# Spate Irrigation in Morocco

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Overview Paper Spate Irrigation

Spate Irrigation Network

## 1. General

In southern and eastern Morocco, on the margins of the desert, surface water is supplied by runoff from the Atlas Mountains, which increases during the Mediterranean-like winter, wanes in early summer, and is generally absent until autumn rain and winter snow return. In these arid and desert-like zones, mean annual rainfall is less than 100 mm, falling mainly from October to April (winter rain). Mean monthly temperatures range from about 15°C in January and February to about 35°C in July and August, but with maximum temperatures often exceeding 45°C during this period. An added hazard during the summer months includes dust storms and strong winds, which make for a hostile and unpleasant working environment. The potential evaporation-transpiration is extremely high (around 2 500 mm per annum).

Crops can be dependably produced only with irrigation. Therefore, many years ago people living there - mainly in southern Atlas basins and oriental highlands crossed by ephemeral rivers called 'OUEDS' with unpredictable floodwater in occurrence and amount - adopted a system of agriculture known as spate irrigation agriculture. Locally known as "FAYD" irrigation, it constitutes the main source of subsistence for many farmers' families in these zones. This ancestral technique was practised for years, and consists of diverting seasonal flood flows from the normally dry river beds, conveying it to nearby cropping fields, or damming it and, consequently, inundating the valley bottom of the floodplain.

One of the essential features of arid zones is the hydraulic civilization unit, where irrigation technology aspects are interdependent in their operation with social structures and the prevalent cultural manifestations. This technical and socio-cultural solidarity is important to mention as it allows understanding changes actually ongoing in these zones.

Communities dependent on spate irrigation have improvised, borrowed, and improved their water management technologies in an effort to expand production or at least maintain and more wisely use existing stores. Areas under spate irrigation are, in most cases, using traditional earthen, stone and brushwood structures for water diversion.

These techniques, which have been used for many centuries, have been sustainable because of judicious adaptation by local farmers who made use of whatever materials they were able to find and who modified these structures repeatedly because of the violent force of the floods that are common in arid areas.

## 2. Extend of spate irrigation in Morocco

Considering available water resources that can affect the development of irrigation, the potential perennial irrigable land is estimated at 1.36 million hectares. This represents almost 15 percent of the estimated 8.7 million hectares that make up the global agricultural land of the country.

Terminology used to define irrigation systems, in Morocco, distinguishes between two main sub-sectors: Large Scale Irrigation (LSI) and Small and Medium Scale Irrigation (SMSI) systems. The latter sub-sector comprises all irrigated lands of small and medium size (from a few hectares up to 4 000 hectares) spread throughout the country.

There are three main categories depending on the type of water resources used for irrigation:

- Perennial irrigation schemes where irrigation is possible throughout the year particularly during summer, using regular water resources (springs, rivers, underground water, etc.).
- Seasonal irrigation schemes where irrigation is practised only during winter, using intermittent springs and river underflows.
- Spate irrigation schemes using flood waters in arid and semi-arid zones.

These last two categories are mostly traditional schemes. Government intervention in the "SMSI" sub-sector distinguishes between the modern system where an integrated approach of management and equipment similar to the one used for Large Scale Irrigation (LSI) systems is applied, and the traditional system where only prompt and diffuse management is practised. Available data shows that spate irrigation schemes are mainly concentrated in arid and semi-arid areas.

There are about 784,090 hectares of Small and

Medium Scale Irrigation (SMSI) (Table 1). About 484,090 hectares are irrigable with perennial water, 135,000 hectares with seasonal water and 165,000 hectares[1] with spate water. For schemes using a non-perennial source of water, some schemes use a combination of spate water and intermittent springs or river underflows, while others use only one type of resource. However, figures are generally available for the combined area under spate and seasonal irrigation and as a result it is difficult to distinguish between these two types of irrigation.

In Morocco, the development of spate irrigation is mainly concentrated in southern and oriental basins. Crossed by a very dense hydrographical system draining the high and low Atlas basins, this part of the country comprises nine main homogeneous units with autonomous hydraulic systems:

- Unit 1: Oriental highlands
- Unit 2: Figuig
- Unit 3: Guir – Bouanane
- Unit 4: Ziz – Rheris
- Unit 5: Maïder
- Unit 6: High and Middle Draa
- Unit 7: Low Draa
- Unit 8: Tiznit – Ifni
- Unit 9: Guelmim: Assaka and costal basins (Bouissafen and Aoreora)

In these zones, water is vital. Populations living there have for centuries developed different techniques adapted to local contexts for the mobilization of water resources. Hence, floodwater was derived using spurs or bunds structures, while groundwater resources were exploited through the development of khettara systems and later on by digging shallow and deep private tubewells.

Hydraulic infrastructures developed by the Government in this area are added to what local farmers have already achieved. The most important are the Hassan Addakhil dam in Ziz valley and Mansour Eddahbi dam on the Draa wadi. These efforts were combined with the rehabilitation, reinforcement or construction of some derivation infrastructures, Khettaras, conveyance canals and pumping plants. However, all the potentialities in these zones are still not yet exploited at their maximal level.

