Background document

# Rmel River Basin Adaptation Plan

## 2016

Results of the identification and evaluation of water management options for the Rmel River Basin

**Results of the identification and evaluation of water management options for the Rmel River Basin**

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# Contents

# 1. Introduction

Climate change is expected to affect most regions across the world. The Mediterranean region is a region where changes in climate are expected to have strong impacts, particularly on water resources. To address sustainable water management and adaptation to the impacts of global change in the Mediterranean, an iterative, bottom-up approach was developed in the BeWater project to ensure that stakeholders from local societies play an active role and become engaged in determining appropriate strategies for management of their river basins.

An adaptation plan for the Rmel river basin has been recently containing a set of water management options to address the challenges in the basin. These options have been formulated and evaluated in a participatory approach. The objective of the current document is to describe the detailed evaluation results of the identified water management options.

# 2. Current state and challenges in the Rmel river basin

## 2.1 Description of the basin

The coastal watershed of wadi Rmel is a National pilot study area located on the Eastern coast of Tunisia. Bounded on the west by the Jebel Zaghouan Mountain and on the east by the Mediterranean Sea, it covers an area of 87,000 ha and has a population of 135,438 inhabitants.
The wadi Rmel watershed is subject to a Mediterranean and Continental climate, with an average temperature of 18.5°C. Precipitation is very irregular, with average rainfall ranging from 350 mm to 600 mm.

The basin is covered by forest formations ranging from degraded scrub land to dense forest. Deposit slopes, forming the catchment, are occupied by bushes or scrub land areas as well as forest relics of Aleppo pine. In the hills connecting the mountain, low lands lopes and agro cereal fields are found.

The wadi Rmel watershed is a rich region in wild game, as reflected in the variety of wild species such as boar, jackal, fox, wild cat, and partridge. It is important to stress some species of birds such as hawks that are sedentary, while others are migratory as the booted eagle or dove. The wealth of wildlife has declined but remains important and deserves to be developed as it may be the basis of a great contribution to launch the green tourism in the area: near Tunis, Hammamet and Sousse, an attractive environment can be found where forest and hill dams create attractive landscapes.

As far as economic activities are concerned, they are primarily based on traditional self- subsistence agriculture (annual crops of cereals and vegetables) and a diversified extensive livestock dominated by goats and sheep. The herds are mainly supplied from range land and scrub forests, fallows and stubbles. Forage resources are insufficient and cannot cover the needs of the herds (cattle).

An important part of the rural population is constantly looking for a casual off-farm employment opportunities or emigration to the neighbouring governorates. However, a study conducted by the Department of farmland conservation and management (MARH, 2005) at Sbaihia sub-basin (a representative hill lake in the watershed Rmel), shows that 40% of agricultural land in the basin belong to large farmers or non-resident owners, who practice cereal agriculture. Only 30% of land belongs to the families who belong to the area, which is heavily inhabited by the majority of the population living on low-yielding cereal crops, extensive production and especially off-farm income (migration, construction sites...).The plains and piedmonts are under a heavy human pressure and are systematically cultivated; mainly cereals, without appropriate farming techniques, which speed up the process of land degradation and consequently the phenomenon of erosion.

## 2.2 Global change

Tunisia has undertaken a prospective thinking initiative on the impacts of global change including the climate change on agriculture and natural resources. For this reason, a national strategy for the adaptation of Tunisian agriculture and ecosystems to future conditions as well as a study on

ecosystem protection and climate change adaptation have been developed (MARH, 2007; MEDD, 2007).

Within these studies, climate projections for Tunisia have been made with the HadCM3 model (general circulation model coupled atmosphere-ocean) to quantify and evaluate the increase in temperature and the likely decrease of rainfall in addition to the study of the variability of precipitation and the extremes horizons of 2030-2050, as compared to the reference period 1961-1990. The projected impacts of climate changes were:

- Increased frequency and intensity of extreme dry years.
- Drier and wetter periods should vary greatly from one season to another.
- Moderated decreasing of rainfall (-10 to 20%)
- Temperature increases ( range +1,1ºC in 2030 to +2,1ºC in 2050)

The main resources directly affected by these changes in climate are water resources, ecosystems and agro-systems. The estimated impacts on water resources:

- Groundwater, primarily in groundwater of high salinity, coastal aquifers and not-renewable aquifers, decrease by 28% in 2030.
- The decrease in surface water will be about 5% in the same horizon. The exploitable water will decrease slightly.
- The decrease in summer precipitation will increase the lack of soil moisture. The increase of salinity of groundwater close to the coast leads to the rise of the sea level.

Estimated impacts on Ecosystems

- Increased risk of large fires in the North;
- Rising temperatures and sea levels (50 cm by 2100), will increase the marine erosion of coastal regions and will cause the advance of the sea to the mainland coastal areas:
    - Delta Wadi of Medjerda (loss of fertility of 2600 ha).
    - All sebkhas with an area of 730 ha will turn into lagoons.
    - Gulf of Hammamet with an area of about 1400 ha will turn into lagoon.
    - Archipelago of Kerkennah and Djerba Island, about 30% of the total area would be exposed to marine erosion.

This will supposedly cause salinization of groundwater aquifers in these areas.

Estimated impacts on Agrosystems:

Under these climate assumptions, the impacts on agricultural systems are:

- In the occurrence of a succession of dry years, it will be a lower production of olive and cereal area in the centre and south and reduced cattle in the north but especially in the centre and south.
- In case of favourable rainfall years, the security performance of the dry oil production and yields of rainfed arboriculture will increase by 20%.
- In case of flooding, irrigated cereal production will be affected.
- In the South, climate change may render the situation of oasis (microclimate) more critical.

Besides climate change, also other developments are important for water resources in Rmel. Water demand in Tunisia is estimated at 2689 Mm3 in 2010 and it is projected to reach 2770 by the year 2030. The main water uses are irrigation, drinking water, tourism, and industry. The demand related to irrigation will present 77% of the total potential in 2030, making agriculture by far the largest water consumer. Drinking water demand was estimated at 381 Mm3 in 2010 and it is projected to reach 491 by the year 2030 when considering population growth (inhabitants will be reach 12 million by 2030). For industry, the demand will almost double between 2010 and 2030 going from 136 Mm3 to 203 Mm3. As far as the tourism sector is concerned, water demand was estimated at 19 Mm3 in 2010 and is projected to reach 41 Mm3 by the year 2030 (ITES, 2014).

The trend of mobilization will be totally insured by 2025 for surface water as well as ground water.. Therefore, it will be necessary, from 2020, to consider unconventional water resources in order to respond to the demands from the different sectors.

## 2.3 Challenges

### Challenge A: Water quantity

In the study area, the rainfall regime is characterized by irregularity and high intensity that cause soil degradation. Also, unconventional human activities (overgrazing, bad agricultural practices…), accelerate erosion. The limited water and soil conservation techniques all over the catchment and their conditions are causing reduction of the dam storage capacity. Certain areas remain disserving drinking water. Losses in the drinking water supply network and low flows affect the quantity of water especially during peak hours. Responding to the needs of the local population, proper water management is apriority in our basin. This challenge is related to water and soil conservation techniques, soil degradation, flooding, surface water and ground water, irrigated cropland, soil water reserve, water demand, water availability in reservoirs.

### Challenge B: Water quality

The basin contains an industrial zone of approx. 44 ha. This region consists of 33 enterprises that release their waste liquids (waste of olive presses, lime) in the river wadi Rmel. These waste liquids have a high influence on the water quality in the basin. Wastewater treatment and control of contamination of the river is necessary to preserve the water quality in the basin.
This challenge is related to water quality, industry and tourism, surface water and ground water, water demand.

### Challenge C: Agriculture

The current situation of the irrigated sector is characterized by several levels of exploitation and an overall modest increase resulting from various constraints, mainly related to social and land pressures. The majority of farmers are very aged and are trapped in old techniques and traditional agricultural know how; moreover they are struggling with land conflicts. Good management of irrigated perimeters, support of farmers and improving operational and management requirements constitute a challenge to improve agriculture that represents the main occupation of the basin. This challenge is related to population livelihood and settlements, irrigated cropland, rainfed cropland, job creation, water quality.

### Challenge D: Forest and biodiversity management

The forest is both a valuable protective mantle for soil and an incomparable set of sites and landscapes but it is particularly threatened. The over-exploitation of the forest and the intensive agro-pastoral practices have led to severe degradation of forest resources. Consequently, it becomes crucial to highlight the economic, social, and ecological importance of forests. Future strategies need to develop and ensure the protection of this precious and fragile heritage. This challenge is related to forest fire, forest resources, soil degradation, pasture and cattle raising, population and settlements.

### Challenge E: Awareness of civil society

The lack of awareness of civil society about the importance of natural resources is due to the lack of coordination between the authorities and civil society, as well as the fact that local people were kept out of decision making processes(not only in the basin, but in the whole region). Therefore, awareness, training and integration of civil society in studies and the coordination between society and science are necessary for the success of the project. This challenge is related to population and settlement, forest resources, surface water and ground water, soil degradation, pasture and cattle raising, irrigated cropland, industry and tourism.

### Challenge F: Human resource and employment

The analysis of socio-economic issues has identified constraints that concern the future beneficiaries: the main constraints mentioned by young people are, namely, guidance difficulty towards vocational training, lack of generating income projects, unemployment, migration, and lack of specialized manpower. A better exploitation of existing human resources in the basin and the creation of jobs in the agricultural sector are a relevant challenge for the development of the area.

This challenge is related to job creation, industry and tourism, population and settlements, irrigated cropland, rainfed cropland.

## 2.4 Basin dynamics

A cognitive map of dynamics in the river basin was developed to reflect the interactions and dynamics in the basin based on the understanding by stakeholders. It gathers all declarations provided by the participants during the first workshop, the awareness campaign, individual interviews and some reports in current issues and challenges in the basin. The map is shown in Figure 2.1.

