

Better economics: supporting climate change adaptation with stakeholder analysis

A case study of Morocco



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with stakeholder analysis: a case study of Morocco**

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Acronyms

| | |
|--------|--|
| CBA | Cost-benefit analysis |
| CC | Climate change |
| DPA | Direction Provinciale de l'agriculture |
| GCM | General circulation models |
| GMP | Green Morocco Plan |
| MAD | Moroccan Dinars |
| NEO | National Electricity Office |
| NMD | Network Management District |
| ORMVA | Office Régional de Mise en valeur Agricole |
| ORMVAT | Regional Office of Agricultural Development in Tadla |
| RRA | Rapid rural appraisal |
| WUE | Water use efficiency |

Abstract

Morocco is one of the countries most threatened by climate change. These changes will have a negative impact on key sectors of its national economy, namely water and agriculture. Projections predict that the water available for agriculture will decrease by 16 per cent by 2030 and 34 per cent by 2050. The main strategy for adaptation to this change is the conversion from surface, or flood, irrigation to drip irrigation. Morocco has initiated an ambitious program to convert 550 000 hectares to this more efficient irrigation system. Stakeholders will be affected in different ways by this project but until now, no stakeholder-focused cost-benefit analysis has been conducted. The objective of this study is to address the economics of adapting to climate change in the irrigation water sector in Morocco, using the CBA-focused, multi-stakeholder approach to water sector adaptation developed by IIED. This method combines cost-benefit analysis (CBA) with a more participatory stakeholder analysis in order to support effective decision making by identifying cross-sector benefits, highlighting areas of mutual interest among different stakeholders and more effectively assessing impacts on adaptive capacity. All stakeholders agreed that conversion from flood irrigation to drip irrigation system is the only solution to the irrigation water deficit partly caused by the observed climate changes. The stakeholder analysis identified that all the primary stakeholders of the adaptation project were also experiencing non-monetary welfare gains, as is commonly observed in adaptation projects that aim to build adaptive capacity. Some groups of private and public stakeholders favoured these non-monetary gains over the monetary ones, with small-scale farmers the most reliant on the non-monetary benefits of adaptation. The majority of farmers were not aware of the non-monetary benefits of the drip irrigation system. The Regional Office of Agricultural Development in Tadla (ORMVAT) appreciated this new approach and confirmed that the results of the project will help to convince farmers who have not yet signed up to this project.

Keywords: Climate change; adaptation, water; stakeholder; Morocco

1. Introduction

The Mediterranean is among the areas most threatened by climate change (CC), with water availability likely to reduce by 10 to 30 per cent and agricultural production decrease by 10 to 20 per cent by 2070-90 (World Bank, 2009). For Morocco, CC projections foresee a rise in temperature, decreased rainfall and increased rainfall variability. The average temperature could rise by 1.1°C-1.6°C by 2030, by 2.3°C-2.9°C by 2050 and by 3.2°C-4.1°C by 2080. Rainfall may decrease by 14 per cent by 2020, by 13 to 30 per cent by 2050, and by 21 to 36 per cent by 2080 (World Bank, 2009).

These changes will have a negative impact on key sectors of the national economy, namely water and agriculture. Impact studies of climate change on Moroccan agriculture expect a decrease in the availability of water for irrigation and a decrease in agricultural productivity, especially for rain-fed crops, such as barley, durum wheat and olives. This will negatively affect the income of the rural population, especially small-scale farmers.

In this context, the new Green Morocco Plan (GMP) was developed in order to make the agricultural sector the main engine of economic growth and national development during the next 10 to 15 years. The water situation has been particularly analysed in light of the new strategy because of its scarcity and its vulnerability to climate change. The irrigation rate is still among the lowest in the region, water losses are high, and water productivity per hectare is still relatively low. There are still only limited incentives for the efficient management and conservation of water and the price of water for irrigation does not reflect its scarcity. The only potential safeguard of the sustainability of investments, including investment in irrigation, is the conversion of irrigation systems from surface irrigation (furrow) to drip irrigation. That is why the state has initiated an ambitious program to convert 550 000 ha to efficient drip irrigation systems. Of these, 217 940 ha will be through collective conversion and 332 060 ha through individual conversion. The total cost of the programme is estimated at US\$ 4.35 billion.

The irrigated perimeter of Tadla, one of the seven perimeters covered by this programme, is the most affected by CC. This perimeter is located in a semi-arid region and the irrigated area is about 140 000ha. Water resources in this region are becoming increasingly scarce and there is little potential for mobilising new ones. Rainfall has reduced on average by about 4.7mm per year and the annual rainfall variability is becoming very high. The coefficient of variation increased from 27 per cent during the period 1970-80 to 36 per cent in the period 1981-2003. During the latter period, average annual rainfall decreased by about 100mm.

The main strategy for adaptation to CC in this region is the conversion from surface irrigation to drip irrigation. In the Tadla perimeter, collective and individual conversion programs cover 49,040ha and 39,700ha respectively. The first part of the collective program covers 10,000ha and will benefit farmers belonging to four water use associations. The cost of this operation is estimated to be US\$ 8235 per hectare.

Stakeholders will be affected in different ways by this project. Until now, there has been no stakeholder-focused cost-benefit analysis nor any studies into the actual costs and benefits of adaptation accruing to different stakeholders. The objective of this study is to address the economics of adapting to climate change in the irrigation water sector in Morocco, using the CBA-focused, multi-stakeholder approach to water sector adaptation developed by IIED.

The first section of this study summarises climate change in Morocco and its impact on the water sector. The second section describes the study area and the third presents the methodology used. The fourth section analyses the financial feasibility of conversion to drip irrigation. Finally the study gives a contingent ranking-based stakeholder analysis of the project.

2. Climate change and the water sector in Morocco

2.1 Climate change in Morocco

Since the 1960s, average annual temperatures in Morocco have increased by 0.16°C per decade, while the number of cold days (those with a maximum temperature below 15°C) have significantly decreased. As in all arid region of the world, Morocco is characterised by extremely variable rainfall. The coefficient of variation of annual precipitation ranges from 25 per cent in areas near the Atlantic and more than 100 per cent in the Sahara. Despite this variability, there has been a general decrease in rainfall at the national level, the rains during spring have fallen over 40 per cent and the maximum duration of dry periods over 15 days has increased since the 1960s. In addition, monthly rainfall in Oum er Rbia and the Tensift basin has declined since the 1960s. According to De Martonne's index of aridity, five of Morocco's 13 weather stations became more arid between 1961-1985 and 1986-2000 (World Bank, 2010).

Climate projections on Morocco show gradually increasing aridity because of reduced rainfall and higher temperatures (World Bank, 2009). According to forecasts, the warming trend should continue in Morocco. On the basis of a set of 22 general circulation models (GCM) from the fourth assessment report of IPCC (IPCC, 2007) published recently, studies predict a decrease in winter rains of 20 to 40 per cent over much of the country by the end of the century, while the mean annual temperature will increase by 4°C in interior areas and 2°C on the coast (World Bank, 2010). It is necessary to keep in mind that climate models predict averages rather than extreme values. This means that if aridity increases on average, as predicted, there could still be certain years that will be very rainy.

Increased aridity will have negative effects on agricultural yields, especially from 2030 onwards. Not all crops will be equally vulnerable to climate change; rain-fed crops (non-irrigated) will be particularly affected. If irrigation water continues to be available in sufficient quantities, irrigated crop yields will continue to increase in spite of climate change. It is suggested that the increase in temperature, coupled with sufficient irrigation water, will further the growth of cultivated plants and thus increase harvests of most crops. In the event of increased aridity of the Moroccan climate, however, there is no certainty over whether irrigation water will still be available. Generally speaking, agricultural yields are predicted to remain more or less stable up to 2030, and then drop rather quickly beyond this date. Not all the agro-ecological zones will not be affected in the same way by climate change. The *Favourable* and *Intermediate* agro-ecological zones will be most vulnerable to climate change.

This World Bank (2009) points out that technology trends (agricultural yield improvements in arid and semi-arid conditions), irrigation (water management at the level of agricultural plot, catchment area and region) and land use according to its agricultural function are significant for adapting to climate change.

2.2 The water sector in Morocco

Irrigation plays major role in Moroccan food production. Irrigated zones cover 13 per cent of the total agricultural land and contribute 45 per cent of the agricultural added value in a normal year.