Spate-irrigated area varies according to the hydrology of the year. In 2005, it was estimated at around 83 000 hectares, mainly concentrated in RHERIS basin and GUELMIM lowland. Table 2 shows the irrigated areas under spate irrigation in the nine zones.

Table 1: Irrigable lands in Morocco (in hectares)

| Type of irrigation | LSI Systems | SMSI Systems | Total |
|---|---|---|---|
| Perennial | 880,160 | 484,090 | 1,364,250 |
| Seasonal & Spate | - | 300,000 | 300,000 |
| **Total** | 880,160 | 784,090 | 1,664,250 |

Table 2: Irrigated area under spate irrigation (in hectares)

| | | Irrigated area | |
|---|---|---|---|
| **Hydrologique unit** | **1995 - 1996** | **2000 - 2001** | **2005 - 2006** |
| Oriental Higlands | 2,237.00 | 2,237.00 | 2,237.00 |
| Figuig | 5,000.00 | 5,000.00 | 5,000.00 |
| Guir-Bouanane | 900.00 | 900.00 | 900.00 |
| Ziz-Rheris | 13,500.00 | 13,500.00 | 13,500.00 |
| Maïder | 10,800.00 | 11,090.00 | 12,750.00 |
| High and Middle Draa | 0.00 | 0.00 | 0.00 |
| Low Draa | 6,300.00 | 6,300.00 | 6,300.00 |
| Tiznit-Ifni | 3,635.00 | 3,735.00 | 3,835.00 |
| Guelmim-Assa Zag | 38,415.00 | 38,415.00 | 38,415.00 |
| **Total** | 80,787.00 | 81,177.00 | 82,937.00 |

1) *Many retention dams where constructed since 1987 in the arid areas, mainly Hassan Addakhil dam in Ziz valley and Mansour Eddahbi dam on oued Draa, thus, perimeters which used to be irrigated with spate water are today irrigated with perennial water secured by these newly constructed dams mainly in the Tafilalet region. Therefore, the figure for spate irrigation potential in Morocco should be less than wat is published since 1987.*

### 3. Sources of water for spate irrigation

In Morocco, the most common source of water for spate irrigation is floodwater flows. Still, there is not enough water to satisfy the demand in all villages, some of which, particularly at the tail end of the streams, have been driven to the extreme of building khettaras (Tafilalet), digging tubewells (Guelmim), or using river underflows to augment their water supplies. Many schemes, which used to be irrigated exclusively by spate water, are today using most exclusively groundwater, encouraging in the same way the installation of modern farms producing high value crops with the risk that represents for a sustainable development in these zones.

### 4. Spate irrigation system

#### A. Management

Spate irrigation is mainly on a small scale as most of these areas range between few hectares to 500 hectares. Schemes having medium size are rare (from 500 to 4 000 hectares), and they are concentrated in Guelmim lowlands.

The traditional diversion systems still dominate in Morocco. The primary techniques include deflection spurs or bunds; earthen, stone or brushwood structures; and many small intakes with short canals. In fact, only about 29 000 hectares are actually considered to be modern systems, and these use permanent concrete diversion weirs with sedimentation ponds and single long channels.

Farmers without any assistance from outside agencies traditionally manage spate systems. Usually after modernization, local development agencies provide technical support, and this mainly includes regulating water distribution and assisting with maintenance such as by providing earthmoving machinery (Table 3). Efforts are being made to hand back newly rehabilitated spate systems to farmer organizations.

Awareness among rural women concerning their social and economic circumstances is just beginning to develop, and thus far is present only among the officers of livestock raising cooperatives and members of local associations (contacts with banks and the Professional Dissemination and Organization Division to request information directly, etc.). On the other hand, some cooperatives and associations set up to promote women continue to be directed almost exclusively by men; these men appear to cite, to justify the creation of women's organizations, the decline of activity by women in farming operations following several dry years, as well as unemployment among the few educated women in villages.

In terms of gender participation in spate irrigation activities, women are generally responsible for housework, but they participate in activities such as harvesting and marketing. They are also responsible for many income generating activities to supplement their net annual revenue.

#### B. Water diversion structures

i) Ancestral techniques for flood water harvesting or spate irrigation

In spate irrigation, floodwater is diverted to the fields. The main traditional spate diversion structures include spur type deflectors, bund type diversion or retention dams. An overview of these traditional techniques, described below, shows their ingenuity and their adaptation to mobilize floodwater. The interest in fusible structures consists in their possibilities to protect the command area and spate canals from flood damage as well as the coarse sediments carried by the floods.

***Spur type deflectors***

This is a technique common in other types of irrigation, but it is also practised in spate

Table 3: Spate irrigation systems & responsibilities

| Infrastructure O&M | Traditional Systems (TS) | Improved Infrastructure (II) | Modernized/New Systems (MN) |
|---|---|---|---|
| Farmers (F) | √ | | |
| F + Local Gov (LG) | | | |
| F + Agency (A) | | | |
| F + LG + A | | √ | √ |

irrigation where the following conditions also exist:

- Fairly high river bed slope, ranging from 5 to 10 percent.
- Large and stable river beds in case of ordinary floods.
- Diversion site located at river banks with depth ranging from 3 to 5 metres.