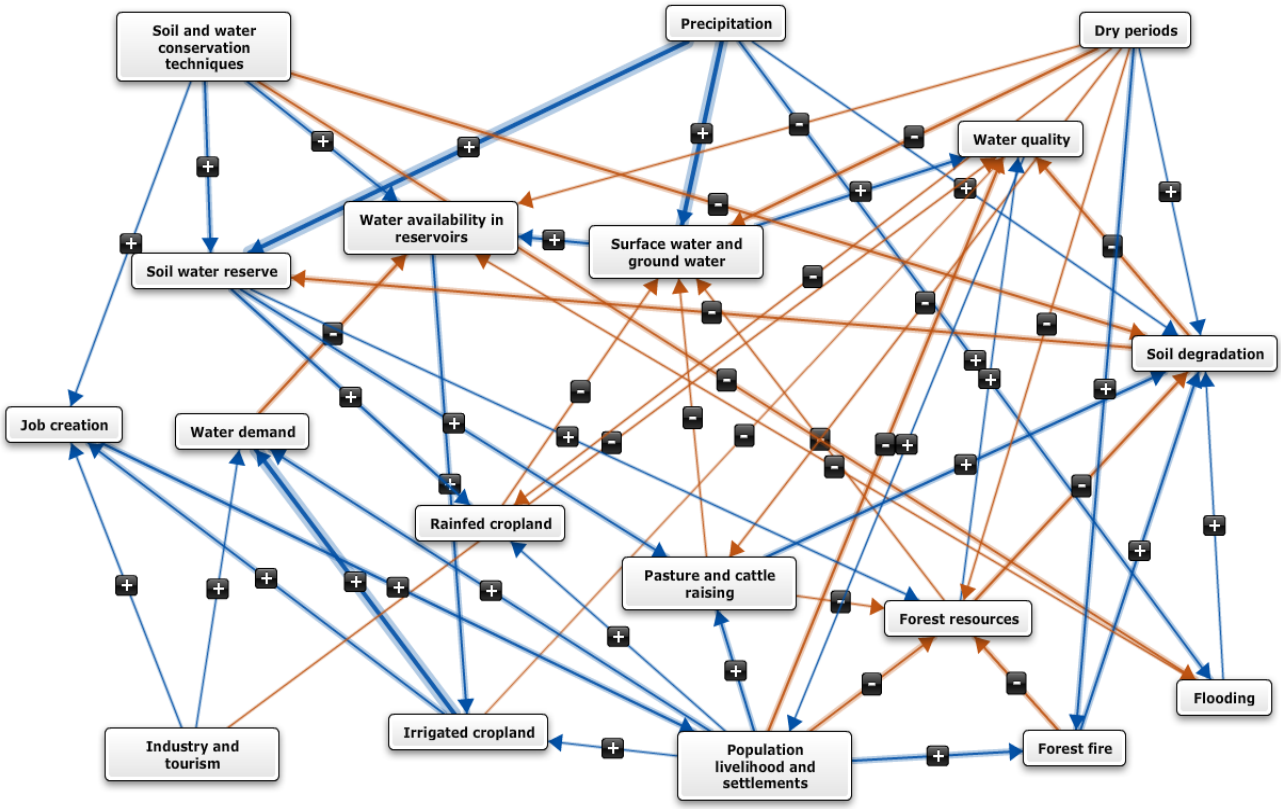


**Figure 2.1:** Cognitive map of the Rmel river basin (blue: +, red: -; strength: thin line: 1, medium width: 2, wide line: 3)

This map contains in total 18 factors. The main factors are water availability, soil degradation, water quality, agriculture (irrigated cropland and rainfed cropland) and job creation. Water availability is influenced by the surface water and ground water (2+) that has a direct relationship with precipitation (+3) which is a driver. So when precipitation occurs, two major challenges (water availability and soil and water reserve) increase. These two factors increase by their turn the agriculture (irrigated cropland (2+) and rainfed cropland (2+)), cattle raising (2+) and forest resources (1+).The preservation of water availability consists especially in setting water and soil conservation techniques (2+) to collect runoff water in order to promote green water and to increase family yields, incomes and creation of jobs (1+).

Dry periods, which are considered as a driver, have a negative influence on water availability (1-) and soil water reserve. This driver affects negatively the other factors influenced already by both water availability and water reserve, including surface and ground water(2-), cattle raising (1-) and forest resources (2-).

Water quality is one of the most relevant challenges in the basin. Several factors were considered to negatively influence on water quality, including soil degradation (2-), population livelihood (2-), irrigated crop production (1-), and industry and tourism(1-). Water quality is positively influenced by

surface water and groundwater (2+) and forest resources (1+). Water quality was considered to have positive effects on population livelihood and settlements (1+).

Forest resources are affected by forest fire (1-) and population livelihood (2-). In this context, a major effort is being proceeded for forest preservation, special measures of prevention and control should be adopted such as the establishment of the adequate techniques to protect and safeguard forest resources from fire, the introduction of new agroforestry species and a better governance of these resources.

Soil degradation is mainly increased by heavy precipitation (3+), forest fire (2+), flooding (1+), cattle raising (2+) and dry periods (1+). According to the map, this factor is decreased by both soil and water conservation techniques (2-) and forest resources(reforestation) (2-). Regarding the previous statements, it is imperative to improve the functioning of existing water and soil conservation techniques and consolidate them by plantation.

Job creation was considered to increase population livelihood and settlements (2+) as more jobs may attract more people. Industry and tourism (1+) as well as agriculture (2+) create jobs as it can be seen in the map through the relationships between these factors.

# 3. Identified water management options

The main challenges of the Rmel watershed and the first list of water management options have been identified during the first stakeholder workshop. This was complemented through additional interviews carried out in the basin to reach a number of 19 options. The latter options were presented discussed and evaluated subsequently by stakeholders during several meetings that took place at regional and central offices including the second workshop of June 4, 2015 (Table 3.1).

**Table 3.1:** Overview of the identified water management options for the Rmel river basin

| WMO # | Name of WMO |
|---|---|
| 1 | Promote new water and soil conservation techniques. |
| 2 | Consolidation of existing water and soil conservation techniques. |
| 3 | Creation and rehabilitation of hydraulic infrastructure |
| 4 | Application of taxes. |
| 5 | Developing agricultural cooperatives. |
| 6 | Good use of agriculture land. |
| 7 | Developing financial awareness tools. |
| 8 | Use of water irrigation technologies |
| 9 | Improvement of the treatment of waste water. |
| 10 | Water discharge control. |
| 11 | Reduction of society pressure on forests |
| 12 | Protection against forest fire |
| 13 | Introduction of new agro forestry species and enrichment of existing forest. |
| 14 | Better governance of forest resources |
| 15 | Awareness campaign and learning |
| 16 | Improved decision making |
| 17 | Promote projects that generate more income. |
| 18 | Encourage investments |
| 19 | Developing skills for young people |

A description of the water management options was prepared, and then reviewed by different stakeholders. The final definitions are presented in Annex II.

Finally, we characterised each of the identified water management options using the set of criteria described in chapter 2 through an expert assessment. Each water management option is

characterized by a number of descriptors which are: a) Implementation time horizon, b) Expected lifetime, c) Timelag between implementation and effectiveness, d) Character, e) Implementation costs, f) Operational costs, g) Effectiveness, h) Approach to adaptation, nature of approach, i) Potential to address climate change, j) Feasibility and acceptability. This characterisation of options is shown in Table 3.2.

**Table 3.2:** Characterisation of the water management options for the Rmel river basin

| | Implementation scale | | | | Implementation time horizon | | | Expected lifetime | | | Timelag between implementation and effectiveness | | | Character | | | | Implementation costs | | | | Operational costs | | | | Efectiveness | | | | Approach to adaptation | | | Nature of approach | | | | | | Potential to address climate change | | Feasibility | | | Acceptability (a priori) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | National | Regional | Municipal | Basin | Short (< 5 yrs) | Medium (5-20 yrs) | Long (> 20 yrs) | Short (< 5 years) | Medium (5-20 years) | Long (> 20 years) | Short (< 5 years) | Medium (5-20 years) | Long (> 20 years) | Demand | Supply | Support | Environmental conservation | < 10,000 € | 10,000 - 100,000 € | 100,000 - 1,000,000 € | > 1,000,000 € | < 10,000 € / yr | 10,000 - 100,000 € / yr | 10,000 - 1,000,000 € / yr | > 1,000,000 € / yr | High | Medium | Low | Uncertain | Green | Grey | Soft | Bear the loss | Share the loss | Modify the threat | Prevent effects | Change use | Research | Educate, inform and encourage change | Robustness | Flexibility | No major obstacle | Minor obstacles | Serious obstacles | High | Low |
| 1 | | | | 1 | 1 | | | | 1 | | 1 | | | | 1 | | | | | 1 | 1 | | | | 1 | | | | | 1 | | | | | 1 | | | | 1 | | 1 | | | | 1 |
| 2 | | | | 1 | 1 | | | | 1 | | | 1 | | | | | 1 | | 1 | | | 1 | | | | 1 | | | | 1 | | | | | 1 | | | | 1 | | 1 | | | 1 | |
| 3 | | | | 1 | 1 | | | | 1 | | 1 | | | | 1 | | | | 1 | | | | 1 | | | 1 | | | | 1 | | | 1 | | | | | | 1 | 1 | | 1 | | 1 | |
| 4 | 1 | | | | | 1 | | | | 1 | 1 | | | 1 | | | 1 | | | | | | 1 | | | | | | 1 | | 1 | | | | | | | 1 | | 1 | | 1 | | 1 |
| 5 | | | | 1 | | 1 | | | 1 | | 1 | | | | | 1 | | | 1 | | | 1 | | | | | 1 | | | | 1 | | | | | | | 1 | | 1 | | | 1 | | |
| 6 | | | | 1 | | 1 | | | 1 | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | | | 1 | | 1 | | 1 | | | 1 |
| 7 | 1 | | | | 1 | | | 1 | | | 1 | | | | 1 | | | 1 | | | | 1 | | | | | 1 | | | | 1 | | 1 | | | | | 1 | | | 1 | | 1 | |
| 8 | | | | 1 | 1 | | | | 1 | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | | 1 | | 1 | | | | 1 | | |
| 9 | | | | 1 | 1 | | | | 1 | | 1 | | | | 1 | | 1 | | | 1 | | | 1 | | | | 1 | | | | 1 | | | | | 1 | | 1 | | | 1 | | | 1 |
| 10 | | | | 1 | 1 | | | | 1 | | 1 | | | | | | 1 | 1 | | | | 1 | | | | | 1 | | | | 1 | | | | 1 | | | 1 | | | 1 | | | 1 |
| 11 | | | | 1 | 1 | | | | 1 | | 1 | | | | | | 1 | 1 | | | | 1 | | | | | | 1 | | | 1 | | | | 1 | | | | 1 | | | 1 | | | 1 |
| 12 | | | | 1 | 1 | | | | 1 | | 1 | | | | | | 1 | | 1 | | | 1 | | | | | 1 | | | | 1 | | | | 1 | | | | 1 | | | 1 | | 1 | |
| 13 | | | | 1 | 1 | | | | | 1 | | 1 | | | | | 1 | | 1 | | | 1 | | | | | | 1 | | 1 | | | | | 1 | | | | | 1 | | | 1 | | | 1 |
| 14 | 1 | | | | 1 | | | | | 1 | | 1 | | | | | 1 | 1 | | | | 1 | | | | | | | 1 | | 1 | | | | | | | 1 | | 1 | | 1 | | | 1 |
| 15 | 1 | | | | 1 | | | | | 1 | 1 | | | | | 1 | | 1 | | | | 1 | | | | | 1 | | | | 1 | | | | | | | 1 | | 1 | | | 1 | | | 1 |
| 16 | 1 | | | | 1 | | | | | 1 | 1 | | | | | 1 | | 1 | | | | 1 | | | | | 1 | | | | 1 | | | | | | | 1 | | 1 | | | 1 | | | 1 |
| 17 | | | | 1 | 1 | | | | 1 | | 1 | | | | | 1 | | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | | 1 | | | 1 | | 1 | | | 1 | |
| 18 | | | | 1 | 1 | | | | 1 | | 1 | | | | | 1 | | | 1 | | | 1 | | | | 1 | | | | 1 | | | | | 1 | | | 1 | | | 1 | | | 1 | |
| 19 | | | | 1 | 1 | | | | 1 | | 1 | | | | | 1 | | | 1 | | | 1 | | | | 1 | | | | 1 | | | | | 1 | | | | 1 | | 1 | | | 1 | |

# 4. Evaluation of water management options

## 4.1 Impact assessment

### *4.1.1 Impacts of water management options on the basin*

The impacts of water management options on the basin are shown in Figure 4.1. The factors display positive and negative relationships with different options. For instance, option 1 (*promoting new water and soil conservation techniques*), strongly and positively influences rainfed cropland, soil water reserve & water availability in the reservoirs, pasture and cattle raising. However, it influences negatively the surface and ground water, soil degradation and flooding. The option 3 (*creation and rehabilitation of hydraulic infrastructure*), has strong negative relationship with water demand. The option 7 (*Development of new financial instruments*), shows strong and positive influence on irrigated cropland and job creation. The option 12 (*protection against forest fire*) displays a positive influence with forest resources criteria and a negative one with forest fire criteria. Finally, the population livelihood and settlements criteria is strongly and positively affecting the option 19 (*developing skills for young people*), while the water quality criteria is being positively affected by the option 12 (*protection against fire*).