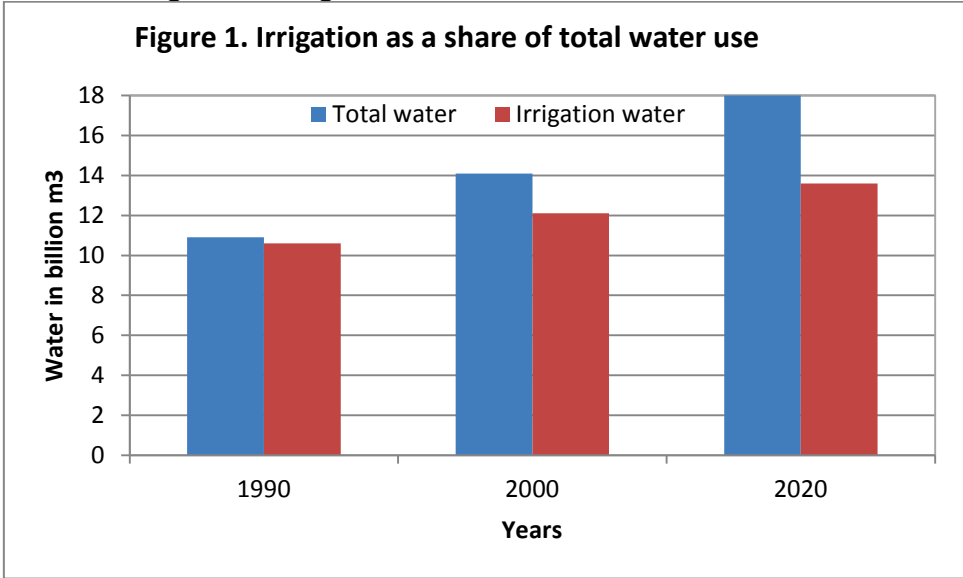
Morocco receives an average of 150 billions of cubic metres of water per year. The volume of "useful or efficient" rain is estimated at 30 billion m³ of which 22 billion m³ are mobilised in the present technical and economic conditions (18 billion m³ of surface water and 4 billion m³ of underground water). This quantity is equivalent to 730 m³ of water *per capita* per year.

Surface water resources are concentrated in the Atlantic zone (73 per cent), especially in the Sebou and Oum-Erbia basins. The Mediterranean zone (Rif) has 11 per cent of the country's hydraulic potential but agriculture is limited there because of its poor soil resources. The

South and the Oriental zones receive only 16 per cent of potential surface water (DPG, 2010).

The agricultural sector uses most of the mobilised water but its share has been decreasing over the years. In 1990, irrigation accounted for 97 per cent of water use; in 2000 the share was only 86 per cent and less than 85 per cent in 2006. By 2020, agriculture is predicted to use only around 69 per cent of the total (Agoumi and Debbarh, 2006).

Figure 1. Irrigation as a share of total water use



Source: Agoumi and Debbarh 2006. *Ressources En Eau Et Bassins Versants Du Maroc : 50 Ans De Développement (1955-2005)*

To support its development, Morocco has long been committed to controlling and mobilising its water resources with the adoption of integrated management of water resources. This policy has enabled Morocco to construct significant amounts of water infrastructure, consisting of 130 large dams with a total capacity of about 17 billion m³ and thousands of boreholes and wells to control groundwater resources. These facilities have supplied people with drinking water and enabled the development of large-scale irrigation (about 1.5 million hectares).

In Morocco, water control investments continue to account for the largest share of investments. A large-scale irrigation system under the authority of the Office Régional de Mise en valeur Agricole (ORMVA) covers nine regions and 880,160 hectares, with potential to expand to 1,260,000ha. Medium and small-scale irrigation systems cover 484,090ha and are controlled by the Direction Provinciale de l’agriculture (DPA).

Since 1965, state-funded irrigation has included both water supply to farms as well as on-farm operations. The *Code des Investissements Agricoles*, or Farm Investment Bill set the farmers’ contribution to irrigation in 1969. Farmers pay 40 per cent of equipment costs, a direct participation fee proportional to the area irrigated and annual fees for water use. Direct participation is a fixed cost paid back to the government at a subsidised interest rate, after the fourth year, for farmers owning more than 20 hectares. Farmers with five hectares or less pay no participation costs, and producers with less than 20 hectares are not charged for the first five hectares. Given the fact that only 2-10 per cent of farmers have more than 20 hectares, and that the participation does not apply in Ouerzazate and Tafilalet, the state bears a large part of participation costs.

2.3 Impact of climate change on the water sector in Morocco

On average, even without climate change, increased urban demand will cause a decrease in the amount of water provided by dams for agricultural purposes. Projections show a decrease of 2 per cent of water for agriculture in 2030, and 5 per cent in 2050 due to increased urban demand alone. Climate change will cause a larger decrease of water for agriculture: using the median of the 22 climate models (GCM), the decrease would be 16 per cent by 2030 and 34 per cent in 2050. The effect will vary from one basin to another. The basin of Oum Rabia, which already suffers shortages of surface water, should be particularly affected because of the large proportion of urban needs to total demand. An integrated approach that addresses the water supply to major cities such as Casablanca is needed to manage the impact of climate change on water availability for agriculture.

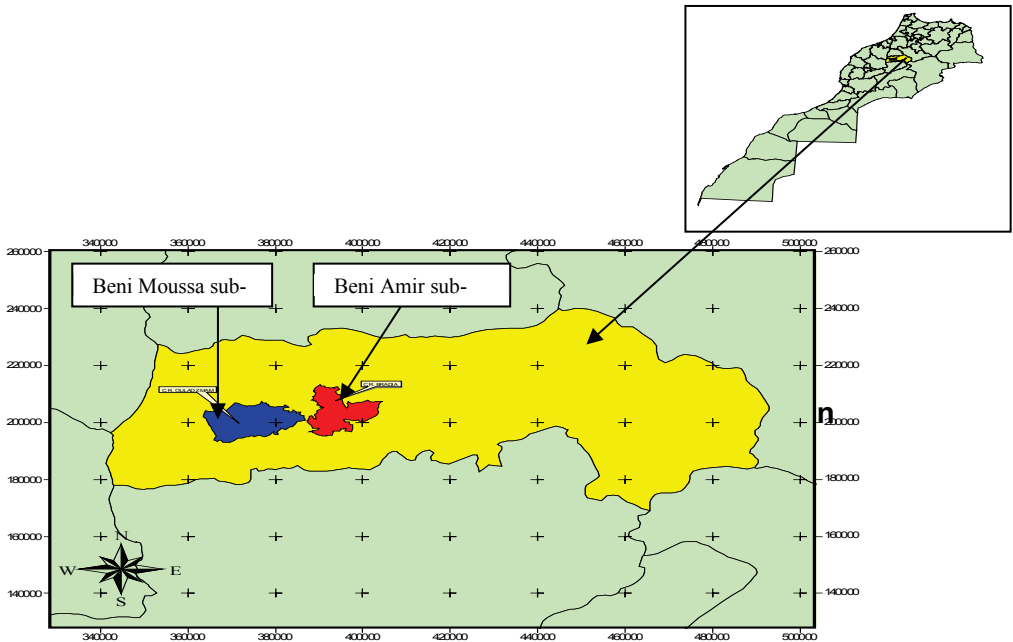
The same tendency is observed for groundwater. Many aquifers in Morocco have registered a substantial decrease in their water reserves. A recent FAO study (FAO, 2008) estimated that current use of groundwater would need to be reduced by 28 per cent to reach sustainable levels.

To cope with the increasing scarcity of water resources the government adopted an ambitious national programme for water saving in irrigation (PNEEI) as part of the transverse component of the Green Morocco Plan. The programme is part of a water-saving strategy and concerns the conversion of 550,000 hectares to the more efficient drip irrigation. Of this, 217,940ha would be collective conversion and 332,060ha through individual conversion. The collective conversion program concerns seven irrigated perimeters and the cost of external drip irrigation networks is estimated at 10.9 billion Moroccan dinars MAD(US\$1.29 billion).

3. Characteristics of the irrigated perimeter of Tadla

Tadla, one of the seven perimeters included in this programme, is the one most affected by CC. This perimeter is located in the Middle Atlas of Morocco 200 kilometres southeast of Casablanca at an altitude of 400 metres. It is bordered by Khouribga plateau to the north, Oued Zem plateau to the east, the river Oued El Abid to the west and the Atlas Mountains to the south (Figure 2).

Figure 2. Map of the region



The perimeter is a monotonous large plain of 325,095ha with an arable area of 259,600ha. The source of water is the Oum Rabia river and its tributaries Oued Srou and Oued El Abid. The perimeter is divided into two zones.