With this technique, part of the river flow is diverted using an earthen channel with a bed level lower than the river bed level. This forces the flow to leave its natural course and conveys it to nearby cropping fields.

Generally, this technique is appreciated because:

- Spate canals are protected from any flood attacks, as the river course is empty of any obstacles.
- During strong floods, which generally carry a lot of sediment, the intake is destroyed avoiding any intrusion of these coarse sediments into the conveyance channel.
- Re-construction of these intake structures after each flood is easy and relatively cost-free.

***Bund type diversions***

This technique is generally used for rivers with the following characteristics:

- A fairly low gradient.
- Well-established river banks.
- An average river width.

It is based on shutting the river course using an earthen bund constructed from local materials without any compaction. The water level is heightened by the presence of the obstacle, which will allow water to be diverted into canals constructed above the river bed level. With this type, diversions are possible from both riversides.

This diversion system is more efficient compared with spur type deflectors. Increase in water level allows more land to be irrigated. In addition, siltation occurring behind the embankment eliminates some of the coarse sediments before the spate water is diverted into the canal. The fusible bund is washed out by strong floods, which eliminates all kinds of deposits.

***Retention Dams***

Flood water flow is dammed, and as a result, it inundates the valley bottom of the floodplain. The water is forced to infiltrate the soil, and the wetted area can be used for agriculture (mainly for cereals such as barley) or for pasture improvement. It is used under the following suitable conditions:

- A large river bed with very low gradient.
- A river bed texture and composition suitable for cereal cultivation.

This technique is usually found in desert areas (Sahara) where floods are less frequent and bring a limited volume of water.

ii) Newly adopted techniques

Traditional methods used by farmers to divert floodwater shows a great efficiency considering their simplicity in conception and materials used. However, they have experienced limitations considering the quantity of floodwater diverted, and the frequent failure of the traditional structures also meant that maintenance was vital if the prospect of diverting the next flood(s) was to be high. The minimum amount of labour, draft animal and materials needed for maintenance could only be made available through strong cooperation among upstream, midstream and downstream farmers.

The replacement of traditional earthen and brushwood diversion structures with gabion, masonry and into some extend concrete ones was at the core of the water management reforms in spate irrigation areas. The overall goal was to bring about a sustainable improvement in the living conditions of the farmers in the upstream, midstream and downstream service areas. The specific targets were to:

- improve the production by increasing the water diversion efficiency and the annually irrigated area; and
- divert large floods in a reliable and regulated manner to augment the possibility of irrigating downstream fields, while minimizing erosion and deposition of coarse sediments in canals and fields.

During the 1980s, the main interventions aimed at improving the traditional diversion structure by constructing a permanent gabion or masonry weirs or bunds and small civil works to reinforce diversions intakes, and construct a classical improved water distribution system. These so- called 'modern' diversion structures have promoted larger inequity in the distribution of irrigation water between upstream and downstream farmers due to the collapse of traditional evolving water rights; and brought complication for conducting crops by constructing permanent structures and digging channels inside the scheme. Examples of modern diversion structures are given in Figure 1.

To overcome these problems more focus was given to the improvement of the structures using a mix of modern and traditional techniques

Figure 1: Examples of modern diversion structures

Barrage Id Mhand

Barrage Id Daoud

in collaboration with farmers. Therefore, the rehabilitation of spate diversion dams aims at:

- facilitating operation and maintenance of hydro-dynamic structures; and
- allowing a better usage of water intake structures.

The annexed structures to the diversion dams comprise:

- settling basin to allow all coarse sediments transported by flood water to settle;
- sediment excluder constructed between the dam and the distribution system;
- rejection spillway;
- reinforced gated or un-gated intakes (single or double); and
- guide walls.

In some cases, flood lamination dams upstream of the diversion structures have been added to reduce the peak water floods to avoid any damage to command areas and reduce the design discharge used for the diversion dam.

## C. Water distribution structures

Villages often have a physically different distribution system for floodwaters, which run through much larger canals than those handling normal or base flows. Because these canals are large, many farmers can take water from them simultaneously. Figure 2 shows some examples of distribution structures in a number of spate irrigation systems in the country.

In the newly-launched projects, by the Government, for the rehabilitation of the existing spate irrigation structures, efforts were made to keep the farmers' distribution priorities. Hence, design of spate distribution structures aimed at ensuring a minimum water level of 20 cm flowing with an average speed of 0.50 m/s to cause an authentic flood in the plots without any erosion in the field.

The floodwater – typically lasting a few hours or a few days – is channelled through a network of primary, and sometimes secondary or even tertiary flood channels. These large canals end with a dissipation structure of triangular form at the upstream part of each irrigation sector. This increases the irrigated area and improves spate water distribution.