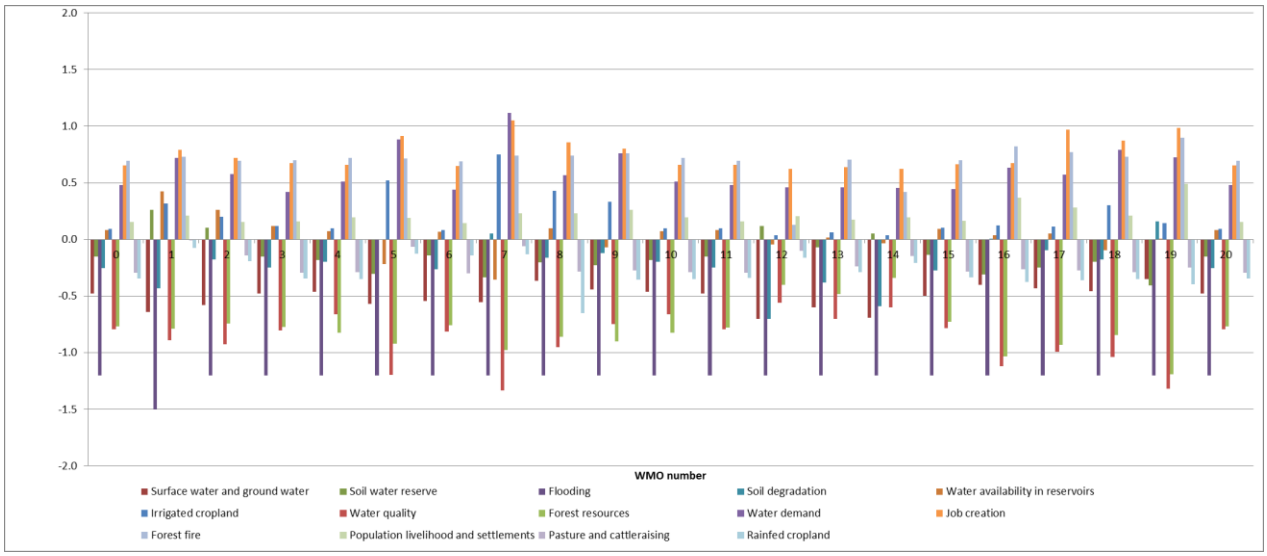


**Figure 4.1:** estimated impacts of water management options.

## 4.2 Multi-Criteria Analysis

### *4.2.1 Selected criteria and their preference values*

The characteristics of the options (Table 3.2) and the factors from the FCM (Figure 4.2) were considered as criteria for the Multi-criteria Analysis (MCA). We pre-selected 6 characteristics and 9 factors from the FCM as potential criteria. Out of this list of 15 potential criteria, participants of the 2nd stakeholder workshop selected all 15 criteria to be included in the MCA. The results are shown in the diagram below (Figure 4.2). The soil degradation is the criterion that received the highest number of votes followed by surface water and ground water; however rainfed cropland got the lowest number of votes.

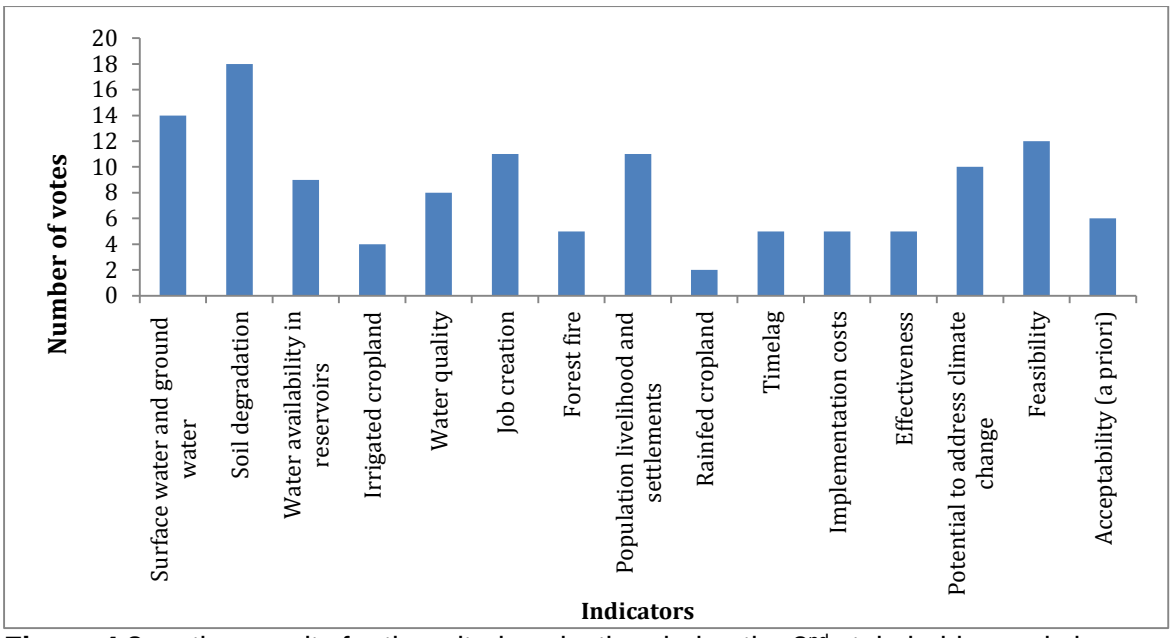


**Figure 4.2:** voting results for the criteria selection during the 2nd stakeholder workshop.

Participants were asked if there were missing criteria. They proposed three additional ones: EC1: remediation of the land tenure situation, EC2: ability of the population to organize and EC3: integration of operational research.

In a next step, workshop participants were asked to assign a score from 1 to 10 for the criteria selected according to their importance (Figure 4.3).

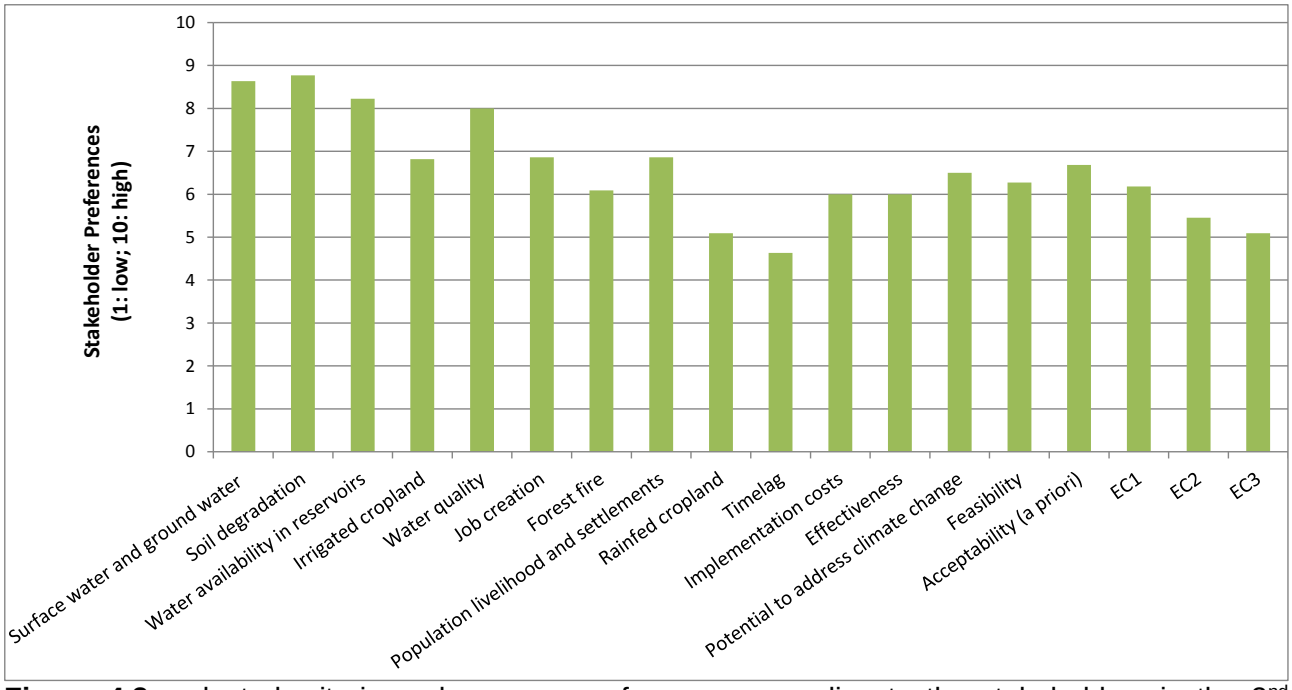


**Figure 4.3:** selected criteria and average preferences according to the stakeholders in the 2nd workshop. The criteria EC1-3 are additional criteria suggested by stakeholders, but they were not used in subsequent steps of the Multi Criteria Analysis.

### *4.2.2 Performance of the selected criteria*

Once the stakeholders selected the criteria, they were asked to indicate how each criterion should change preferably. For almost all criteria, a higher level is preferred (more water available, more

crop production). For two criteria (soil degradation and forest fires) a decrease is considered as desirable. Job creation is positive if there is a slight increase, but if in case of high increase, it is not considered as desirable anymore, mainly because of the fear of a degradation of the resources. Since the increase in the pressure of the population on the environment is modelled in the map, none of the options were considered as being able to pass the breakdown threshold; we only considered the positive part of the curve. Similarly, an increase in population livelihood is positive as long as it reduces poverty. However, any further increase would not be considered as an improvement compared to the threshold by some stakeholders. Because we do not expect the proposed management options to be able to pass the threshold by 2030, we just considered the positive part of the curve in the analysis.

