially charged but different price levels may be negotiated depending on the time delay in payment. Traders in expensive capital equipment, such as tractors and pumps, usually offer credit for up to two years. Shopkeepers and merchants give credit for shorter periods. However, deposits, security and/or a reserve of capital are required for most forms of public and private credit, and this practice precludes poorer farmers from taking advantage of credit for purchase of equipment *(Makin, 1997).*

Farmers in spate irrigation systems rarely have access to formal credit facilities of banks and financial institutions owing to the inherent risks of spate-irrigated agriculture and the low value of the crops that are produced. In Wadi Zabid, Yemen, only large landlords with large holdings have access to credit with subsidized interest rates from the Agriculture Credit Bank, which they mainly use for the installation of tubewells for selling groundwater to smallscale farmers. The latter do not have access to these cheap credit facilities as the bank requires that at least 50 percent of the investment should be self-financed by the farmer *(IIP, 2002).*

Solidarity and mutual assistance mechanisms

Traditional mechanisms of solidarity and mutual assistance exist in the spate-irrigated areas to help people who are in need or struck by a calamity, or during important and expensive social events such as a wedding. However, households facing crop failures cannot rely on mutual assistance when it occurs too frequently, or affects some landowners more than others because of the location of their fields and their access to water.

Among the Tigre population living in the Sheeb area of Eritrea, groups of five to ten farmers work together on a rotation basis, whereby the farmer for whom the labour is performed provides food. Labour and oxen are also mobilized to cultivate the land belonging to widows and very poor households. Mutual self-help groups are spontaneously formed to help during field activities, or the construction of houses.

In Balochistan (Pakistan), it is common that labour and other means of production are shared to a certain extent. Although tractors gradually take over the role of draught animals, bullocks are still lent to poor villagers for a number of days for no rent. Farmers without seeds at the start of the cropping season may ask their more fortunate neighbours to help them out. If a farmer cannot access his field or his field bunds have broken during the flood season, others will come to his aid by either irrigating the field on his behalf or assisting in the repair of the field bund *(Halcrow, 1993 a and e; Van Steenbergen, 1997).*

The prevailing solidarity mechanism in the rural areas of Balochistan is the Islamic duty, *zakat* (charity), to give part of the agricultural produce and livestock as alms to the needy, with preference given to members of the same family or clan. The payment of *zakat* may also be used to finance local religious institutions, such as the mosque or religious school. *Zakat* is either given in cash or kind and the prescribed amount is one-tenth of the harvest of rainfed and spate-irrigated crops, one-twentieth of the harvest of pump-irrigated crops and one-fortieth to one-fifth of the livestock. However, it seems that the actual donations are often less than the prescribed amounts and that not all landowners pay their *zakat* on a regular basis.

Another type of assistance is to allow the poor to pick small amounts of vegetables and melons, or to collect wheat kernels left on the threshing floor, for their home consumption. A less common practice is to give some land in usufruct to a poor relative. Relatives and neighbours offer gifts in cash and kind during special occasions, such as births, weddings and funerals *(Halcrow, 1993 b and e; Halcrow, 1998).*

Basic amenities – drinking water and flood protection

Two issues are of particular relevance to the quality of life in spate irrigation areas: access to drinking water and the risk of flooding. Table 2.7 provides a summary of possible options for improving access to drinking water and addressing flood protection and erosion risks.

TABLE 2.7
Improvements for domestic water and protection against flood and erosion

Improvement	Description	Likely impact	Remarks
	Domestic water improvements		
Improved domestic water ponds	Providing lining of pond; making pond at adequate depth (2.5 m), fencing; sedimentation traps and sand filters	Will increase duration of storage and improve quality of water	Domestic water from ponds may never meet drinking water standards but usually there is no alternative.
Sand dams	Creating an artificial storage by gradually building up a weir and trapping coarse sand behind it	Will provide water supply	
Wells in river beds	Creating conventional wells (dugwells or shallow tubewells) inside river bed or on the river bank	Will provide reliable water supply during dry season	Subject to washout during floods
Including groundwater recharge as an objective in spate water distribution	Spreading water to recharge areas, making use of existing infrastructure or through a system of low guide bunds (Iran)	Will increase the reliability of water supply, especially in dry periods	Extensive experience with flood water spreading in Iran
	Flood and erosion protection measures (see also Chapter 4)		
Village flood protection	Protection bunds to avoid village flooding where agricultural land has risen because of sedimentation	Will avoid loss of residential property and livestock due to uncontrolled irrigation	Important programme in cultivated spate-irrigated areas of the coastal Tihama plains
River bank protection	Vegetative or structural measures	Will prevent river from changing course and causing great damage and will also stabilize intakes of flood channels	In the case of vegetative measures, the protection of trees and shrubs is required.
Dune stabilization	Planting of trees to control tree movements around the command area	Protection of command areas and villages	Care required not to introduce invasive species