Today, there are two primary types of distribution systems that are used in spate irrigation schemes in Morocco:

a. *Distribution without secondary canals*

Spate water is diverted to the fields through triangular dissipation structures placed at the entrance of the scheme. Generally made from gabion, they terminate in a drop structure or a spillway to prevent erosion. They are connected to the main water divider situated immediately after the sedimentation excluder of the main spate canal. This method has the potential to be accepted by farmers for its similarity with the ancestral method and its respect of ancient water rules. It is also easy to implement and requires less investment and maintenance. However, because of its localization, the number of farmers who can benefit from small floods is limited. It also presents a relatively significant danger for soils and risks destruction of distribution systems where there is bad levelling of soils directly situated downstream of the triangular distribution structure. Another weakness of this method is its dependence upon farmers situated nearby the triangular distribution structure for its maintenance and survival.

b. *Distribution with primary and secondary canals*

To maintain existing water rules and cover the maximum area for schemes of medium size, it was necessary to divide the scheme into separate zones. Each zone is dominated by a triangular

Figure 2: Examples of distribution structures in a number of spate irrigation systems

structure for energy dissipation situated at the end of each secondary canal. This triangular structure is made from successive gabion spillways where the last one is designed at the natural ground level. This allows for the distribution of spate water as per the traditional method from the upstream part of the scheme with a good water repartition inside the scheme even for big floods. In addition, the priorities and order of distribution are similar to the ancestral water rules. Also, it is easy to operate the structures and have access to them. Moreover, there are a larger number of beneficiaries covered by this system which, even though the cost is higher, allows for improved maintenance of the system.

### D. Water distribution rules and rights

In contrast with modern LSI systems, spate diversion systems typically concern areas where traditional irrigation methods exist. These areas are smaller, and the local communities have practiced irrigation techniques developed in ancient times and refined over centuries. Therefore, these areas have inherited traditions, local habits, rules and culture, especially with regard to water rights, distribution, and use.

The farmers' communities located upstream generally have a more favorable position especially during weak floods which gives them priority for water right. Management of spate irrigation projects is therefore a very delicate business and requires effective cooperation among all affected farmers' communities. However, in certain regions, because farmers' know-how has been developed throughout the centuries, it has allowed the transformation of initially rudimentary systems into areas with excellent and efficient results in terms of both water usage and equality among users. When a flood occurred, many villages could irrigate simultaneously, but all were limited to a quantity of water proportional to the amount of irrigated land in the village.

This traditional water management system aimed to secure on average two irrigation turns at the earliest time of the flood/irrigation season. The farmers believed that a two-irrigation turn was sufficient to secure cereals production (mainly barley); but three irrigation turns can result in an increased yield. Ultimately, when more floods occur, it also promotes fair flood water sharing within and among the upstream, midstream and downstream irrigated areas. Simultaneous achievement of the above objectives has been a formidable challenge, particularly because the floods, the major source of irrigation water, are unpredictable in timing, volume and duration, and destructive in nature.

Spate water exploitation is in general guided by the community water rights where the priority is given to the upstream farmers. But some exception can be noticed, particularly in Tafilalete plain, where the distribution of spate water between different perimeters was regulated through an agreement made by the concerned farmers. Hence, each perimeter receives part of spate flow from Oued Ziz. All diversion structures have been designed based on this agreement and a consensus exists to avoid any new construction or change at the existing structures. For beneficiaries of the same "seguia" the priority of the upstream part is maintained with some exceptions, during the sowing period, were the irrigation turn restart from where it was interrupted during the last flood. After this period generally lasting three months, the rule is to irrigate only lands that have been already sowed.

However, in many areas, the old division of water rights has largely disappeared. The government has abolished the old priorities favoring upstream villages. Higher up on the river, water is released from the new government reservoirs for a few days each month and sent straight downstream to the last of several new diversion dams built in the river. The last village along the river has the right to the full flow released into the river from the dam. The water is then fed into new primary canals that, in turn, feed a group of old base flow ditches. When that village's time is up, the diversion dam gate serving the village immediately upstream is opened. One by one, the canals closer to the storage reservoir take a turn which lasts for a period scaled to the size of their irrigated areas. This is good news for anyone interested in equitable apportionment: It comes close to ensuring deliveries throughout the system.

## 5. Organizational structure of spate irrigation

Communal development is the main characteristic of spate diversion in general with some exceptions for equipped areas, which receive public support through the Government's regional development agencies.

At the national level, all activities related to spate irrigation are under the control and responsibility of the Directorate for the Development of Agricultural Hydraulic Infrastructures (DAHA), which is under the authority of the Agricultural Administration of the Ministry of Agriculture.

At provincial level, the administration in charge of such activities is the Provincial Directorate of Agriculture (DPA), or in some areas, the regional development agency called ORMVA.

Besides these institutions, under law N° 2-84, related to the Water Users' Association (WUA) promulgated by Dahir N° 1-87-12 of 21 December 1990, local beneficiaries became an essential partner.

Although projects and programmes for the restoration of spate irrigation schemes received recognition in all economical and social development plans, these programmes were limited to emergency intervention. Government intervention in these areas has been limited because of the worry of disturbing local societal traditions and balances.