We combined this information with the estimated changes and characteristics and show the result in a heat diagram in Figure 4.4. The results show that options 8 (use of water irrigation technologies) and 19 (developing skills for young people) could have the most preferable impacts on surface water & ground water as well as population livelihood. Option 7 (development of new financial instruments) could result in the most preferred outcomes with regards to job creation and irrigated cropland. The changes assessed for water quality, soil degradation and forest fires are the most preferred for the option 12 (protection against forest fire). The water availability in reservoirs and rainfed cropland are estimated to change in a preferable direction with the first option (promote new water and soil conservation techniques). Almost all of the options have the most preferred characteristics with regards to the timelag and implementation costs. About half of the options considered score well with regards to acceptability. Most options have medium preferences with regards to their characteristics.


**Figure 4.4:** Heat diagram showing preferred changes and characteristics of the criteria included in the MCA. Numbers refer to the water management options in Table 3.1**.**

### *4.2.3 MCA results*

To evaluate the water management options, we combined the results of the impact assessment for each water management option, the characterisation of each water management option, the criteria selected by stakeholders and the preferences assigned to them in a MCA. Below, we show three sets of results; in Figure 4.5 we show the outcome based only on criteria derived from the Fuzzy Cognitive Map (and the impact assessment). In Figure 4.6 we show the outcome of the MCA based only on criteria from the characterisation of the options and in Figure 4.7 we show the outcomes of the MCA based on the full set of criteria as selected by participants of stakeholder workshop II.

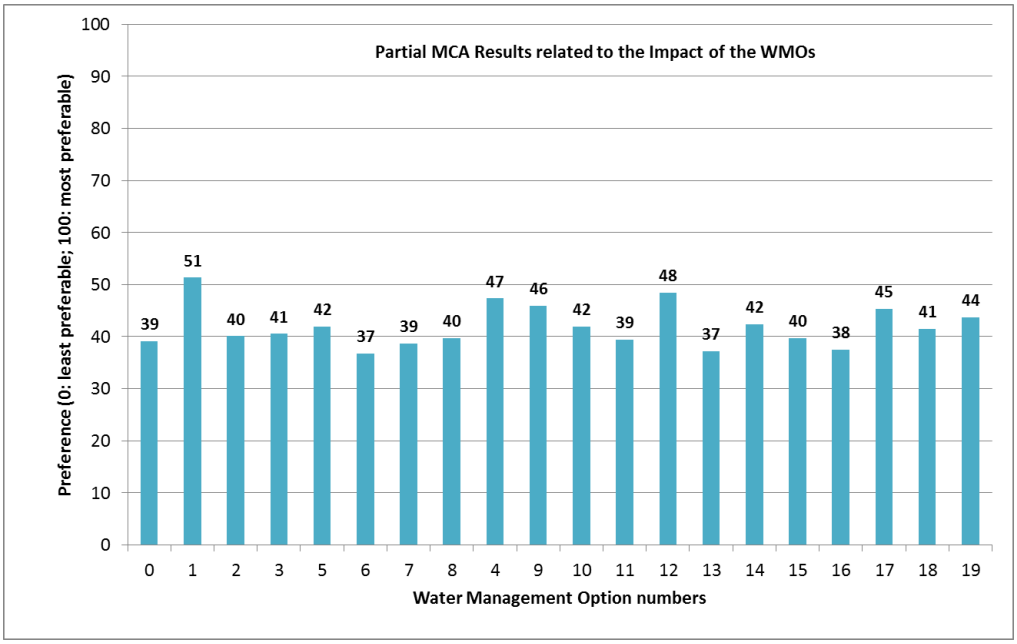


**Figure 4.5:** outcome of the Multi-Criteria Analysis based on criteria (and their changes) derived from the Fuzzy Cognitive Map and the impact assessment. Numbers refer to the water management options in Table 3.1.

Figure 4.5 shows that partial MCA results vary between 37 and 51. Option 1 (promote new water and soil conservation techniques) has the highest score followed by option 12 (protection against forest fire), however option 6 (development and sustainable use of agricultural land resilient to climate change) and option 13 (introduction of new agro forestry species and enrichment of existing forest) have the lowest values. We could notice that several options have very close results; we particularly mention: option 2 (consolidation of existing water and soil conservation techniques), option 3 (creation and rehabilitation of hydraulic infrastructure), option 5 (develop agricultural cooperatives), option 8 (use of water irrigation technologies), option 10 (water discharge control), option 14 (promoting a better governance of forest resources), option 15 (awareness campaign and courses on the management of natural resources) and option 18 (encourage investments).

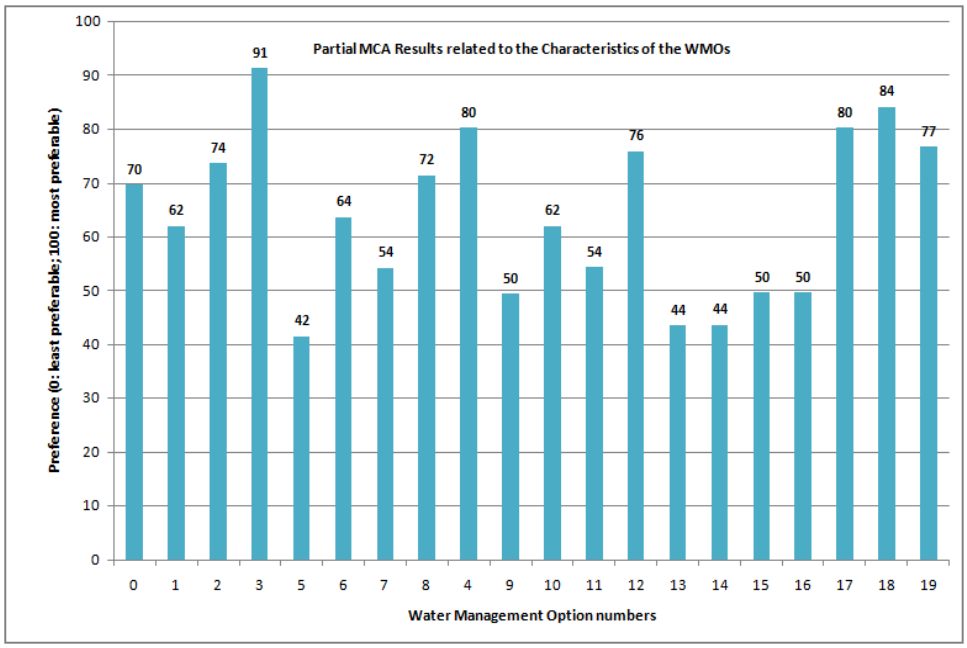


**Figure 4.6:** outcome of the Multi-Criteria Analysis based on criteria derived from the characterisation of the options. Numbers refer to the water management options in Table 3.1

Figure 4.6 shows a big difference on the results of options. These results vary between 91 and 42. The option 3 (creation and rehabilitation of hydraulic infrastructure) was the most preferable while the option 5 (develop agricultural cooperatives) was the least preferable. Some options as the option 13 (introduction of new agro forestry species and enrichment of existing forest) and 14 (promoting a better governance of forest resources); option 15 (awareness campaign and courses on the management of natural resources) and 16 (involve stakeholders in all steps of decision making) have the same value.

The overall outcomes of the MCA are shown in Figure 4.7. According to these results, the three options that target the first challenge ″water quantity″ vary between 52 and 58; the option 3 (creation and rehabilitation of hydraulic infrastructure) has the highest score while the option 2 (consolidation of existing water and soil conservation techniques) has the lowest one. For the second challenge ″agriculture″, the option 8 (use of water irrigation technologies) has the highest score while the option 6 (development and sustainable use of agricultural land resilient to climate change) has the lowest one. The option 10 (water discharge control) from challenge 3 ″water quality″ has the most important score compared to the option 3 from the same challenge. Concerning the fourth challenge ″Forest resources″, the option 12 (protection against forest fire) has the highest score, however the option 13 (introduction of new agro forestry species and enrichment of existing forest) has the lowest important one. The option 15 (awareness campaign and courses on the management of natural resources) and 16 (involve stakeholders in all steps of decision making) of the challenges 5 ″The awareness of the civil society″ have very close results. The three options tackling the challenge 6; ″Human resources and jobs″ have also very similar outcomes.

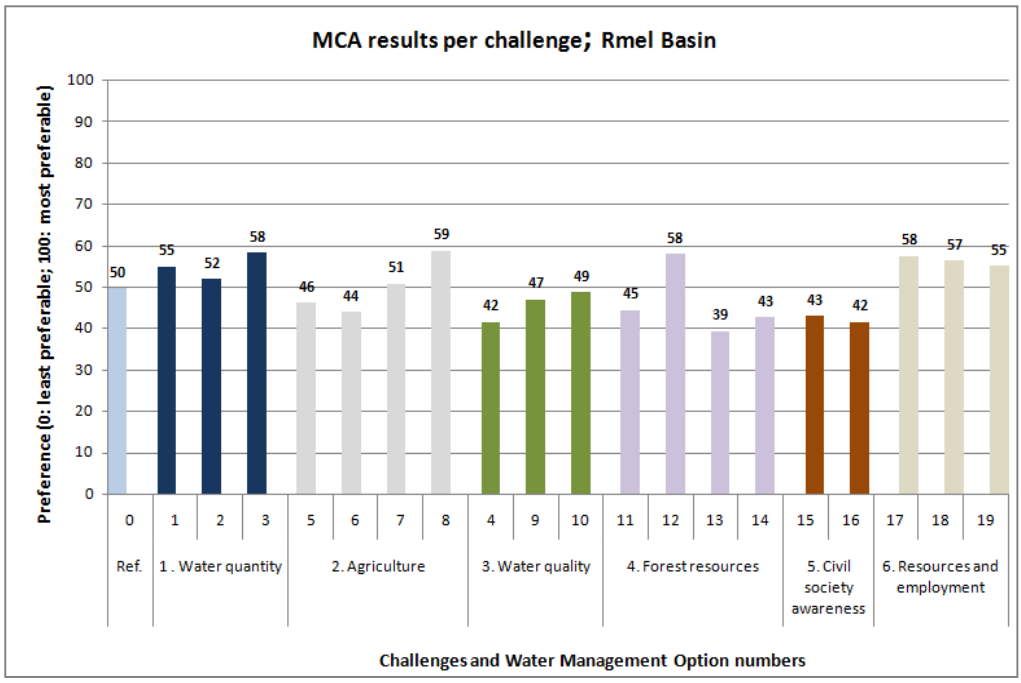


**Figure 4.7:** outcome of the Multi-Criteria Analysis based on criteria (and their changes) derived from the Fuzzy Cognitive Map and the impact assessment. Numbers refer to the water management options in Table 3.1.