1. A rain-fed zone called the “bour” with an area of 133,600ha which contains arable land but also forest, pasture and non-productive areas. Although it is mainly rain-fed, some farmers have access to small and medium-scale irrigation.
2. A large-scale irrigation zone with an area of 98,300ha divided into two sub-zones separated by Oum Rabia river.
 - The Beni Moussa sub-zone in the west with an area of 69,500ha which is fully irrigated from the Bin El Ouidane dam that was built on Oued El Abid river. This large sub-zone is called Beni Moussa-East and West.
 - The Beni Amir sub-zone in the east with an area of 27,500ha. The water source was the Oum Rabia river but since 2001-02, it has been the Ahmed El Hansali dam built on this river.

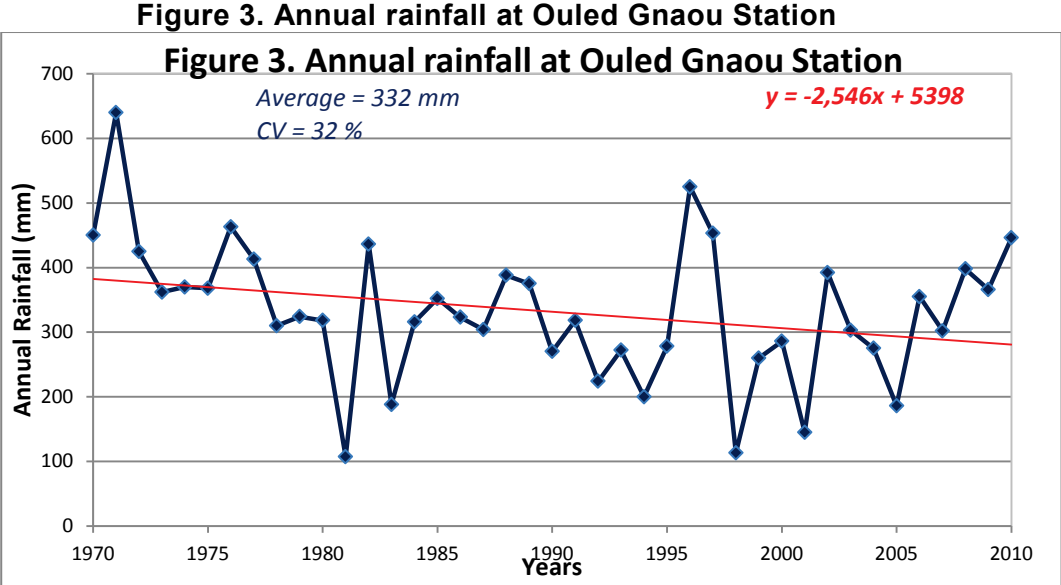
The dominant crops in the perimeter are cereals. In the bour (rain-fed area), cereals cover 51 per cent of the cultivated area and in the irrigated areas the main crops are cereals (19 per cent), sugar beet (5.7 per cent), vegetables (3.5 per cent), citrus (3.4 per cent), olive trees (7 per cent) and forage crops (10.4 per cent).

3.1 Climate characteristics of Tadla region

The climatic data used in the following analysis came from Ouled Gnaou weather station which is the main weather station in the Tadla area. It contains a set of complete climatic information for the period 1970-2010 that allows a deep analysis of general weather conditions and variability in the region.

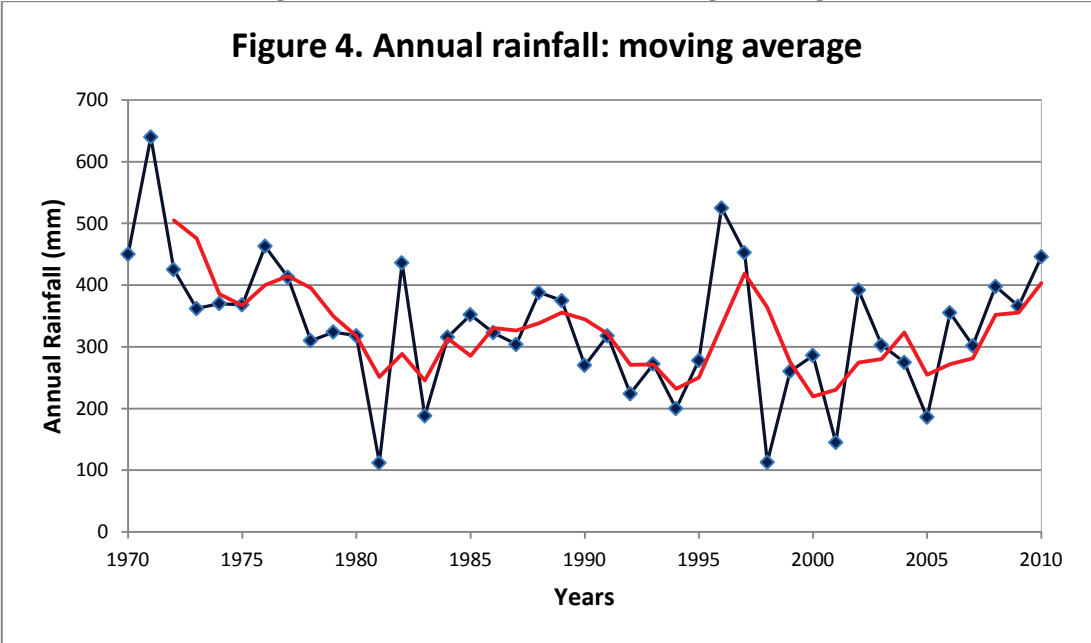
3.1.1 Rainfall variability

Rainfall analysis (Figure 3) shows that, the amount of annual rainfall in Ouled Gnaou is variable from year to year. There is no cyclic phenomenon; some years are wet and others are relatively dry. The less rainy years have become more frequent over the last 20 years. In general, the amount of annual rainfall has tended to decrease. From 1970 to 2010, the average rainfall reduction has been about 2.5mm a year. The annual rainfall variability is very high with a coefficient of variation of 32 per cent. For the period covered, the highest amount of rainfall (640 mm) was received in 1971 and the lowest (107 mm) was in 1981.



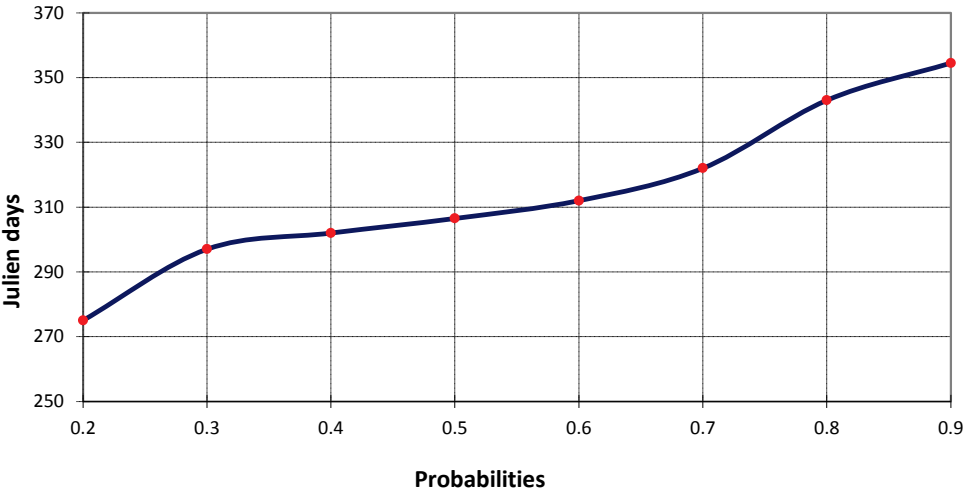
The moving average in Figure 4 shows a big change in the rainfall regime at Ouled Gnaou station since 1981. From 1981 to 2010, annual rainfall decreased, on average, by about 100mm. The average annual rainfall changed from 403mm in 1970-80 to just 305mm in 1981-2010. At the same time, variability increased; it was 23 per cent in 1970-80 and 33 per cent in 1981-2010.

Figure 4. Annual rainfall: moving average



In the Ouled Gnaou region, the probability of receiving the first significant rains in November is about 70 per cent (Figure 5). Since this station is located in an irrigated area, farmers can start sowing on November 1 which corresponds to the median (50 per cent probability).