One of the crucial social aspects for the success of the development strategy for spate irrigation is the involvement/participation of the stakeholders or beneficiaries. All stakeholders must be involved in planning, designing and implementing spate diversion structures, and consensus is necessary for effective operation and maintenance. Involvement of WUAs may also benefit the community for collective action. This new strategy inaugurates a new approach for participatory management:

- To give more responsibilities to beneficiaries in implementation, exploitation and maintenance of irrigation structures.
- To initiate and promote dialogue for concerted action between beneficiaries and administration.
- To improve water use efficiency.
- To allow better usage of irrigation structures for an improved water service.
- To optimize water management costs.
- To permit sustainable rural development.
- To increase sustainability of irrigation equipment.

In some fields, water users have full responsibility for operation and maintenance, while the administration only provides support to farmers toward the accomplishment of their overall objectives and engagements (Table 4).

It has been possible to encourage the creation of farmers' organizations capable of taking responsibility to manage the diversion schemes in the spate season and do minor maintenance work. However, they still need substantial support to make the farmers' associations less dependent on public services, to do more important repair work and make farmers benefit permanently from these diversion schemes. Thus, this process of participatory approach has been accompanied

Table 4: Water users' participation in irrigation water management in SMIS

| Field | | WUA responsibility | Contract |
|---|---|---|---|
| Hydro-agricultural investment | | | Negotiated contract between administration and water users' association |
| | Infrastructure conception | Partial | |
| | Follow up and control of works | Partial | |
| | Finance of structures | Partial | |
| Technical water management services | | | Control and eventual public or private support to water users associations |
| | Programming and organization of irrigation | Full | |
| | Distribution and control | Full | |
| | Maintenance work's programming | Full | |
| | Maintenance and repair | Full | |
| Financial management of irrigation scheme | | | Control and eventual public or private support to water users' associations |
| | Operation budget | Full | |
| | Staff recruitment and payment | Full | |
| | Invoicing to water users | Full | |
| | Supplies | | |

by other measures like training on rehabilitation of spate irrigation structures to improve operation and maintenance of the rehabilitated infrastructures. However, the technical support of the Ministry of Agriculture should not be limited to aspects of rural engineering but it should also be extended to crops management.

## 6. Soil moisture conservation and cropping pattern under spate irrigation

Most farmers are still using the traditional practice of direct sowing. Ploughing after irrigation is the most widely used method. In fact, after the occurrence of the floods, farmers proceed by direct sowing followed by one or two passages with the cover crop. Rarely, farmers will plough the plots and sow them before the irrigation. This practice is locally known as 'taâjajt'. It is very difficult because ploughing is done on dry soil, and large surfaces can only be ploughed with a significant amount of time.

Although trying to use slightly more sophisticated skills, farmers continue to use their ancestral habits in choosing to sow barley or wheat, leading to heterogeneous densities of population in the plots. Hand weeding (without tools) is also common.

Soils in Morocco are generally very weak with a low composition of organic matter, which gives them less cohesion. This characteristic is much more pronounced in arid zones, which make up a large part of the country. Soils in areas under spate irrigation are loamy to silt-clay, regenerating from alluvial deposits caused by river floods used for irrigation over the past centuries. Land tenure is characterized by smallholders (micro-farms). Average farm size is almost 1 hectare divided into 3 plots. About 90 percent of the farmers own less than 5 hectares. Private ownership represents 95 percent of land tenure. The remaining 5 percent are part of religious holdings called 'Habous'.

In spate irrigation, farmers generally adopt a conservative approach which is linked to a strategy to reduce risks (fodder by-products, less vulnerable to water deficit) rather than to maximize the grain yield. With the exception of the still timid adoption of improved varieties of wheat, farmers are mostly using local varieties. The average quantities of seeds used are around one q/ha for barley and wheat, and 0.28 q/ha for maize.

The main farming system under spate irrigation is represented by a combination of cereals: fallow and livestock. Yet, in perimeters using a mixture of seasonal irrigation and spate irrigation, farmers are either cultivating palm trees and cereals (in arid zones) or olive trees and cereals (in semi-arid zones).

Agricultural production is dominated by barley and to a lesser extent by wheat and maize. Its importance depends on rainfall, the number of floods and the state of spate diversion infrastructures. The farmers believe that two to three irrigation turns can secure sufficient cereals production.

Generally, cereals complete their entire growth period (from October-November to February-March) depending upon the soil moisture stored during the flood season. Yields for wheat are around 15 quintals per hectare for a good year when at least two floods occur at the beginning and the end of cropping cycle. If the plants receive only one irrigation turn, yields decrease to reach on average 5 to 10 quintals per hectare.

Table 5 presents average yields and productions realized during the period 1996-2002 which reflect relatively good hydrological years. These productions varied according to the availability of water and the occurrence of floods. It appears from these figures that the recorded yields are low revealing the impact of combined factors related to the production methods explained above.

Table 5: Average yields for crops under spate irrigation

| Crop | Average yield (q/ha) |
|---|---|
| Wheat | 12,0 |
| Barley | 15,0 |
| Maize | 9,0 |

Source: Bouaziz et al.