Groundwater quality and availability are often an important issue in arid areas. In places, the aquifer is too deep or the quality of groundwater prohibits its use for domestic consumption. In Sheeb in Eritrea for instance, groundwater salinity ranges from 1 200–1 800 µs/cm and in Wadi Labka from 2 250–2 650 µs/cm. Small prisms of fresh water stored in the bed of the spate rivers can be an important source of domestic water supply in areas which have generally saline groundwater and where locally specific recharge measures can be undertaken, such as the construction of artificial aquifers behind check dams on small streams, the use of subsurface dams or low-level recharge weirs, such as those used by farmers in Hadramawt in Yemen, or in some cases the rearrangement of the entire water distribution schedule in order to spread recharge over a larger area.

In addition, improvements may be made in the shape of water ponds for human and livestock use. There are several measures that can improve the services from such ponds, in particular increasing the time they are filled (deepening, silt trapping, using a liner, rationing water) and improving the quality of their water (wells, sand filters, fencing) and the ease of maintenance (introducing steps, controlled inflows – also to reduce sediment intake – and using scraper boards for cleaning out accumulated sediment). These options may secure water supply for a number of months after the flood season and will provide water of low quality, but in many areas there is no alternative.

Progressive elevation of farm land is the result of accumulation of sediments. In some long established systems, the land level has risen above the level of the village itself. This has led to a constant risk of flooding.

GENDER CONSIDERATIONS

Gender issues deserve careful attention for two reasons. First, it is important to understand that no household livelihood improvement strategy can succeed if it does not take women into account and the role they play in the family. Second, it is important to ensure that the proposed improvements in spate irrigation schemes benefit women as well as men and do not modify the balance of power within the household or the burden of work at the expense of women.

Understanding the different roles of women and men and the distribution of tasks within the household is therefore necessary. Women play important roles in spate-irrigated agriculture and in particular in rearing livestock. In poorer households they are often engaged as wage labourers or are involved in producing handicrafts for sale. All domestic tasks are usually the exclusive responsibility of the female household members, including the fetching of potable water and the collection of fuelwood. Women are often members of informal saving groups or other self-help groups at village level. The roles of men and women involved in spate farming vary between regions and cultures. This diversity of situations is illustrated in Table 2.8.

TABLE 2.8
Men's and women's roles in spate-irrigated agriculture

Country	Scheme/Area	Roles of men and women in spate irrigation
Eritrea	Sheeb	Women undertake agricultural activities, such as harvesting, threshing and transport of grains and straw, while men are usually responsible for maintaining and operating the irrigation infrastructure. A number of women are involved in mainly the sale of handicraft products, such as mats and baskets. A few women, usually widows, divorcees or former freedom fighters, run shops. Owing to the policy of the Eritrean Government, women are also active in community affairs, although many men reject these activities outside their houses for cultural reasons. Women have little or no authority over the slaughter or sale of livestock, but are responsible for the distribution of milk and meat to household members as well as the selling of eggs.
Ethiopia	Konso	In periods of drought, when men migrate in search of employment, women are in charge of all agricultural activities, including the maintenance of the stone terraces and irrigation. Women are also involved in petty trade and sale of fuelwood.
Pakistan	Balochistan	Almost all agricultural activities are carried out by women, except the tillage of the land. Women may assist the male members of their households with the supervision of the in-field irrigation and the repair of minor damage to the earthen channels close to their fields during daylight. Animal husbandry is predominantly the domain of women, who are responsible for cutting and transport of fodder, milking goats and cows, preparation of a variety of dairy products and taking care of sick and pregnant animals, as well as the drying of dung for fuel. The grazing and welfare of livestock is the responsibility of men.
	Dera Ghazi Khan	Women have specialized knowledge of the intensity and magnitude of spates and rainfall in their areas, are involved in supervising irrigation, guarding infrastructure, and applying spate water at field level. Men usually carry out the diversion and distribution of spate waters.
Yemen	Shabwah Governorate	Women carry out most crop husbandry activities, including the application of farmyard manure, sowing, weeding, harvesting, threshing and removing of the crop residues from the fields. Men are responsible for the maintenance of the canals and terraces, irrigation, ploughing of the land with tractors, beekeeping and the marketing of crop produce and livestock.
	Wadi Zabid and Wadi Tuban	Men and women undertake most tasks together, including the cleaning of small canals. Generally women are responsible for the more traditional production practices, including spate irrigation, while men specialize in the more modern agricultural practices. Raising livestock is considered to be the responsibility of women and their children. Although women are actively involved in, and often responsible for, most agricultural and livestock activities, the marketing of any produce is exclusively reserved for men.