Figure 5. Probability of first significant rainfall



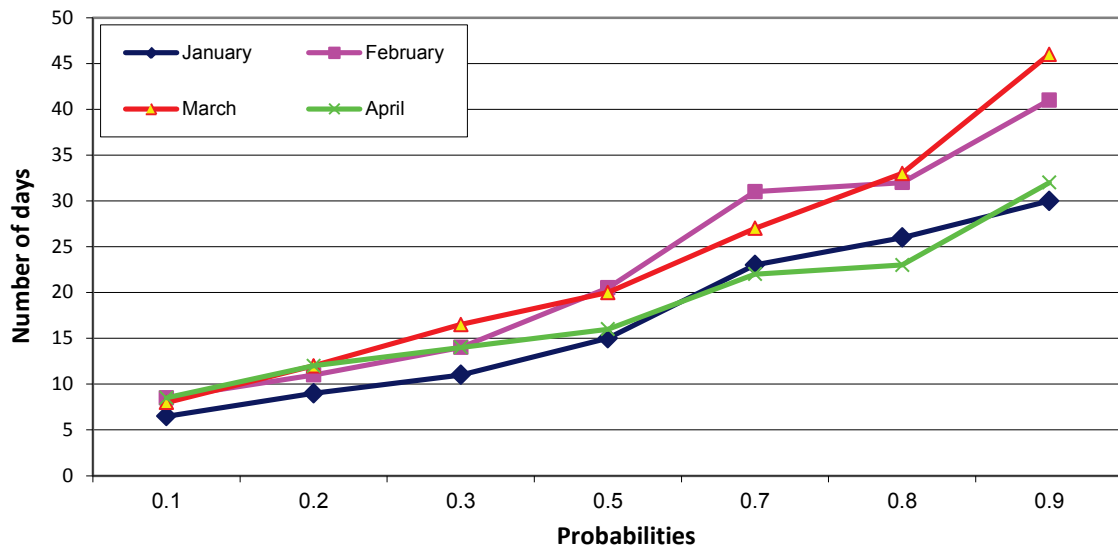
3.1.2 Risks of dry periods

Knowing the risks of dry periods is an important element for crop and water management in irrigated zones. The analysis of the risks of dry periods at Ouled Gnaou station, calculated

from daily rainfall records from 1970 to 2010, shows that October is the most risky month. In spite of a few fluctuations over time, November and December are the least risky and the most stable. In this regard, it is desirable to get crops established in early November; it is to be avoided in October.

The risk of having long dry periods towards the end of the growing season at Ouled Gnaou station is high during February and March but lower in April and January (Figure 16). Consequently, it is recommended to irrigate between February and March.

Figure 6. Length of drought periods at the end of season



3.2 Water resources

3.2.1 Surface water

The main river in Tadla, Oum Rabia, originates in the calcareous high plateaus of the Middle Atlas. The annual average flow of this river is 35 cubic metres per second with a maximum of 1700m³/sec and a minimum of 8m³/sec. Its most important tributary is Oued El Abid which has an average flow of 32 m³/sec.

There are two dams in the irrigated perimeter of Tadla: the Ahmed El Hansali dam built in 2001 on Oum Rabia River, which has a total capacity of 740 million m³ of water, and the Bin El Ouidane dam built in 1954 on the west of Oued El Abid River which has a total capacity of 1500 million m³.

A continuing decrease in precipitation has significantly affected the water levels in the dams. The amount of water available no longer reaches half of their storage capacity.

The irrigation and drainage network consist of:

- 200km of main canals
- 630km of primary and secondary canals
- 1800km of tertiary canals
- 427km of collectors
- 416km of drains.

3.2.2 Ground water

Ground water resources are composed of two aquifers: the unconfined upper aquifer and the deeper confined aquifer. The evolution of the level of water table is monitored in piezometric stations at ORMVAT and the Agency of Oum Rabia basin. The water level is continuously decreasing because of pumping of water from wells and the low rainfall. In 1987-93, and to a lesser extent in 1997-99, there was a significant rise in the level of the water table especially in the Beni Moussa region. This recharge was due to high rainfall and infiltration. This latter was due to bad irrigation management.

3.2.3 Water distribution

Irrigation is programmed based mainly on the amount of water stored in dams at the beginning of the growing season and on the estimation of applications needed considering rainfall. The total amount of water allocated to ORMVAT is fixed by the Oum Rabia basin agency at the beginning of the season.

ORMVAT, through its Department of Irrigation and Drainage Management, is in charge of the organisation of irrigation water distribution. The modes of distribution of water differ from one region to another. In Beni Amir, the distribution is based on the area (hectares) and in Beni Moussa, it is based on the importance of the crop (sugar beet, alfalfa). These modes pose two problems.

- There are difficulties adjusting between what the crops require and the way the water supply system works. This is because of the rigidity of the distribution system in relation to the new approach of having the freedom to choose crops.
- The amount of water available at the beginning of the cropping season is not a good criterion.

The system covers 27,000 farmers and an irrigation network of 3000km. The programme of water distribution is composed of a certain number of water turns (rotations) among farmers for each growing season. The programme is then sent to the Network Management District (NMD) for implementation.

The irrigation calendar is based on:

- Which crops need to be irrigated.
- The irrigation schedule for each crop taking into account the irrigation flow:
 - For sugar beet: 8 hours per hectare if the flow is 30 litres per second or 12 hr/ha if the flow is 20 l/s (= one full allowance).
 - For fruit trees: 4 hr/ha if the flow is 30 l/s or 6 hr/ha if the flow is 20 l/s (one half allowance).

Each water turn runs in general week. It handles an irrigation block of 25 to 40 hectares and it is distributed among farmers taking into consideration their planned crops or their farm size depending on the region.

Each week, farmers have to present their water demands to the *aiguadier*, a person who is in charge of collecting all the demands. Each *aiguadier* is responsible for 400 to 1000 farmers, and determines the duration of irrigation, based on cropped areas. The *aiguadier* also measures the flows in the tertiary and secondary canals taking into account water requirements per block.

The Center for Network Management synthesises all the demands formulated by the *aiguadiers* and then sends them to the NMD for a possible water release, which is under the control of NEO (National Electricity Office).

Copies of the irrigation programmes are sent to the water distribution agents and the water-gate guards who are in charge of executing it. The distribution agent regulates the flow in the secondary network and the water-gate guard the tertiary one. Degradation and poor conditions of the irrigation network can cause disruption of the water distribution operation, which makes the farmers unhappy, especially the ones at the downstream side of the network.

4. Methodology

This study uses the CBA-focused, multi-stakeholder approach to water sector adaptation developed by IIED. This method combines cost-benefit analysis (CBA) with a more participatory stakeholder analysis in order to support effective decision making by identifying cross-sector benefits, highlighting areas of mutual interest among different stakeholders and more effectively assessing the impact on adaptive capacity.

4.1 Data collection

In order to address the project objectives we used two methodologies to collect the necessary data: structured interviews for the quantitative cost-benefit analysis and rapid rural appraisal (RRA) for stakeholder analysis.

The data for the quantitative cost-benefit analysis was collected during November 2011. These data concern the costs of establishing a drip irrigation network, the water use for drip irrigation technology at farm level and the yields for different crops under drip irrigation. Altogether, fifty farmers were randomly selected but strata importance was considered in the distribution of the cases. The main criterion for selecting these farmers was the use of drip irrigation technology. The sampling framework was developed in collaboration with the Regional Office of Agricultural Development in Tadla (ORMVAT) extension services.

To carry out the stakeholder analysis, we identified four categories of stakeholders.

- 1. Private sector:** This group is mainly represented by drip irrigation companies.
- 2. Public sector:** This category is represented by two individual government agencies, ORMVAT and the Water Basin Agency.
- 3. Households:** This group represents essentially farmers and agricultural workers.
- 4. Environment:** The interests of the environment were represented by the research unit on environment and agricultural resources valorization at Beni Mellal University.

Altogether, 36 subjects were interviewed during the field study: 4 members of the ORMVAT directorate, 2 representatives from the Water Basin Agency, 3 members of the Water Federation in Tadla (representing water use associations), 5 agricultural workers (including 3 women), 8 farmers under individual conversion, 10 farmers under collective conversion, 2 irrigation companies and 2 professors from the research unit.

Interviews were carried out in Arabic. Interviews were not recorded due to their informal nature and at the request of the interviewees. Interviews were conducted separately with different stakeholders using pre-prepared guidelines. We took care to include all sub-stakeholder groups including small, medium and large-scale farmers participating in both individual and collective conversion. This was to make sure that all interests are included, as each sub-stakeholder groups may have different incentives for adaptation.

The sample of farmers consists of 3 small, 3 medium and 2 large-scale farmers under individual conversion, and 4 small, 3 medium and 3 large-scale farmers under collective conversion.

The response rate among the sample subjects was unusually high for a stated preference method: all respondents provided meaningful answers during the interviews, which lasted on average 15 minutes.

4.2 The net present value approach

In the financial analysis we will use the net present value (NPV) as an indicator for the cost-benefit analysis. Net present value is the difference between the value of the future benefit and costs associated with the project, discounted at the required discount rate (Baulcomb and Bezabih, 2011).