### *4.2.4 Sensitivity analysis*

We conducted two sensitivity analyses to investigate how the outcomes of the MCA were related to the panel of participating stakeholders and to the list of considered criteria. These analyses provide insight if some options would have received a very different evaluation in the MCA if some stakeholders had not taken part in the evaluation or if one criterion had not been considered. The results are presented in box plots (Figures 4.8 and 4.9), which show the distribution of MCA outcomes when randomly selecting a subset of stakeholders or criteria for 1000 times. The boxes represent the middle 50% of MCA outcomes for each WMO. The thick line in the middle of each box shows the median value in the distribution of MCA outcomes for a WMO, i.e. half of the MCA outcomes are greater than or equal to this value and half are less.

The sensitivity of the MCA outcomes to the panel of stakeholders is shown in Figure 4.8. Little variation is shown in the MCA outcomes in connection to the stakeholders that participated in stakeholder workshop II. This suggests that the stakeholders that participated in the second stakeholder workshop generally had a high level of agreement with each other with regards to their preferences for different criteria. It should be noted that the results of this sensitivity analysis do not reflect sensitivity of the MCA outcomes to preferences of stakeholders that did not participate in the second stakeholder workshop.

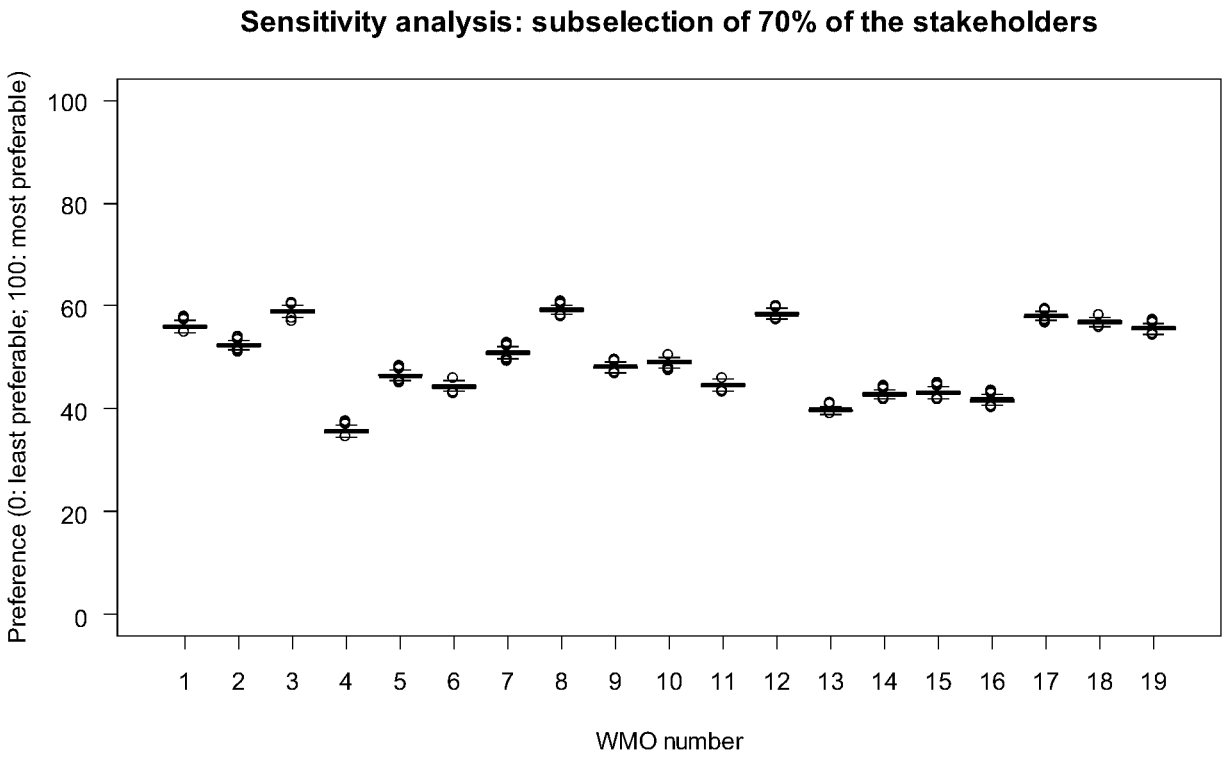


**Figure 4.8:** sensitivity of the MCA outcomes to the panel of stakeholders by randomly selecting for 1000 times a sub-panel of 70% of the stakeholders. Numbers refer to the water management options in Table 3.1.

The sensitivity of the MCA outcomes to the panel of selected criteria is shown in Figure 4.9. In contrast to the sensitivity of the MCA results to the participants of stakeholder workshop II, the MCA outcomes were highly sensitive to the criteria used to evaluate each WMO. The options developing financial awareness tools (WMO 7: development of new financial instruments) and Developing skills for young people (WMO 19: developing skills for young people) are most strongly affected by the selection of criteria, while Use of water irrigation technologies (WMO 8: use of water irrigation technologies) and Improvement of the treatment of waste water (WMO 9: improvement of the treatment of waste water) are least strongly affected by the selection of the criteria.

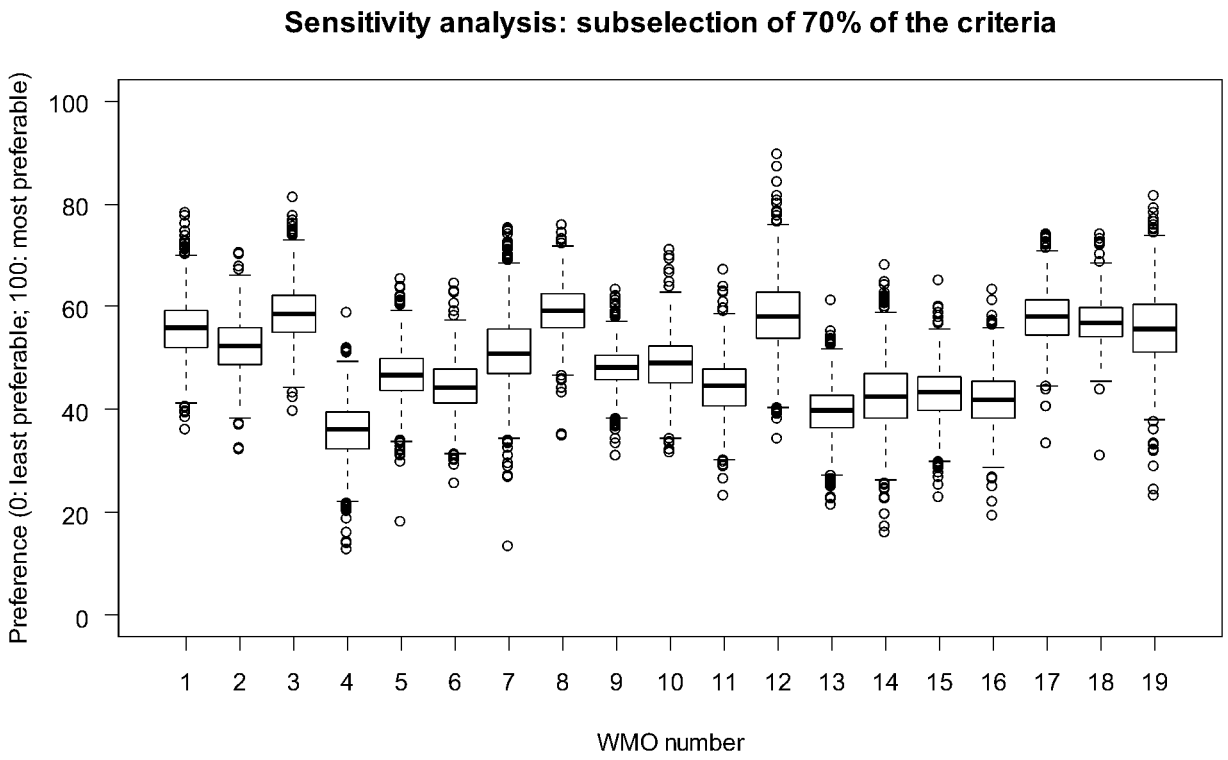


**Figure 4.9:** sensitivity of the MCA outcomes to the selected criteria randomly selecting for 1000 times a sub-selection of 70% of the criteria. Numbers refer to the water management options in Table.1

Among the impacts, rainfed cropland is a criterion that has little influence on the MCA outcomes, while irrigated cropland and population and livelihood are important impacts to be considered as they have a large influence on the results of the MCA. With regards to the characteristic of the options, acceptability is a criterion having a strong influence on the MCA outcomes, while effectiveness and potential to address climate change have relatively little influence. It should be noted that the results of this sensitivity analysis do not reflect sensitivity of the MCA outcomes to criteria that were not selected by stakeholders during the 2nd stakeholder workshop.

## 4.3 Cost assessment

A cost assessment was carried out for all options. The results of this assessment are considered to be indicative only, because a detailed assessment for 19 options was not feasible with given resources. Hence, the results of the cost assessment need to be interpreted with care. A more detailed assessment of costs and benefits is required before these options could be implemented.

### *4.3.1 Costs of water management options*

Based on the collected data from different stakeholders, (unit cost and schedule of implementation of each action) a calculation of the cost for each water management options was done. Details are presented in annex II and results are shown in Figure 4.10. The figure shows that the option 10 (water discharge control) presents the highest cost followed by option 11 (Reduction of society pressure on forests).Option 4 (application of taxes to protect water quality) is the least expensive. The options 14 (promoting a better governance of forest resources), 15 (awareness campaign and learning on natural resources management), 16 (involve stakeholders in all steps of decision making) and 19 (developing skills for young people) have very close costs.