Apart from spate irrigation all other cultural techniques used are similar to those associated with the practice of cereals in rainfed areas.

## 7. Maintenance of spate irrigation systems

The frequent failure of traditional structures has meant that timely maintenance was vital if the prospect of diverting the next flood(s) was to be high. The farmers' organization has been effective in mobilizing resources, in executing the maintenance work, protecting the rights of downstream farmers and mitigating conflicts. Most of the maintenance intervention on headwork and conveyance channels has been primarily accomplished by mobilizing human labour and draught animals of the farming community.

The modern structures necessitate a different type of maintenance. They do not depend on labour and the collection of brushwood, but instead require earthmoving machinery, such as loaders, bulldozers and trucks, which in turn call for different organizations, managerially, financially and technically. The chances for success are much greater if these machinery units are provided to the beneficiaries by the government authorities.

Between 1991 and 1993, seven earthmoving machinery units for the maintenance and rehabilitation of irrigation schemes were purchased to reinforce operational capacities of regional and local development agencies and maintain spate systems. They were distributed to 8 provinces under the coverage of the following executive agencies:

- ORMVA of Ouarzazate
- ORMVA of Tafilalet
- DPA of Tata
- DPA of Tiznit
- DPA of Al Hoceima
- DPA of Safi
- DPA of Marrakech

Activities achieved by these machinery units concern mainly earthen works for:

- Irrigation scheme protection works
- Cleaning of diversion headworks
- Repair of irrigation schemes' access roads
- Ravine and drains embankment
- Canal digging
- Construction of earth embankments, etc.

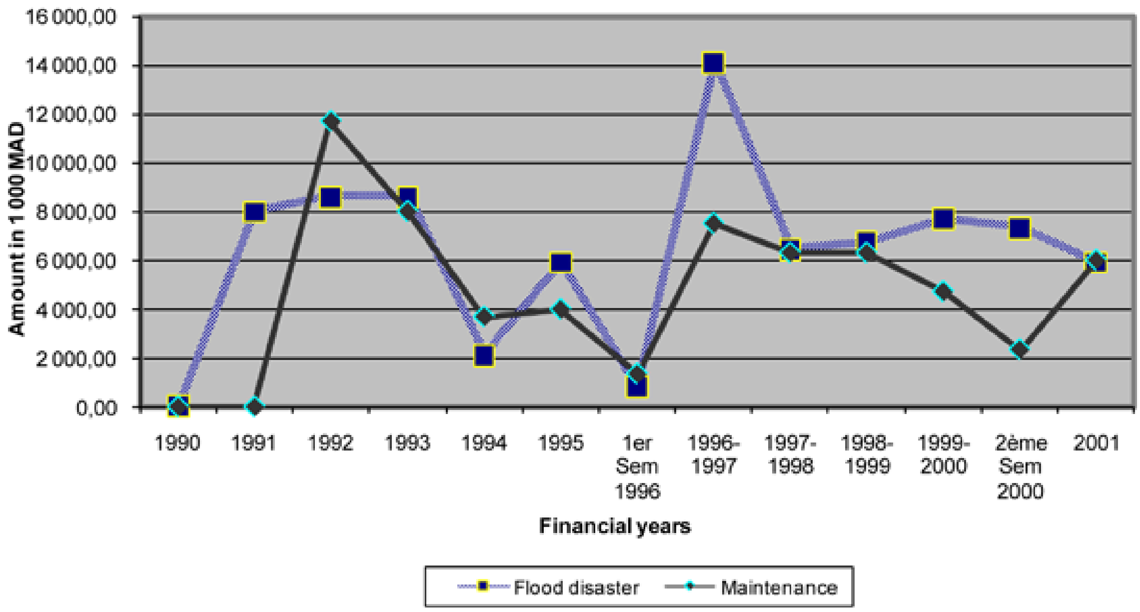
Financial achievements as per the credits allocated to the DPA and ORMVA for the exploitation of the machinery units are presented graphically in Figure 3.

Credits allocated to the maintenance of irrigation schemes are mainly used for the operation of the machinery units in spate irrigation systems. These credits were smaller in the beginning because beneficiaries paid a part of the costs, mainly including fuel expenses. Thus, the evolution curve straightens up as other charges increased for the repair and maintenance of the machines.

## 8. Bank protection and river training

Bank protection and river training are done through a combination of substantial structures and natural vegetation. Controlling river beds through bunds constructed by bulldozers across the river is possible with earthmoving machinery units. They are generally combined with the

Figure 3: Allocated credits for flood disaster & maintenance in SMSI schemes




construction of gabion works (Figure 4)

In these areas, farmers are engaged in another struggle; this time not for water but against sand. To protect their lands from advancing dunes, the villagers lay out on top of an advancing dune what looks like a set of very small corrals, built of palm fronds laced together. The Moroccan authorities call the works ‘quadrillage’ because a dune so stabilized is divided into dozens of squares.