This equation can be written as:

$$NPV = \sum_{i=1}^n \frac{\text{net benefit}}{(1 + \text{discount rate})^i}$$

Where n= the life time of the project
i= any given year

The higher the NPV the more economically viable the project because the project is earning over the discount rate. If the NPV is negative, the project is not economically viable (Baulcomb and Bezabih, 2011).

We assumed an economic life of 10 years for the investment, operating cost and investment benefits. We estimated gross incomes from investment in the conversion to drip irrigation based on observed citrus yield increases between 2001 and 2010. We use average local prices for 2010 for different citrus varieties. Moroccan agriculture is free of taxes.

In addition, since the Moroccan government supports 80 per cent of investment in drip irrigation, we calculated the NPV with and without this subsidy.

4.3 Contingent ranking-based stakeholder analysis

A preliminary in-depth interview was conducted with members of the Water Federation (representing water use associations in the Tadla region) to identify all the costs and benefits to farmers. Based on these responses, we drew up a list of farmers' benefits and costs. This confirmed that the costs of switching to drip irrigation include fixed and variable costs of equipment and maintenance, both monetary impacts that will be assessed under CBA. Farmers were presented a shortened list containing a mixture of monetary and non-monetary cost and benefits and asked to confirm the reported costs and benefits by providing details of each in the context of their specific circumstances (crop species, farms size, conversion scheme), and percentage measures of monetary benefits where applicable.

The purpose of this task, and an equivalent exercise in each stakeholder group, was to ensure full awareness of the options, in order to provide meaningful grounds for a contingent ranking exercise. (Bateman *et al.*, 2006)

The ranking exercise ranked all the relevant benefits in order of importance. The CBA provides the exact value of monetary impact; this exercise was designed to indirectly elicit the value of the non-monetary impact and provide an estimate of their relative magnitude. All stakeholder interests would become clear.

A stakeholder meeting was conducted with farmers participating in collective conversion. After discussion of the anticipated benefits they were likely to see under their circumstances, they were asked to rank the importance they attributed to each cause behind a benefit, since numbers on monetary benefits were not yet available. Then the same ranking exercise was presented as for individual conversion farmers. Finally, they were asked to identify the main barriers that prevented them from adopting drip irrigation during the individual conversion, and the major incentive to adopt during collective conversion.

Interviews with the ORMVAT, Water Basin Agency, agricultural workers, drip irrigation companies and representatives of the environment interests followed a similar format: respondents were asked to reflect on their costs and benefits from converting to drip irrigation, before ranking them in order of importance.

5. Results

5.1 Financial feasibility of conversion to drip irrigation

5.1.1 Survey results

The average farm size for small-scale farmers is 4.2ha (Table 1). Small-scale farmers represent 90.9 per cent of total farmers in the region but farm only 51 per cent of the total area under cultivation. The average farm size for medium and large farms are 14.3ha and 26.7ha respectively. Medium-sized farms cover 15.5 per cent of the area and represents 5.6 per cent of farms in this region. Only 3.5 per cent of farms are classed as large, but they cover 33.5 per cent of the land.

Table 1. Farm structure for farmers using drip irrigation in Tadla perimeter

| Farm category | Number in % | Area in % | Average farm size (ha) |
|------------------|-------------|-----------|------------------------|
| Large (>20ha) | 3.5 | 33.5 | 26.7 |
| Medium (10-20ha) | 5.6 | 15.5 | 14.3 |
| Small (<10ha) | 90.9 | 51 | 4.2 |

According to the household survey carried out during this study,, the average age of farmers is 56 years. More than 74 per cent of farmers are illiterate and only 6 per cent of them have a high school level of education. The average family size is around seven people. More than 97 per cent of farmers have agriculture as their primary activity, and it is the main source of income for 73 per cent. Off-farm activities generate 17 per cent of household income and concern a variety of activities.

Cereals are the main crop for farmers using flood irrigation systems for all categories of farmers (Table 2). For small-scale farmers, more than 50 per cent of the area is cultivated with cereals whereas about 37 per cent of large-scale farms are devoted to cereal production. Citrus is exclusively cultivated by medium and large-scale farmers. The main reason for this is the high costs of establishment and the three years that elapse between tree planting and the first crop of fruit. The area under sugar beet represents 20 per cent and 22 per cent of total farm land for large and medium sized farms respectively. Alfalfa, olive trees and vegetables are cultivated by all farm categories but small-scale farmers devote the largest share of land for these crops.

Small-scale farmers have the highest rate of crop intensification, estimated at 144 per cent. This rate is about 110 per cent and 133 per cent respectively for large and medium sized farms. Because of their small farm size, small-scale farmers tend to maximise their revenue from the same portion of land.

Table 2. Cropping pattern under flood irrigation system (in %) in Tadla perimeter

| Crops | Large (>20ha) | Medium (10-20ha) | Small (<10ha) |
|--------------------|---------------|------------------|---------------|
| Citrus | 14.7 | 20 | 0 |
| Sugar beet | 20 | 22 | 26 |
| Cereals | 37 | 40 | 51.5 |
| Alfalfa | 7 | 13.8 | 18.8 |
| Maize F., | 6 | 3.2 | 2.1 |
| Olive trees | 12.2 | 12.3 | 11 |
| Vegetables | 13 | 21.6 | 34.5 |
| Intensification R. | 109.9 | 132.9 | 143.9 |

Table 3 shows that only a part of the farm area is converted to drip irrigation. On average 70 per cent of the area is converted to drip irrigation. After conversion, cereals, especially wheat, remain the main crop cultivated by all categories of farmer and this crop continues to be grown under flood irrigation systems. Farmers also continued to grow alfalfa under flood irrigation. Conversion to drip irrigation allowed farmers to give more prominence to crops with a high added value (citrus, sugar beet and vegetables) in their production systems. Drip irrigation has become the standard method of irrigation in Tadla for citrus – most newly planted citrus orchards are irrigated with drip systems. After conversion, all farmers tend to increase the area dedicated to high value crops. The immediate consequence of this orientation is the reduction in area assigned to cereals and forage crops (mainly alfalfa). Farmers do not tend to introduce new crops after conversion but simply give them more importance. They either choose vegetables like melons, red peppers or potatoes or planted orchards (in most cases citrus). Usually, young citrus plantations are grown in association with vegetables during the first three years.

Table 3. Cropping pattern after conversion to drip irrigation system (%) in Tadla perimeter

| Crops | Large (>20ha) | | Medium (10-20ha) | | Small (<10ha) | |
|-------------|---------------|------------|------------------|------------|---------------|------------|
| | Drip irr. | Flood irr. | Drip irr. | Flood irr. | Drip irr. | Flood irr. |
| Citrus | 17.3 | 0 | 22 | 0 | 0 | 0 |
| Sugar beet | 26 | 0 | 22 | 0 | 26 | 0 |
| Cereals | 0 | 31 | 0 | 38 | 0 | 51.5 |
| Alfalfa | 0 | 5 | 0 | 10.1 | 0 | 18.8 |
| Maize F., | 6 | 0 | 3.2 | 0 | 2.1 | 0 |
| Olive trees | 12.2 | 0 | 12.3 | 0 | 11 | 0 |
| Vegetables | 16.5 | 0 | 25.3 | 0 | 34.5 | 0 |

When asked about the effects of conversion on crop yields, all farmers indicate that they had seen an increase. This increase is very variable among and within categories of farmers. For citrus trees the yield increased in average from 21 tonnes per hectare under flood irrigation to 38 t ha⁻¹ under drip irrigation systems. The continuous irrigation and application of nitrogen and other elements improves crop yields.

Table 4 shows the water saved after the conversion to drip irrigation. The largest quantity of saved water is observed in citrus. Medium sized farms save about 4876 cubic metres per hectare and the quantity of water saved by large-scale farmers is estimated at 4420 m³ ha⁻¹. This represents a decrease of 56 per cent of water needed for citrus under flood irrigation. In term of a weighted average, medium sized farms save about 3831 m³ ha⁻¹ year⁻¹, large and small farms save respectively 3412 and 2776 m³ ha⁻¹ year⁻¹.

Table 4. Water saved in m3 per ha after conversion to drip irrigation in Tadla perimeter

| Crops | Large (>20 ha) | Medium (10-20 ha) | Small (<10 ha) |
|------------------|----------------|-------------------|----------------|
| Citrus | 4400 | 4876 | 0 |
| Sugar beet | 3888 | 4424 | 2944 |
| Maize F., | 2214 | 2414 | 2295 |
| Olive trees | 1512 | 1374 | 1123 |
| Vegetables | 3656 | 3884 | 3205 |
| Weighted average | 3412 | 3831 | 2776 |

5.1.2 Financial feasibility of conversion to drip irrigation

What is the financial feasibility of converting irrigation systems from flood to drip irrigation systems in order to face the increasing water scarcity?