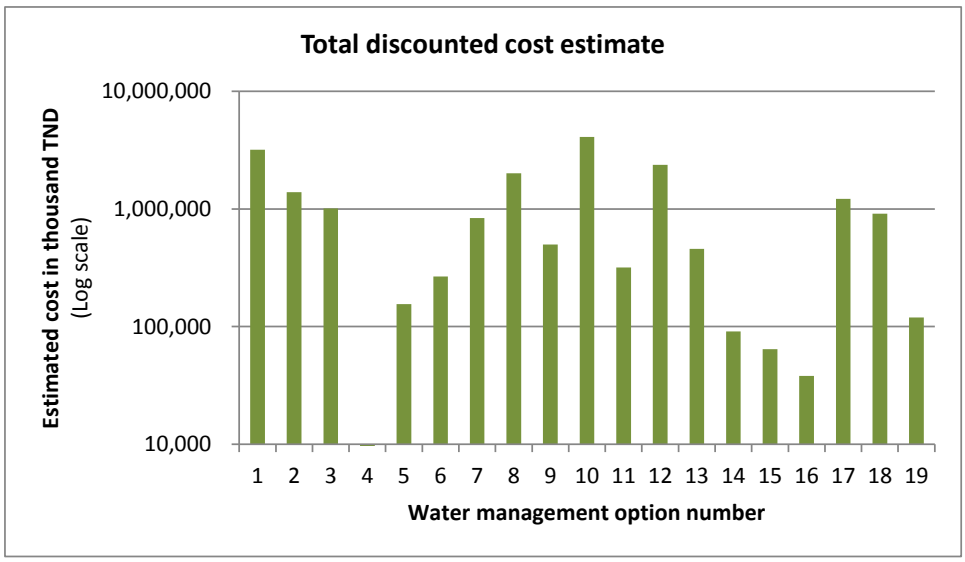


**Figure 4.10:** total discounted cost estimate on a logarithmic scale

According to Figure 4.12, three categories of options can be distinguished:

- a first category that includes the least expensive options, i.e. less than 100,000 TND, (option14 (promoting a better governance of forest resources)),15(awareness campaign and learning on natural resources management) and 16(involve stakeholders in all steps of decision making)),
- a second one that groups options that have cost in the range of 100,000 TND to 1,000,000 TND (option 3 (creation and rehabilitation of hydraulic infrastructure.), 5 (develop mutual companies of agricultural services), 6 (development and sustainable use of agricultural land resilient to climate change), 7 (development of new financial instruments.),9 (improvement of the treatment of waste water), 11 (reduction of society pressure on forests),13 (introduction of new agro forestry species and enrichment of existing forest) and 19 (developing skills for young people)),
- a third category that represents the options that cost more than one million TND (option 1 (promote new water and soil conservation techniques), 2 (consolidation of existing water and soil conservation techniques), 8 (use of water irrigation technologies), 10 (water discharge control), 12 (protection against forest fire) and 17 (promote projects that generate more income)).

The option 4 (application of taxes to protect water quality), can be considered as an exception since its cost was negligible compared to other options.

### *4.3.2 Cost-effectiveness*

To be able to compare the costs of options with regards to their benefits, we performed cost-effectiveness analysis. The cost-effectiveness analysis combines results of the partial MCA results for the impact assessment (i.e. the characteristics are not considered) and the cost assessment and was calculated for each WMO as the ratio between the cost of implementation and the effectiveness indicator (the difference between the partial MCA results obtained for an WMO and the partial MCA result related to the baseline). The cost-effectiveness ratio in Figure 4.11; a WMO is highly cost-effective it the price per unit is low.

The figure shows that option 4 (application of taxes to protect water quality) has the best cost / effectiveness ratio followed by option 14 (promoting a better governance of forest resources) and 19(developing skills for young people). The options 1 (promote new water and soil conservation techniques), 8(use of water irrigation technologies) and 12 (protection against forest fire) have a cost / effectiveness ratio very close and relatively low. The options 2 (consolidation of existing water and soil conservation techniques), 3 (creation and rehabilitation of hydraulic infrastructure), 7 (development of new financial instruments), 10 (water discharge control) and 11 (reduction of society pressure on forests) have a low cost / effectiveness ratio. The options 5 (establish mutual companies

of agricultural services), 6 (development and sustainable use of agricultural land resilient to climate change), 13 (introduction of new agro forestry species and enrichment of existing forest) and 14 (promoting a better governance of forest resources) have a negative cost / effectiveness ratio indicating that these options do not turn in the right direction, i.e. these options involve costs, but lead to an overall deterioration of conditions as compared to the baseline scenario without changes in management.

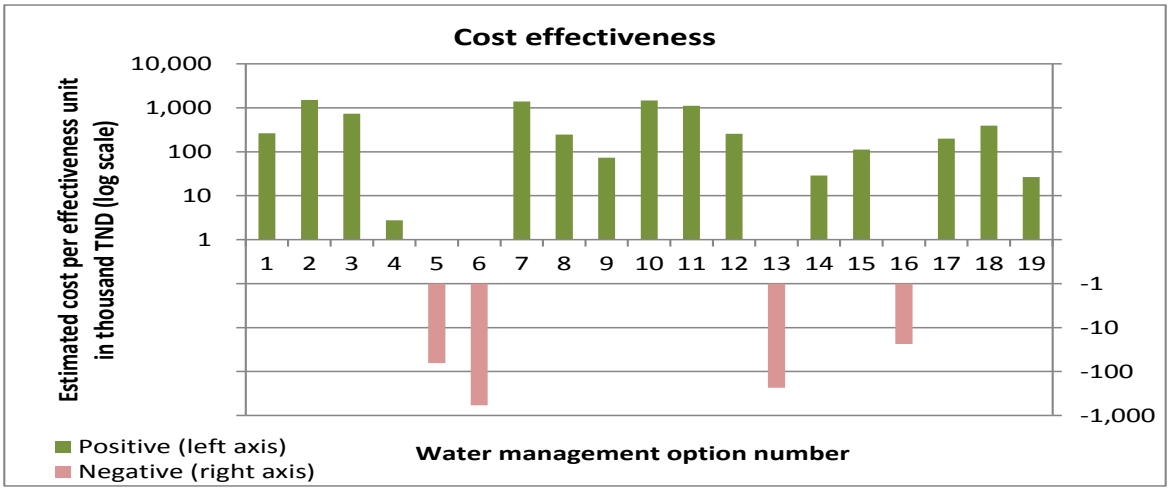


**Figure 4.11:** cost effectiveness in 1000 TND per unit of effectiveness

# 5. Discussion of results

The formulation of issues and water management options for the Rmel river basin has been built and developed according to inputs obtained from stakeholders from different sectors. Based on these inputs six challenges (water quantity, agriculture, water quality, forest resources, awareness of civil society, and human resources and jobs) were identified, as well as 19 options to address them.

The impact assessment of the WMOs on the river basin dynamics and challenges revealed that promoting new water and soil conservation techniques(WMO1) strongly and positively influences rainfed cropland, soil water reserve, water availability in the reservoirs, pasture and cattle raising. While it negatively affect the surface and ground water, soil degradation and flooding. The water demand criteria could be decreased by the creation and rehabilitation of hydraulic infrastructure (WMO3). Moreover, irrigated cropland and job creation could be increased by the development of new financial instruments. Similarly, population livelihood and settlements could be increased by the developing skills for young people (WMO19).

Impacts of the WMO on ecosystem services indicated that the provision of most of these services is improving the context compared to the baseline by protection against forest fire (WMO12) and promoting a better governance of forest resources (WMO14) corresponding to the challenge "forest resources". Development of new financial instruments tackling the challenge "Agriculture", leads to an increase in irrigated cropland, but a degradation of most other ecosystem services compared to the baseline. With regards to overall options, the most ecosystem services, and water quality are decreased compared to the baseline. The water availability in reservoirs is slightly improved compared to the baseline by options 1 and 2 relating to the first challenge "water quantity". The irrigated cropland was the criteria that had undergone an improvement by the highest number of options.

During the 2nd stakeholder workshop, participants were asked to select the criteria (factors derived from the basin's cognitive map, and characterisation criteria) used in the MCA. In a next step, they assigned a score from 1 to 10 for the criteria selected according to their importance; Then, they

proposed three additional ones: EC1: remediation of the land tenure situation, EC2: ability of the population to organize and EC3: integration of operational research. The results based on the selected criteria for the MCA indicate that promoting new water and soil conservation techniques (WMO1) has the highest preference score followed by protection against forest fire (WMO12), however the development and sustainable use of agricultural land resilient to climate change (WMO6) and the introduction of new agro forestry species and enrichment of existing forest (WMO13) have the lowest values. These results show that grey options are generally more preferred in this basin than the green solutions.

Preliminary results of Multi-Criteria Analysis (MCA) were presented to the participants. After presenting the results, participants were divided into six groups. The first group discussed challenge 1 (Quantity of water), the second challenge 2 (Agriculture) and the third challenge 3 (Water quality). Group 4 dealt with challenge 4 (Forestry resources), while the two remaining groups respectively discussed challenge 5 (Sensitization of civil society) and 6 (Human resources and employment). The results combined the results of the impact assessment for each WMO, the characterisation of each WMO, the criteria selected by stakeholders and the preferences assigned to these criteria. These results showed that the highest preference was for creation and rehabilitation of hydraulic infrastructure (WMO3) related to the first challenge (water quantity). Use of water irrigation technologies (WMO8) is shown related to challenge 2 (agriculture). While, water discharge control (WMO10) is related to challenge 3 (water quality) and protection against forest fire (WMO12) displayed being related to challenge 3 (forest resources). The options tackling challenge 5 and challenge 6 have very close preferences.

After presenting the results, participants were invited to review and comment on the preliminary outcomes. They commented the partial results indicating if the preference scores corresponded with their expectations. Some options were considered well reflected by the analysis results, like options corresponding to challenge 1 (water quantity), challenge 2 (agriculture) and challenge 3 (water quality). Other options were considered ranking lower than expected, like option14: (promoting a better governance of forest resources) from the challenge 4 ''forest resources''. According to the participants, this option should was expected to have the highest preference score, because the improvement of governance is expected having an impact on the protection against forest fires (WMO12). Moreover, it would have ensured the reduction of society pressure on forests (WMO11). Similarly, option 16 (involve stakeholders in all steps of decision making) received a low preference score, but almost all stakeholders insisted on the importance of a decision-making in which all actors are involved. In contrast, option13 should, according to stakeholders, have a value clearly lower than the one it received.

In addition to the Multi-Criteria Analysis, the cost of each water management option was assessed. During stakeholder consultation II, participants discussed in detail the results by examining the unit costs and the implementation timeline for each action in each option. Based on these costs, cost-effectiveness for each option was calculated. The outcomes indicates that the options application of taxes to protect water quality (WMO4) and promoting a better governance of forest resources (WMO14) relating to legislation have the highest cost-effectiveness. Some options have negative cost-effectiveness showing that by implementing of these options; the situation will be worst compared to the baseline.