Table 2.9 proposes a set of questions that help in ensuring that women's needs and priorities are considered in spate improvement projects *(Molden, 2007).*

TABLE 2.9
Checklist of questions on gender and spate irrigation (adapted from *Molden, 2007*)

- How are women's needs expressed and communicated?
- What is the distribution of tasks within the household?
- Do women have recognized access to land and water?
- Are women represented in water users' associations?
- How will proposed improvements affect the distribution of work between women and men?
- How does the project take into account women's need for flexibility?
- How will the project affect and possibly improve domestic and drinking water supply?
- Were women consulted about the location of improved domestic water facilities?
- How will the project and possible changes in cropping patterns affect household food supply and nutritional needs?
- Who is responsible for the livestock? How will the project impact livestock watering? Were women consulted about the location of livestock-watering facilities?
- Are separate financial mechanisms required to take into account specific needs of women?
- Is the importance of backyard gardening recognized and adequately taken into account?
- Have capacity-building components of the project considered specific training for women?

THREATS TO LIVELIHOODS IN SPATE-IRRIGATED AREAS

The livelihood strategies based on the cultivation of spate-irrigated crops in combination with additional incomes from livestock and wage labour are undermined by a number of factors:

- The importance of spate-irrigated agriculture as a source of income for many households diminishes as the average size of their landholdings decreases through further subdivision due to inheritance. At some stage landholdings cannot sustain a family any longer and if no other option is available some members of the family must emigrate.
- Spate irrigation is risky, with a low return on labour. Where options for more reliable income exist, farmers will tend to shift their priorities and abandon their land and this leads to rapid degradation of irrigation infrastructure and the impossibility for the remaining families to maintain the system.
- As more landowners instal their own wells and become less dependent on spate water for the irrigation of their fields, the remaining spate farmers are often unable to mobilize sufficient labour and draught animals for the timely reconstruction of the diversion structure and the cleaning of the flood canals. As a result, the diversion of spate water to their fields becomes more difficult and more landowners have to give up spate-irrigated agriculture. The spate irrigation system thus ceases to function as the capacity to maintain the irrigation infrastructure is no longer available.
- The groundwater table in many spate-irrigated areas is falling rapidly owing to the installation of an increasing number of dugwells and tubewells, as a strategy for coping with risks which allows farmers to become less dependent upon the unpredictable supply of spate water for irrigation purposes. The result is that older and shallower wells dry up, the quality of the groundwater deteriorates and an increasing number of fields are abandoned. Ultimately, the population of entire villages may have no other choice than to migrate permanently as they have lost secure access to potable water and/or arable land.

- Degradation and widening of the river bed may progress to such an extent that farmers are unable to reconstruct diversion structures that are high and/or long enough to divert spate water into their flood canals. Uncontrolled cutting of trees and bushes as well as overgrazing in and along the river bed may accelerate this natural process.
- In some cases, ill-designed modernization interventions in spate irrigation systems, where traditional diversion structures are replaced by a concrete weir, may have a detrimental impact for farmers in the middle and tail sections of the schemes and make it 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.

For any spate irrigation improvement project to be successful, these threats need to be understood, valued and assessed in terms of their possible impact on the success of the project. Proposed improvements must focus on increased and more stable earnings, and on solutions for maintenance of infrastructure (in particular in terms of labour required), to reduce uncertainty related to floods and to improve the environmental sustainability of spate systems. A diagnosis based on the above list should be used as a starting point for the design of spate projects, with an understanding, in specific conditions, of the relative importance of each of these threats and the possible options that a spate project can offer.