ORMVAT statistics shows that in 2008 about 10,658 hectares in Tadla region were involved in individual conversion to drip irrigation. The main crop cultivated under this new irrigation system was citrus, with more than 57 per cent of the total converted area. ORMVAT's objective is for drip irrigation system to become the standard method of irrigation for citrus in the region. For this reason we chose to limit the analysis to citrus orchards.

5.1.2.1 Investment cost

The main determinants of cost of a drip irrigation system are the area to be irrigated, power source, source of water, type of crop, type of soil and existing farm equipment. The total investment cost and the main items for drip irrigation in a citrus orchard are presented in Table 5. The storage basin, pump, filter system, drip-line and drippers are the main items. Drip-lines and drippers represent about 43 per cent of the total investment. Pipes and storage basins represent, respectively, 20 per cent and 15 per cent of the total investment.

In general, the annual fixed costs of drip irrigation systems are larger than surface systems due to the greater initial investment required to purchase and install them. Conversion to drip irrigation system requires significant investment; average investment for our sample was estimated to about MAD 50,792 (US\$5,883.66). The economic life for the drip-line system was 10 years.

Table 5. Investment for drip irrigation (for 1 hectare of citrus)

| Equipment | MAD |
|-----------------------------------|---------------|
| Storage basin | 7666 |
| Electric pump, full filter system | 6667 |
| Pipes (main and sub-main lines) | 10,000 |
| Drip-line, drippers | 21,875 |
| Labour | 3584 |
| Transportation | 1000 |
| Total per hectare | 50,792 |

5.1.2.2 Operating costs

Annual operating costs will vary depending upon the frequency of irrigation, the amount of water applied per irrigation and irrigation water cost. The calculation of irrigation cost is based on two cost categories, variable cost and fixed cost. In general, variable costs are proportional to the amount of water pumped. Labour is needed for monitoring, maintenance,

repair and pipe moving. Fixed costs occur regardless of the amount of water used and generally consists of depreciation and interest based upon the amount of investment. Depreciation was not taken in consideration in the present analysis because the NPV analysis only uses cash flows for investment appraisal and depreciation is not a cash flow. When farmers switch from flood irrigation to drip irrigation system we observed a reduction in irrigation water quantities and labour. Farmers save the equivalent of MAD 1370 and 720 per hectare per year in irrigation water and labour respectively. Including these savings, the total operating cost per hectare is about MAD 210 (Table 6).

Table 6. Annual operating costs (per hectare) for drip irrigation (MAD)

| | |
|--------------------------------------|------------|
| Repairs | 500 |
| Power source | 1000 |
| Additional fertilisers and pesticide | 800 |
| Saved water | -1370 |
| Saved labour | -720 |
| Total per hectare | 210 |

5.1.2.3 Yield response

During the first three years there was a negative effect of drip irrigation on citrus yield. This is due to the need for the tree roots to adapt to the new irrigation system. Yield then increases to an average of 30 tonnes per hectare (Table 7). This increase in yield is due to the improvement in the timing of water applications. Frequent, small irrigations with drip systems enable farmers to minimise water stress. Farmers can also apply nutrients and pesticides in a precise and timely manner with drip irrigation system.

The gross return on the investment incomes was estimated over the whole economic life of the drip irrigation systems. The differences between the value of yield increase and additional cost are estimated each year.

Table 7. Effect of drip irrigation on annual yield of citrus production (t/ha)

| Year | Surface irrigation | Drip irrigation | Increase in yield |
|------|--------------------|-----------------|-------------------|
| 2001 | 21.5 | 20.28 | -1.22 |
| 2002 | 22.0 | 20.23 | -1.77 |
| 2003 | 21.2 | 19.21 | -1.99 |
| 2004 | 22.5 | 22.57 | 0.07 |
| 2005 | 22.6 | 28.56 | 5.96 |
| 2006 | 23.1 | 29.37 | 6.27 |
| 2007 | 25.5 | 30.51 | 5.01 |
| 2008 | 28.0 | 32.69 | 4.69 |
| 2009 | 31.1 | 34.16 | 3.06 |
| 2010 | 27.9 | 32.01 | 4.11 |

5.1.2.4 Net present value analysis

Without the government subsidy, the NPV was estimated as MAD -28,315 after an initial investment of MAD 50,792 per hectare (Table 8). This means simply that the conversion project is not economically viable. The main reason for this is that the initial investment cost for switching to drip irrigation system is too high compared to the increase in citrus yield.

Although farmers can produce up to 45 t ha⁻¹ under drip irrigation in Morocco if they use the appropriate techniques (Ait Houssa *et al.*, 2005), the highest yield a farmer in our sample reached was an average over 10 years of about 37 t ha⁻¹.

In Morocco, the farmers that choose to adopt drip irrigation benefited from a state subsidy that covers 80 per cent of the initial total investment. Table 9 shows the NPV results where the farmer pays only 20 per cent of the investment. Then, the net present value was estimated as MAD 12,319 (US\$1,427.28) after an investment of about MAD 10,158 paid by farmers. In this case the project is economically viable from the farmer's perspective.

Drip irrigation system associated with appropriate cropping technologies can provide opportunities to improve both farm-level net returns and the net public benefits in an area with limited water resources. Potential farm-level benefits include reductions in water and labour costs, higher crop yields, and a broader set of production opportunities in regions where water supplies are particularly limited.

Potential public benefits include higher farm-level net returns and the net values generated by agriculture and the other uses for water made available when farmers replace flood irrigation with drip irrigation. Public benefits can also be enhanced when drip irrigation reduces or eliminates negative impacts and opportunity costs, such as inefficient water use, nutrient leaching, and the rapid depletion of non-renewable groundwater resources.

This analysis did not take into consideration all the possible public benefits of switching to drip irrigation systems but focused only on the feasibility of conversion for individual farmers. The decision to adopt drip irrigation system results in a supply of positive externalities, one of which is water saving for better climate change adaptation. In most cases, positive externalities such as ecosystem services are a public good, so governments need to provide farmers with incentives to change their management decisions in ways that increase these externalities.

Table 8. Net present value of conversion to drip irrigation without subsidy

| Year | Yield increase (t/ha) | Gross income (MAD) (x2000) | Additional cost (MAD) | Net income | Discount 10% | NPV (MAD) | Cumulative NPV (MAD) |
|------------------|-----------------------|----------------------------|-----------------------|------------|--------------|-----------|----------------------|
| Investment costs | | | | | | -50792 | -50,792 |
| 2001 | -1.22 | -2440 | 210 | -2650 | 1.00 | -2650 | -53,442 |
| 2002 | -1.77 | -3540 | 210 | -3750 | 0.91 | -3409 | -56,851 |
| 2003 | -1.99 | -3980 | 210 | -4190 | 0.83 | -3463 | -60,314 |
| 2004 | 0.07 | 140 | 210 | -70 | 0.75 | -53 | -60,366 |
| 2005 | 5.96 | 11,920 | 210 | 11,710 | 0.68 | 7998 | -52,368 |
| 2006 | 6.27 | 12,540 | 210 | 12,330 | 0.62 | 7656 | -44,712 |
| 2007 | 5.01 | 10,020 | 210 | 9810 | 0.56 | 5537 | -39,175 |
| 2008 | 4.69 | 9380 | 210 | 9170 | 0.51 | 4706 | -34,469 |
| 2009 | 3.06 | 6120 | 210 | 5910 | 0.47 | 2757 | -31,712 |
| 2010 | 4.11 | 8220 | 210 | 8010 | 0.42 | 3397 | -28,315 |
| Total | | | | | | -28,315 | |

Table 9. Net present value of conversion to drip irrigation with 80% subsidy

| Year | Yield increase (t/ha) | Gross income (MAD) (x2000) | Additional cost (MAD) | Net income | Discount 10% | NPV (MAD) | Cumulative NPV (MAD) |
|------------------|--------------------------|----------------------------------|--------------------------|------------|-----------------|--------------|----------------------------|
| Investment costs | | | | | | -10158 | -10158 |
| 2001 | -1.22 | -2440 | 210 | -2650 | 1.00 | -2650 | -12,808 |
| 2002 | -1.77 | -3540 | 210 | -3750 | 0.91 | -3409 | -16,217 |
| 2003 | -1.99 | -3980 | 210 | -4190 | 0.83 | -3463 | -19,680 |
| 2004 | 0.07 | 140 | 210 | -70 | 0.75 | -53 | -19,732 |
| 2005 | 5.96 | 11,920 | 210 | 11,710 | 0.68 | 7998 | -11,734 |
| 2006 | 6.27 | 12,540 | 210 | 12,330 | 0.62 | 7656 | -4078 |
| 2007 | 5.01 | 10,020 | 210 | 9810 | 0.56 | 5537 | 1459 |
| 2008 | 4.69 | 9380 | 210 | 9170 | 0.51 | 4706 | 6165 |
| 2009 | 3.06 | 6120 | 210 | 5910 | 0.47 | 2757 | 8922 |
| 2010 | 4.11 | 8220 | 210 | 8010 | 0.42 | 3397 | 12,319 |
| Total | | | | | | 12,319 | |

5.2 Contingent ranking-based stakeholder analysis

5.2.1 Stakeholders in the conversion to drip irrigation system

Stakeholder analysis has become a key process in developing and/or implementing a policy or programme and is a way to understand a system through its actors, their interests, their goals, their power and their relationships. When stakeholder analysis and other key tools are used to guide the implementation, the policy or programme is more likely to succeed. Identifying the key stakeholders is extremely important to the success of the analysis.