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# Annex I

## Documentation of the Fuzzy Cognitive Map

Table I.1: Definition of the factors in the cognitive map

| Number | Name of factor | Definition |
|---|---|---|
| F1 | Precipitation | Irregular and high intensity regime of precipitation |
| F2 | Surface water and ground water | Volumes of water in rivers and the level of aquifers. |
| F3 | Soil water reserve | Volume of water that is stored in the soil |
| F4 | Flooding | Natural extreme event. |
| F5 | Soil degradation | Caused by heavy precipitation on bare soils and steep areas. |
| F6 | Water availability in reservoirs | Volume of water available in dams, hill, lakes, etc. |
| F7 | Irrigated cropland | Irrigated fields that are created downstream after the construction of the dam. |
| F8 | Water quality | Refers to pollution of rivers and aquifers by industrial zone that is recently created. |
| F9 | Forest resources | Various tree species (productive and protected species). |
| F10 | Water demand | Water demand of different sectors (Agriculture, population, industry and tourism). |
| F11 | Soil and water conservation techniques | Limited within the catchment, they are located on steep up stream farmlands to collect runoff water. |
| F12 | Job creation | Creation of jobs in agricultural and environmental sectors to promote development in the region. |
| F13 | Forest fire | Disaster that can be natural or anthropogenic. |
| F14 | Industry and tourism | Includes different enterprises, factories ,olive presses and thermal stations, etc. |
| F15 | Population livelihood and settlements | Includes all population categories and settlements in different sectors based on promoting new agricultural and environmental projects |
| F16 | Pasture and cattle raising | Developed mainly in Rural communities. |
| F17 | Rainfed cropland | Land contains crops that rely on rainfall. |
| F18 | Dry periods | Succession of dry years. |

Table I.2: Documentation of the relationships in the cognitive maps

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **F1** | 0 | 0.9 | 0.9 | 0.6 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F2** | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F3** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0.6 | 0 |
| **F4** | 0 | 0 | 0 | 0 | 0.3 | -0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F5** | 0 | 0 | -0.6 | 0 | 0 | 0 | 0 | -0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F6** | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F7** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.3 | 0 | 0.9 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 |
| **F9** | 0 | -0.3 | 0 | 0 | -0.6 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F10** | 0 | 0 | 0 | 0 | 0 | -0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F11** | 0 | 0 | 0.6 | -0.6 | -0.6 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F12** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 |
| **F13** | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | -0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F14** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0.3 | 0 | 0.3 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F15** | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | -0.6 | -0.6 | 0.6 | 0 | 0 | 0.6 | 0 | 0 | 0.6 | 0.3 | 0 |
| **F16** | 0 | -0.3 | 0 | 0 | 0.6 | 0 | 0 | 0 | -0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F17** | 0 | -0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F18** | 0 | -0.6 | 0 | 0 | 0.3 | -0.3 | 0 | 0 | -0.3 | 0 | 0 | 0 | 0.6 | 0 | 0 | -0.3 | -0.3 | 0 |

Table I.3: Documentation of the reasoning behind the relationships in the cognitive maps

| From | To | Justification |
|---|---|---|
| F1 Precipitation | F2 Surface and groundwater | Strong positive relation because a fraction of precipitation reaches rivers directly as runoff or, indirectly, through deep drainage to groundwater and stream base flow. |
| F1 Precipitation | F3 Soil water reserve | Strong positive relation because a fraction of rainfall infiltrates into the soil and is available for plants. |
| F1 Precipitation | F4 Flooding | Medium positive relation as flooding occurs occasionally |
| F1 Precipitation | F5Soil degradation | Strong positive relation because precipitation is the main reason of the soil degradation in the Rmel watershed |
| F2 Surface water and ground water | F5 water availability in reservoirs | Medium positive relation because the water in reservoirs does not come only from surface water and groundwater ,it comes from precipitations also |
| F2 Surface water and ground water | F8 water quality | Medium positive relation displays that surface water can affect the quality of water |
| F3Soil water reserve | F9 Forest resources | Low positive relation because the soil water reserve could maintain the growth of forests |
| F3Soil water reserve | F16 Pasture and cattle raising | Medium positive relation because the more we have water the more grass we have for the cattle |
| F3Soil water reserve | F17 Rainfed cropland | Medium positive relation because rainfed croplands depend on water |
| F4 Flooding | F6 Water availability in reservoirs | Low negative relation due to the damage that could be done by flooding |
| F4 Flooding | F5 Soil degradation | Low positive relation because flooding may cause runoff that leads to the soil degradation |
| F5 Soil degradation | F3Soil water reserve | Medium negative relation because when soil is degraded its retention capacity decreases |
| F5 Soil degradation | F8 water quality | Medium negative relation because when soil is degraded the salinity increases and affects water quality |
| F6 Water availability in reservoirs | F7 Irrigated cropland | Medium positive relation because when we have water in reservoirs the irrigated cropland will not depend only on rainy seasons |
| F7 Irrigated cropland | F8 water quality | Low negative relation because of the use of fertilizers and pesticides |
| F7 Irrigated cropland | F1 Water demand | Strong positive relation because of the water-consuming crops (watermelon, tomatoes…) |
| F7 Irrigated cropland | F12 Job creation | Medium positive relation because developed agriculture attracting somehow employers |
| F8 Water quality | F15 population livelihood and settlements | Low positive relation because in somehow when the water quality is good it might improve the population livelihood and hence it would have a positive impact on population-related sectors |
| F9 Forest resources | F2 surface water and ground water | Low negative relation because in some way with more forest we have more trees consuming water from aquifers |
| F9 Forest resources | F5 Soil degradation | Medium negative relation because forest resources contribute in protecting the soil |
| F9 Forest resources | F8 water quality | Low positive relation because forest protect soil from degradation and eventually the water quality, moreover the growth of forest does not require fertilizers so the water quality is intact |
| F10 Water demand | F5 water availability in reservoirs | Medium negative relation because when the water demand goes up the water availability decreases especially in summer |
| F11 soil and water conservation techniques | F3 soil water reserve | Medium positive relation because these techniques would decrease the runoff so the soil water reserve is preserved |
| F11 soil and water conservation techniques | F4 Flooding | Medium negative relation because these techniques can lessen the impact of flooding |

| | | |
|---|---|---|
| F11 soil and water conservation techniques | F5 Soil degradation | Medium negative relation because these techniques can lessen the impact of the rainfall and runoff that cause the soil degradation |
| F11 soil and water conservation techniques | F5 water availability in reservoirs | Medium positive relation because these techniques provide the protections of reservoirs and do not allow sediment storage in reservoirs. They keep the storage capacity of the reservoirs |
| F11 soil and water conservation techniques | F12 Job creation | Low positive relation because these techniques require workers and funding, which is lacking currently |
| F12 Job creation | F15 population livelihood and settlements | Medium positive relation because more jobs may attract more people |
| F13 Forest fire | F5 Soil degradation | Medium positive relation because fire will damage plants and trees so it will accelerate the soil degradation |
| F13 Forest fire | F9 Forest resources | Medium negative relation for the fact that more fires destroy forest resources |
| F14 Industry and tourism | F8 water quality | Low negative relation because of the waste water of factories, olive presses… |
| F14 Industry and tourism | F10 Water demand | Low positive relation because growing industry and tourism need more water |
| F14 Industry and tourism | F12 Job creation | Low positive relation because when the industrial and touristic sectors grow, they create jobs |
| F15 population livelihood and settlements | F7 Irrigated cropland | Low positive relation. higher population would require more food production |
| F15 population livelihood and settlements | F8 water quality | Medium negative relation because the growth of population livelihood affect the water quality |
| F15 population livelihood and settlements | F9 Forest resources | Medium negative relation because of the growth of urbanization. |
| F15 population livelihood and settlements | F10 Water demand | Medium positive relation because when population grows, it needs more water |
| F15 population livelihood and settlements | F13 Forest fire | Medium positive relation and this is due to the lack of awareness to the importance of forest resources |
| F15 population livelihood and settlements | F16 Pasture and cattle raising | Low positive relation. This relation is due to the fact that when jobs are created they will target the population livelihood so pasture and cattle raising increases |
| F15 population livelihood and settlements | F17 Rainfed cropland | Low positive relation. Higher population would require more food production |
| F16 Pasture and cattle raising | F2 surface water and ground water | Low negative relation because more cattle means more needs in water |
| F16 Pasture and cattle raising | F5 Soil degradation | Medium positive relation because of the overgrazing and overexploitation of the land |
| F16 Pasture and cattle raising | F9 Forest resources | Low negative relation because of the overgrazing |
| F17 Rainfed cropland | F2 surface water and ground water | Low negative relation because rainfed croplands depend on surface and ground water coming from precipitations |
| F18 Dry periods | F2 surface waterand ground water | Medium negative relation because in dry periods surface water and groundwater are the most important water supply |
| F18 Dry periods | F5 Soil degradation | Low positive relation because in dry periods vegetation cover will decrease and during autumn period precipitations on bare soils will probably lead to soil loss. The evaporation processes active during dry periods and leads generally to the salinization of the soil surface (bring the salt on surface) |

| | | |
|---|---|---|
| F18 Dry periods | F5 water availability in reservoirs | Low negative relation because in dry periods there is a frequent use of water from the reservoirs |
| F18 Dry periods | F9 Forest resources | Low negative relation because in dry periods forest resources became more fragile |
| F18 Dry periods | F13 Forest fire | Medium positive relation because high temperature can ignite fire |
| F18 Dry periods | F16 Pasture and cattle raising | Low negative relation because in dry periods pasture and cattle raising are affected due to the vegetation shortage |
| F18 Dry periods | F17 Rainfed cropland | Low negative relation because in dry periods rainfed croplands are affected because of lack of precipitation |

# Annex II
## Detailed descriptions of the water management options

### Water Management option1
# Promote new water and soil conservation techniques

**Challenge:** Water quantity

**Description**
This option aims to promote new water and soil conservation techniques to collect runoff water. These techniques are placed on agricultural lands (upstream) and are based on technological and engineering solutions (waterway development techniques and watershed development techniques). Moreover, from now on, this option should consider the practices and participatory approaches.

Example: Mechanical terraces, mechanical benches, dry stone lines. Build more hill lakes, dikes.

**Reference**
1st stakeholder workshop of 24thJune + interviews, report (1)* + meeting within Regional Office for Agricultural Development, reports PDP*, associations, Non-Governmental Organisation.

**See reference list*

**Implementation in cognitive map**
Relationships are changed from:
- Soil and water conservation techniques to Soil degradation from 2- (-0.6) to 3- (-0.9)
- Soil and water conservation techniques to Soil water reserve from 2+ (+0.6) to 3+ (+0.9)
- Soil and water conservation techniques to Flooding from 2- (-0.6) to 3- (-0.9)
- Soil and water conservation techniques to Water availability in reservoirs from 2+ (+0.6) to 3+ (+0.9)
- Dry periods to Water availability in reservoirs from 1- (-0.3) to (-0.1).

**Cost estimation**
The cost estimation is based on the following assumptions:
- Creation of mechanical benches for a total amount of 4500ha in 15 years;
- Creation of dry stone lines for a total of 500 ha in 5 years
- Creation of 3 hill lakes; one in year 3, the second in year 7 and the third in year 10
- Construction of recharge structures at a rhythm of 8 units in 15 years
- Construction of dry stone threshold for a total of 750 ha in 15 years
- Construction of manual benches for a total of 1500 ha in 15 years.