In many cases, newly adopted techniques and technologies for the reform of existing spate irrigation systems are not taking into account the traditional practices of farmers. As a result, farmers appear not to be interested in dealing with operation and maintenance of the structures and newly installed devices (Figure 5).
Large civil engineering investments have been approved for vast areas within public development programmes for spate irrigation. However, even today, most spate irrigation projects are managed and maintained by farmers from the informal economy.

Figure 4: Gabion protection works

Figure 5: Traditional protection works from advancing dunes

## 9. Socio-economic aspects of spate irrigation

### A. Gender participation

In terms of gender participation in spate irrigation activities, women are generally responsible for housework, but they participate in activities such as harvesting and marketing. They are also responsible for many income-generating activities to supplement their net annual revenue (Table 6).

Table 6: Gender participation in spate irrigation

| Activity | Men | Women |
|---|---|---|
| Infrastructure related | √ | |
| Operation (water distribution) | √ | |
| Maintenance | √ | |
| Agricultural Practices | √ | √ |
| Harvesting | √ | √ |
| Marketing | √ | √ |

### B. Cost of development

Available data on spate irrigation projects remain very rare. In addition to the four detailed examples presented below, other figures are provided in the project document for the rehabilitation of spate irrigation schemes in Guelmim province (GCP/MOR/012/ITA) where the total costs for the rehabilitation of schemes Oum Laacher and Talmaadert were respectively around US$ 900 034 (US$ 450/ha) and US$ 442 865 (USS 443/ha). Investment costs per hectare generally range from 440 to 699 US$/ha, according to figures gathered from different sources (Table 7).

Table 7: Incurred costs by projects

| Project name | Type of intervention | Cost (US$/ha) |
|---|---|---|
| Rehabilitation project of Oum Aghanim scheme | Permanent diversion weir<br>Conveyance canals<br>Distribution structures<br>Maintenance | 273.00<br>294.20<br>52.86<br>57.51 |
| Rehabilitation project of Touizgui scheme | Permanent diversion weir<br>Conveyance canal<br>Distribution structures<br>Maintenance | 204.50<br>347.75<br>146.81<br>53.79 |
| Rehabilitation project of Tambardoute scheme | Permanent diversion weir<br>Conveyance canal & distribution structures<br>Maintenance | 424.14<br>204.28<br><br>62.75 |
| Rehabilitation project of Afra scheme | Diversion & protection structures<br>Distribution structures<br>Maintenance | 348.00<br>547.00<br>87.90 |

Table 8: Impact of spate diversion projects on farm incomes

| Project Name | Number of Households | Net Annual Revenues[2] (US$/ household) |
|---|---|---|
| Rehabilitation project of perimeter Touizgui | 200 | 1,209.30 |
| Rehabilitation project of perimeter Oum Lachaar | 412 | 1,345.34 |
| Rehabilitation project of perimeter Talmaadert | 102 | 1,236.76 |

### C. Farm income

In terms of farm income, the following table indicates the net annual revenues from spate irrigation in US$ per household for some of the projects listed above. Villagers used to supplement their income by participating in other income generating activities initiated under newly adopted rehabilitation programmes in these areas (see Table 8).

## 10. Constraints to spate irrigation development in Morocco

Because of its association with low value subsistence crops and high risks, spate irrigation has awoken the limited interest of public authorities and development agencies. Furthermore, for several reasons, most big projects have not reached their anticipated results. Modernization of traditional structures can help to maintain and improve spate diversion systems, but the success of such schemes depends upon the degree of involvement of beneficiaries at the first level and the control of hydrologic specificities of floodwaters in arid zones. Other major problems faced by spate-irrigation farmers include:

- Agricultural production is uncertain because the probable occurrence of floods, their magnitude and frequency are unpredictable.
- Floods are violent and unpredictable in time and amount, and they generally result from heavy storms. There is a risk of large floods washing away canal intakes and head reaches, and a consequent loss of command. Hence, there is an increase in the cost of maintenance because of frequent destruction of the diversion embankments by spates.
- The traditional distribution system also lacks adequate control structures; field-to-field irrigation results in erosion and uneven field elevation because there are no spillways between individual fields thus leading to considerable variability in the depth of water applied.
- Sediments and suspended materials are not easy to predict or estimate. In addition, stability of diversion structures is very weak according to the nature of riverbeds. All these constraints make the construction of permanent diversion structures very difficult.
- There is a lack of adequate provision for operation and maintenance after completion of river improvement works. Manipulation of equipment when floods occur is not possible.

Traditional water technologies may not be able to keep pace with growing demand, but they are usually less expensive to operate and allow farmers and village cooperatives more direct control over the supply and distribution of their water. Newer technologies have been designed to deliver greater quantities of water, and may provide a more reliable source of water that is less susceptible to natural fluctuations in water regimen. But the attitude "out with the old and in with the new" has long been a trend everywhere, and must be as economies develop and populations expand, increasing the need for more water and other resources.