Analysis of secondary data and preliminary interviews helped us to identify the key stakeholders involved in the conversion program. Four categories of stakeholders were identified for our case study.

a. Households: This group of stakeholders embodies essentially farmers and agricultural workers. Farmers are key stakeholders because water availability and use directly affect agricultural incomes. Agricultural workers are stakeholders because the adoption of drip irrigation system will reduce the demand for labour force irrigation activities which will affect their revenue.

b. Public sector: This category is represented by two individual government agencies, ORMVAT and the Water Basin Agency. The ORMVAT is a stakeholder because it has several functions at the irrigation scheme, the main ones being: agricultural land management, the management of irrigation and drainage and agricultural development. The operation and maintenance of hydro-agricultural development is provided by the department of management of irrigation and drainage. It includes the management and distribution of irrigation water, maintenance of hydro-agricultural equipment, supervision of farmers on the use of irrigation techniques, the billing of water for irrigation and debt collection. ORMVAT is also responsible for the execution of the Green Morocco Plan at Tadla perimeter.

The Water Basin Agency of Oum Er Rabia was the first agency set up in Morocco, given the importance of water resources for the regions of Tadla-Doukkala and coastal Casablanca-Safi. The agency's mission is primarily to assess, plan, develop and manage water resources in the basin of Oum Er Rabia, to ensure the preservation of public water and anticipate

coping with exceptional situations (shortage of water, and floods). It is also responsible for the protection of groundwater reserves. The Water Basin Agency regulates water allocation between sectors at basin level.

c. Private sector: This group is mainly represented by drip irrigation companies and local dealers. Irrigation companies are stakeholders because they carry out technical studies for drip irrigation projects and sell equipment for drip irrigation. They work with farmers, providing technical assistance and helping them to prepare their applications for subsidies. Local dealers are stakeholders because they provide inputs to farmers in the region and the conversion to drip irrigation will affect their activities.

d. Environment: In our case study the interests of the environment were represented by the research unit on environment and agricultural resources valorization at Beni Mellal University. The environment is stakeholder because drip irrigation enhances the sustainability of groundwater reserves. By increasing the availability of surface water, drip irrigation will alleviate pressure on alternative agricultural resources. As a result, groundwater resources will increase in quality and quantities.

5.2.2 Perceived monetary benefits and non-monetary benefits for farmers

5.2.2.1 Monetary benefits

a. Agricultural income

All categories of farmer who switched to drip irrigation reported an increased yield per hectare on their farms. Small-scale farmers reported that on average yield increased by 20 to 30 per cent, while for medium and large-scale farmers, yield increases vary between 30 and 40 per cent depending on the crop and soil type. Farmers increase crop yield by improving the timing of water applications to match the crop's water requirement more closely than with flood system.

When farmers use flood irrigation, they often tend to over-irrigate or under-irrigate their crops, depending on the amount of water they receive which is not necessarily the amount that their crop requires. Frequent, small irrigation with drip system enable farmers to minimise water stress on plants throughout the season. Farmers switching to drip irrigation systems reported that they could apply nutrients and pesticides in a precise and timely manner which leads to a higher input use efficiency. In the old flood irrigation system, fertiliser use was less efficient due to leaching and to lack of knowledge about the optimal amount of fertiliser for each crop.

Increase in water use efficiency (WUE) was mentioned as the primary mechanism that caused the increase in farmer's income. Water requirements are reduced under drip irrigation as less water is lost to surface evaporation, runoff, and deep percolation. Farmers stated that with drip irrigation systems, WUE increased by up to 50 per cent.

Farmers had no or limited control over the timing of irrigation under flood irrigation system. Due to the water shortages in Tadla perimeter, water is allocated to farmers on a scheduled basis. As a result, farmers sometimes had to irrigate at inappropriate times like early in the morning or at night. In contrast, farmers that had switched to drip irrigation systems, only require access to irrigation water for 1 to 4 hours per day, depending on the crop species. The availability of water at the farm level allows farmers to freely choose the time of irrigation as opposed to being allocated fixed timeslots. This is because the availability of water now is more than the demand and that has reduced the restrictions on water use.

b. Labour costs

One of the advantages of the adoption of drip irrigation system is the net reduction in labour costs. All farmers mentioned that flood irrigation is an incredibly time-consuming system. Farmers needed 10 to 12 hours to irrigate one hectare of sugar beet under flood irrigation system whereas under drip irrigation systems they need only 2 to 3 hours. The labour

needed to apply different chemical fertilisers and weed control is saved under drip irrigation. This results in a significant cut in the cost of labour. Some farmers reported that they no longer need irrigation workers because drip irrigation is an automated irrigation technology. The reduction in hired labour varies from about 30 per cent for small-scale farmers to 80 per cent for large-scale farmers. This difference is mainly due to the fact that large farms depend more on hired labour than small farms.

Some large-scale farmers reported that, under flood irrigation system, they had contracted permanent workers and the payment was in kind (25 per cent of yield). Under drip irrigation system these categories of farmers don't need to employ these workers any more, saving 25 per cent of their yield.

The replacement of open canals by underground pipelines results also in a cutting down on cleaning costs of open canals. Farmers did mention that drip irrigation systems required some new farm activities, such as the removal and installation of pipelines and emitters between seasons but the labour needed for these new activities is insignificant compared to the reduction in labour needed for irrigation.

5.2.2.2 Non-monetary benefits

a. Dependency on hired labour

The flood irrigation system irrigation mobilises a lot of workers. For example, according to farmers, one hectare of citrus requires about 10 man days a year for irrigation and six man days for chemical fertiliser application. During recent years, farmers in Tadla have had increasing difficulty in mobilising labour for such activities which are perceived as less attractive compared to working in the secondary and tertiary sector. This is particularly pronounced during the winter, especially if the water turn is scheduled during the night. The emigration of young people has also increased the scarcity of agricultural labour forces.

Farmers reported that drip irrigation significantly improves working conditions through the easy handling and ease of monitoring and control of irrigation. It is also easier to follow the work and control the workers. Moreover, operators can avoid irrigating at night and spread the irrigation out over time to avoid peaks of work. These benefits have been key reasons for adopting drip irrigation systems for some farmers, especially older ones who have less strength to work and whose children have left the farm, and farmers with other non-agricultural activities (business or private) and who are therefore not present on the farm.

Farmers under both collective and individual conversion, especially medium and large-scale farmers confirmed the problem of labour shortages and motioned that this problem increases stress which negatively affects their health.

b. Leisure time

Small and medium-scale farmers, who employ family labour and who switched to drip irrigation systems experienced a significant increase in leisure time. Even farmers who did not spend time on the farm themselves saw similar benefits. Some of the small-scale farmers reported that they used this extra time for non-agricultural activities in order to improve their off-farm income.

c. Health

All categories of farmers reported that after switching to drip irrigation system they experienced better health. For small-scale farmers the main reasons for this were the observed increase in income and also the decrease in time spent on physical work in the field. Avoiding irrigation during winter and night also has a positive impact on farmers' health, especially small-scale farmers using family labour for irrigation.

Medium and large-scale farmers feel in a better health because by adopting the new system of irrigation they eliminated some negative stress factors (see the problem of dependency on hired labour, above).

d. Education

Small-scale farmers who have already switched to drip irrigation system mentioned that their children had more time to attend education and that their higher disposable income enable them to enrol children in education when they reach the appropriate age. They also reported that higher farming income from drip irrigation made it affordable to pay for private education. Medium-scale farmers perceived it as important that under the drip irrigation system, they would have enough income to provide their children with skills that would enable them to avoid working in the agricultural sector.

5.2.2.3 Ranking of monetary and non-monetary benefits for farmers

Health, education and leisure time were ranked as the most important benefit from having switched to drip irrigation systems followed by the monetary benefit of increased farming income. One farmer said that the purpose of making profits from farming was to provide the children with a better education and he added that it was the lack of education that had caused him to have to undertake hard agricultural work, and he doesn't want his children to experience the same.

For the remaining benefits, reduced dependency on hired labour was more important than the cost of labour for the medium and large-scale farmer, but the other way around for the small-scale farmer.

Small-scale farmers under collective conversion ranked health, education and leisure time as their primary expected benefit. This was followed by farming income. Medium and large-scale farmers ranked increase farm income before health, education and leisure time. Small-scale farmers ranked the cost of labour as the next benefit. This makes sense, since small-scale farmers are farming a very small area of land and the increases in their income will be insignificant compared to the non-monetary benefits.

5.2.3 4.2.3 Perceived monetary and non-monetary benefits for agricultural workers

This group was represented by Ouralah community next to Afourar city (25 kilometres from Tadla perimeter). The total number of households in this community is about 100 and 40 per cent of these households depend on agricultural work in the Tadla perimeter. Seventy per cent of the workers are women.

According to the four women and the three men interviewed, the community was not aware about the drip irrigation conversion project, especially the collective one. They reported that this was the first time that any official group asked them for their opinion.

After understanding the objective of this project, they said that they performed many agricultural activities depending on the seasons and irrigation work concerns only men and represents only 10 to 20 per cent of their work. This means that the community will see a decrease of 3 to 4.5 per cent of total income if the whole Tadla perimeter is converted to drip irrigation.

The community was not convinced that the conversion programme will affect their revenue because of emigration and believe that the construction of the Tadla agro-industrial zone planned by the Green Morocco Plan will provide plenty of employment opportunities.

5.2.4 Perceived monetary and non-monetary benefits for ORMVAT

5.2.4.1 Monetary benefits

Cost of maintenance of the network

The irrigation network is the most costly element of an irrigation scheme. Silt deposition, weed infestation, malfunctioning of structures and other undesirable situations make it practically impossible to control the flow in these canals. Insufficient funding for ORMVAT complicates the maintenance task. As a result, the system is unable to deliver the necessary water and distribute it equitably. ORMVAT spends annually an average a total of MAD 4 million (464,465US\$) (444 MAD (51.55US\$) per hectare) for the maintenance of the network. Under drip irrigation systems this cost will decrease significantly.

5.2.4.2 Non-monetary benefits

a. Management of water scarcity

ORMVAT representatives believe that the solutions to the water scarcity problem are two fold. First, there needs to be supply-side management practices like watershed development, and water resource development through major, medium and minor irrigation projects. Second, there needs to be demand management by efficient use of the available water both in the short and long run. This includes drip irrigation and other improved water management practices. Efficient use of water, will make ORMVAT's role of managing scarce water resources easier.

b. ORMVAT's relations with farmers

ORMVAT reported that switching to drip irrigation systems will help them to better satisfy farmers' demands for irrigation water which will improve the level of confidence and relations between farmers and ORMVAT. This will also contribute to regional social and political stability.

c. Increased food security

Switching to drip irrigation systems will increase the availability of irrigation water and increase the total irrigated land area which will improve the level of food production at regional level. The replacement of traditional crops by high-value vegetables, cash crops and fruits will contribute to meeting the food security objective of the GMP.

5.2.4.3 The ranking of monetary and non-monetary benefits for ORMVAT

According to ORMVAT, better and easier management of the water scarcity problem is the most important benefit of switching to drip irrigation systems. The decrease in network maintenance costs came second followed by the improvement of food security and better relations between farmers and ORMVAT.

5.2.5 4.2.5 Perceived non-monetary benefits for the Water Basin Agency

5.2.5.1 Non-monetary benefits

a. Sustainability of groundwater resources

WBA representatives mentioned that the adoption of drip irrigation will lead to a reduction in water use and therefore make water available for other sectors, especially domestic use. Switching to drip irrigation will reduce the pressure on groundwater which will necessarily save water when considering the basin as a whole. This will contribute towards the sustainability of groundwater reserves and mean they can serve as a water source for future generations.

b. Relations with ORMVAT

In recent years the water deficit across the basin was becoming a real problem for the WBA. In periods of drought, pressure from the ORMVAT to allocate more water to the agricultural sector represents a serious challenge for the WBA. The adoption of drip irrigation systems will allow it to satisfy more farmers and to irrigate more land with the same amount of water which will improve professional relations between ORMVAT and the WBA.

c. Relations with farmers

As a service delivery agency, satisfaction from delivering a good service and consequently getting positive feedback from farmers is important to the WBA. Delivering a good service helps establish trust between them, that in the long term will promote co-operation between the WBA and farmers.

5.2.5.2 The ranking of non-monetary benefits for the WBA

The WBA identified the sustainability of groundwater reserves as the most significant benefit from switching to drip irrigation systems. Improvement in professional relations between WBA and ORMVAT was ranked second and better relations with farmers was ranked third.

5.2.6 Perceived monetary benefits for the private sector

Growing horticultural crops under the drip irrigation systems increased demand for inputs from local dealers, positively affecting their activities and income. The fact that switching to drip irrigation systems improves crop intensification means that most input suppliers and transporters are in business all year round. Input suppliers mentioned that conversion to drip irrigation systems will improve their income by about 15 per cent.

When it comes to irrigation companies, there were only five of these in the Tadla region in 2000 and now there are 28. According to their association, this evolution is due principally to individual conversions to drip irrigation. In the past they averaged two irrigation projects per month whereas now they can have up to six projects by month, which means that their turnover was multiplied by three.

5.2.7 Perceived non-monetary benefits for environment

Environmental researchers point out that drip method of irrigation helps to reduce the over-exploitation of groundwater that is partly due to inefficient use of water under flood irrigation. Drip irrigation also completely eliminates environmental problems associated with the flood irrigation system, like water logging and salinity. Decreasing amounts of leaching of chemical fertilisers, especially nitrogen, will slow down the contamination of aquifers and deep level groundwater reserves which will improve the groundwater quality for domestic use.

Conversion to drip irrigation from flood irrigation systems will also reduce degradation in soil quality degradation due to the excessive use of chemical fertilisers.

Researchers insisted that these two positive externalities have equal importance for the environment and if you break one element of the chain the whole system will collapse.

6. Conclusion

All stakeholders agreed that conversion from flood to drip irrigation systems is the only solution to the irrigation water deficit partly caused by the observed climate changes. That is why the government has initiated its ambitious programme to convert 88,740 hectares in the Tadla perimeter to the more efficient irrigation method.

As a strategy for CC adaptation, conversion from flood irrigation to drip irrigation can provide opportunities to improve both the farm-level net returns and the public net benefits generated with limited water resources. Potential farm-level benefits include reductions in water deliveries and labour costs, higher crop yields, and a broader range of production opportunities in regions where water supplies are particularly limited.

Potential public benefits include higher farm-level net returns and higher net values generated by agriculture and in water being made available for other uses. These public benefits are enhanced as drip irrigation reduces or eliminates negative impacts and

opportunity costs, such as water use inefficiency, nutrient leaching, and the rapid depletion of non-renewable groundwater resources.

Traditional CBA does not take into consideration all the possible public benefits of switching from a flood irrigation to drip irrigation system and focused only on the feasibility of conversion for individual farmers. The decision to adopt drip irrigation system results in positive externalities, including water saving for better climate change adaptation. In most cases, positive externalities are a public good, so government must provide farmers with incentives to change their management decisions in ways that increase these externalities.

The stakeholder analysis identified that there were non-monetary welfare gains for all primary stakeholders of the adaptation project, as is commonly found in adaptation projects aiming to build adaptive capacity. Groups of private and public stakeholders favoured non-monetary impacts over monetary gains. Small-scale farmers were the most reliant on these non-monetary benefits of adaptation.

The majority of farmers were not aware of non-monetary benefits of the drip irrigation system and even ORMVAT appreciated this new cost and benefits-focused, multi-stakeholder approach and confirmed that the results of the project will help to convince farmers who have not adhered to this project.

The stakeholders' workshop was an occasion to convince remaining sceptical farmers about the adaptation options and get their commitment to the initiative. In this respect the non-monetary values and benefits discovered in the analysis will play a key role in facilitating a higher acceptance rate and therefore also a stronger general project impact.

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