1) *These figures are estimated using data provided in projects' documents for yields improvements and increase in irrigated areas except for Touizgui perimeters where the figure presented is the one mentioned in the project dodument.*

## 11. Conclusions and Recommendations

### Global strategy of integrated watershed management is necessary

The combined result of the above-mentioned constraints is that the present system is inefficient in the use of the available water and still needs more efforts for improvement. On that account, a global strategy of integrated watershed management is necessary to implement structures for laminate floods. Such flood laminating dams will lower the intensity of aggressive and exceptional floods allowing a good usage of spate water and reducing maintenance expenses. If flows could be delivered to farmers in a controlled manner, the volumes diverted and areas irrigated each year could be considerably increased and better use made of the available water.

### Determine accurate hydrological data

Difficulties in designing spate irrigation structures depend on constraints and difficulties related to the unpredictable nature and hydrological regime of rivers in arid areas and the nature of channels conveying rainfall runoff. To conceive spate irrigation structures, one needs accurate hydrological data to be able to estimate the discharge. This is not an easy task when it concerns ephemeral rivers in arid areas, but it is still possible if more attention is directed toward this concern.

### Develop flood-warning systems

It is also necessary to develop flood-warning systems at watersheds and spate irrigation scheme levels to improve spate diversion structure management, contribute to the protection of infrastructures, and command areas against violent and exceptional floods.

### Reinforced rhythm for rehabilitation of spate irrigation schemes

Greater focus should be given to developing an integrated approach for the rehabilitation of spate irrigation systems, where physical interventions are combined with programmes to improve agricultural production, to concentrate development efforts by specificities of each scheme allowing more improvement in the agricultural production and development role played by each system. Introducing relatively simple improvements to the traditional systems includes:

- The provision of permanent structures to divert and regulate spate flows from the main river to replace the existing traditional structures with arrangements for the exclusion of unwanted sediment from the main canals, and to allow the larger destructive floods to pass downstream.
- The provision of permanent offtake or division structures on the main canals replacing the existing traditional structures to divide flows into manageable proportions and to reduce the risk of canal degradation and temporary or permanent loss of command area.
- The provision of secondary and field-level structures to permit greater control within the system, to improve application efficiencies and to make better use of the available water.
- Training of river courses and bank protection to reduce the risk of bank erosion and temporary or permanent loss of command area.

### Combined exploitation of spate and underground water

Spate irrigation tends to reload the aquifer in the land. This advantage can be of great importance in regulating the rainfall fluctuation in countries like Morocco where long periods of drought occurs. If there are sources of underground water that are not very deep, spate irrigation should be combined with the exploitation of underground water through pumps.

### Participatory approach involving water users

Conception of spate diversion structures and water distribution devices inside spate irrigation schemes jointly with established maintenance actions can only be solved through a participatory approach involving water users. For spate systems, what is important is not necessarily determining irrigation water demand but the necessity of directing maximum flood water, when floods occur, using the most adaptable and acceptable techniques by farmers. Adhesion of farmers should be chased up from the first steps of the elaboration of spate system projects. This will allow the engineer to design equipment that beneficiaries can easily use and maintain. Modalities for this participation need further investigation, and the establishment of a suitable and adapted context in which discussions and negotiations can take place between government technical services and farmers on a sustainable basis.

### Training of Beneficiaries

Specificities of newly adopted techniques made the training of farmers of prime importance consistent with the expectation to hand back these systems to water users associations. It is therefore important:

- to conduct training for farmers on exploitation and maintenance of spate diversion structures and management activities for their associations; and
- to conduct training on methods of riverbank protection in lowland areas, etc.

### Earthmoving machinery units for the maintenance of spate irrigation schemes

Most of these machines have deteriorated and the cost for repair and maintenance is quite prohibitive. However, despite the inefficiency of their management, they have played a key role in maintaining spate irrigation systems and allowing many farmers to irrigate their land. It is therefore crucial:

- to initiate a discussion for the maintenance of newly rehabilitated schemes and the possibilities for repair and renovation of earthmoving machinery; and
- to revise the process and modalities for management and utilization of these units aimed at improving and optimizing their usage taking into account past experiences and prioritizing the participation of beneficiaries.

### Agronomic and soil conservation practices

In terms of agronomic practices, projects and studies even if limited in time and space show that, in arid and semi-arid areas under spate irrigation, choices for tools, agronomic and soil conservation itineraries, allow the optimization of water use efficiency. Therefore, knowledge of all the techniques involved in the spate-irrigation system is essential. It is also necessary to extend these works to different agro-climatic situations, develop appropriate technological packages and ensure their transfer to farmers. More attention should be given:

- to increase and improve actions for monitoring and evaluation of spate schemes exploitation and management; and
- to initiate research and development programmes for agricultural production and cultivation techniques used in spate irrigation systems.

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Spate Irrigation in Morocco

Overview Paper #6

## Colofon

This Overview Paper is prepared by Ismail Oudra, Water Resources and Irrigation Specialist.

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The Spate Irrigation Network supports and promotes appropriate programmes and policies in spate irrigation, exchanges information on the improvement of livelihoods through a range of interventions, assists in educational development and supports in the implementation and start-up of projects in spate irrigation.

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