**Cost elements and cost unit estimation.**

| Year | Mechanical benches | Dry stone lines | hill lakes | Recharge structures | Dry stone Seuil | Manual benches |
|---|---|---|---|---|---|---|
| | ha | ha | unit | unit | ha | ha |
| 2016 | 300 | 100 | | | 50 | 100 |
| 2017 | 300 | 100 | | 2 | 50 | 100 |
| 2018 | 300 | 100 | 1 | 2 | 50 | 100 |
| 2019 | 300 | 100 | | 2 | 50 | 100 |
| 2020 | 300 | 100 | | 2 | 50 | 100 |
| 2021 | 300 | | | | 50 | 100 |
| 2022 | 300 | | 1 | | 50 | 100 |
| 2023 | 300 | | | | 50 | 100 |
| 2024 | 300 | | | | 50 | 100 |
| 2025 | 300 | | 1 | 2 | 50 | 100 |
| 2026 | 300 | | | 2 | 50 | 100 |
| 2027 | 300 | | | 2 | 50 | 100 |
| 2028 | 300 | | | 2 | 50 | 100 |
| 2029 | 300 | | | | 50 | 100 |
| 2030 | 300 | | | | 50 | 100 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Mechanical benches | DT/ha | 300 |
| Dry stone lines | DT/ha | 1,350 |
| Construction of hill lakes | DT/unit | 250,000 |
| Recharge structures | DT/unit | 1,350 |
| Dry stone seuil | DT/ha | 1,350 |
| Manual benches | DT/ha | 1,350 |

The total discounted cost: 3,508,769TND (TND 2016, discount rate: 10%).

## Water Management option2

# Consolidation of existing water and soil conservation techniques

**Challenge:** Water quantity

**Description**
This option aims to improve the function of existing soil and water conservation techniques based on ecological solutions. It is based on the strengthening of these techniques by plantations. The implication of Rural Development firms (e.g., SMVDA) and the setting for incentive context become crucial. This option includes:

- Maintenance and repair of existing benches
- Correction and protection of gullies (linear and transversal plantations)
- Pastoral plantation (nearby of wadis)
- Fixation of rivers by plantation of Acacia and Ceratonia siliuqua
- Consolidation of benches ( pastoral plantation/ plants)
- Plantation in upstream of basin

**Reference**
1st stakeholder workshop of 24 June+ interviews, report(1) + meeting within Regional Office for Agricultural Development, reports PDP, associations, ONG.

**Implementation in cognitive map**
Relationships are changed from:

- Soil and water conservation techniques to Soil water reserve from 2+ (+0.6) to 3+ (+0.9)
- Soil and water conservation techniques to Water availability in reservoirs from 2+ (+0.6) to 3+ (+0.9)

**Cost estimation**
The cost estimation is based on the following assumptions:

- Consolidation of mechanical benches for a total of 750 ha in 15 years;
- Maintenance of existing techniques for a total of 3750 ha in 15 years
- Rehabilitation of existing benches for a total of 3000 ha in 15 years,
- Reprofiling and clearing of wadis for a total of 30 km in 15 years

Only activities are included in the cost assessment of which the participants of the third workshop confirm to be implemented in the basin during the next years.

**Cost elements and cost unit estimation**

| Year | Consolidation of Mechanical Benches | Maintenance of existing techniques | Rehabilitation of benches | Reprofiling and clearing of wadis |
|---|---|---|---|---|
| | ha | ha | ha | Km |
| 2016 | 50 | 250 | 200 | 2 |
| 2017 | 50 | 250 | 200 | 2 |
| 2018 | 50 | 250 | 200 | 2 |
| 2019 | 50 | 250 | 200 | 2 |
| 2020 | 50 | 250 | 200 | 2 |
| 2021 | 50 | 250 | 200 | 2 |
| 2022 | 50 | 250 | 200 | 2 |
| 2023 | 50 | 250 | 200 | 2 |
| 2024 | 50 | 250 | 200 | 2 |
| 2025 | 50 | 250 | 200 | 2 |
| 2026 | 50 | 250 | 200 | 2 |
| 2027 | 50 | 250 | 200 | 2 |
| 2028 | 50 | 250 | 200 | 2 |
| 2029 | 50 | 250 | 200 | 2 |
| 2030 | 50 | 250 | 200 | 2 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Consolidation of Mechanical Benches | DT/ha | 200 |
| Maintenance of existing techniques | DT/ha | 250 |
| Rehabilitation of benches | DT/ha | 300 |
| Reprofiling and clearing of wadis | DT/Km | 25,000 |

The total discounted cost: 1,526,920TND (TND 2016, discount rate: 10%).

## Water Management option3

# Creation and rehabilitation of hydraulic infrastructure

**Challenge:** Water quantity

**Description**

Hydraulic structures will be improved to meet the demands of the population (rehabilitation and upgrading of existing networks, construction cisterns and lifting stations, etc.) while maintaining the balance between demand and distribution. This option includes:

- Rehabilitation and modernization of existing drinking and irrigation networks
- construction of storage tanks to increase water supply hours
- extension of drinking networks to cover other households
- create wells for artificial groundwater recharge
- creating shallow wells in zones where water balances are in excess and improvement of pumping conditions
- create lifting stations to cover water demand of rural populations
- Electrification of existing water points that are created at areas covered by Wadi Rmel groundwater.
- individual connection instead of the standpipe
- Facilitate management for Agricultural Development Groups).

**Reference**

1st stakeholder workshop of 24th June+ report (2) + Awareness campaign of 16th December, reports PDP, decision makers at the Ministry of Agriculture.

**Implementation in cognitive map**

Relationships are changed from:

- Irrigated cropland to water demand from 3+ (+0.9) to 2+ (+0.6)
- Population livelihood and settlements to water demand from 2+ (+0.6) to 1+ (+0.3)

**Cost estimation**

The cost estimation is based on the following assumptions:

- The rehabilitation and modernization of the existing drinking water systems and irrigation networks for a total amount of 50 km in 10 years;
- Creation of 3 lifting stations at a rhythm of one every 5 year;
- Construction of one cistern every year during 5 years and 2 cisterns per year during the 5 following years.

**Cost elements and cost unit estimation.**

| Year | Rehabilitation and modernization | Lifting stations | cisterns |
|---|---|---|---|
| | km | unit | Unit |
| 2016 | 5 | 1 | 1 |
| 2017 | 5 | | 1 |
| 2018 | 5 | | 1 |
| 2019 | 5 | | 1 |
| 2020 | 5 | | 1 |
| 2021 | 5 | 1 | 2 |
| 2022 | 5 | | 2 |
| 2023 | 5 | | 2 |
| 2024 | 5 | | 2 |
| 2025 | 5 | | 2 |
| 2026 | | 1 | |
| 2027 | | | |
| 2028 | | | |
| 2029 | | | |
| 2030 | | | |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Rehabilitation and modernization of existing drinking water systems and irrigation networks | DT/Km | 20,000 |
| Creation of lifting stations | DT/unit | 100,000 |
| Construction of cisterns | DT/m3 | 25,000 |

The total discounted cost: 1,110,253 TND (TND 2016, discount rate: 10%).

## Water Management option4

# Application of taxes

**Challenge:** Water quality

**Description**
Launch of taxes to protect the quality of water resources against the threat that comes from industrial areas which discharge their waste directly into the wadis. Taxation is necessary for agriculture and for drinking water. The enforcement of the existing laws becomes a duty.

**Reference**
1st stakeholder workshop of 24 June+ Awareness campaign of 16 December

**Implementation in cognitive map**
Relationship is changed from:

- Industry and tourism to water quality from 1- (-0.3) to (-0.1).

**Cost estimation**
The cost estimation is based on the following assumptions:

- The enforcement of the existing lawsat a rhythm of 1,000 DT every year.

**Cost elements and cost unit estimation.**

| Year | enforcement of the existing laws |
|---|---|
| | an |
| 2016 | 1000 |
| 2017 | 1000 |
| 2018 | 1000 |
| 2019 | 1000 |
| 2020 | 1000 |
| 2021 | 1000 |
| 2022 | 1000 |
| 2023 | 1000 |
| 2024 | 1000 |
| 2025 | 1000 |
| 2026 | 1000 |
| 2027 | 1000 |
| 2028 | 1000 |
| 2029 | 1000 |
| 2030 | 1000 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| The enforcement of the existing laws | DT/an | 1,000 |

The total discounted cost: 8,367 TND (TND 2016, discount rate: 10%).

## Water Management option5

# Developing agricultural cooperatives

**Challenge:** Agriculture

**Description**

Agricultural cooperatives are companies freely organized by farmers to ensure supply of their operations, improve production conditions and facilitate the flow of products. These companies organized under the principle cooperative do not pursue profit. Their exclusive mission is to promote the development of their members' holdings (cost reduction, improved irrigation systems and facilitating the agricultural flow products).This option includes:

- Encourage farmers to organize themselves in cooperatives
- training of employers in the field of agriculture
- guide farmers by organizing awareness campaigns
- society including farmers, local economy, and communities need to strengthen the market of sustainable agriculture
- Legislative actions to facilitate the creation of cooperatives
- Reorganization of rural and earnings distribution.

**Reference**

1st stakeholder workshop of 24 June+ report (2), reports PDP, report (3), decision makers at the Ministry of Agriculture.

**Implementation in cognitive map**

A factor is added with relationships to:

- Agricultural cooperatives to Irrigated cropland 2+ (+0.6)
- Agricultural cooperatives to Pasture and cattle raising 1+ (+0.3)
- Agricultural cooperatives to Rainfed crop production 1+ (+0.3)

**Cost estimation**

The cost estimation is based on the following assumptions:

- The training of employers in the field of agricultureat a rhythm of one session per year during 15 years;
- The organizing awareness campaigns for farmersat a rhythm of one session every year during 6 years and 2 sessions per year during the following years.
- Creation of a total of 3 cooperatives in 15 years; the first in second year, the second in year 7 and the third in year 12.

**Cost elements and cost unit estimation.**

| Year | training of employers in the field of agriculture | organizing awareness campaigns for farmers | creation of cooperatives |
|---|---|---|---|
| | session | session | Unit |
| 2016 | 1 | 1 | |
| 2017 | 1 | 1 | 1 |
| 2018 | 1 | 1 | |
| 2019 | 1 | 1 | |
| 2020 | 1 | 1 | |
| 2021 | 1 | 1 | |
| 2022 | 1 | 2 | 1 |
| 2023 | 1 | 2 | |
| 2024 | 1 | 2 | |
| 2025 | 1 | 2 | |
| 2026 | 1 | 2 | |
| 2027 | 1 | 2 | 1 |
| 2028 | 1 | 2 | |
| 2029 | 1 | 2 | |
| 2030 | 1 | 2 | |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Training of employers in the field of agriculture | DT/session | 5,000 |
| Organizing awareness campaigns for farmers | DT/session | 10,000 |
| Creation of cooperatives | DT/unit | 5,000 |

The total discounted cost: 170,380 TND (TND 2016, discount rate: 10%).

## Water Management option6

# Good use of agriculture land

**Challenge:** Agriculture

**Description**
This option targets a proper use of farmland to improve production and reduce the amount of consumed water.This option includes:

- Promote conservation agriculture
- Introducing adapted crop varieties (crops that adapt to dry periods)
- Reconsider traditional knowledge and spread best practices.

**Reference**
1st stakeholder workshop of 24 June+ report (2), reports PDP, report (3), decision makers at the Ministry of Agriculture.

**Implementation in cognitive map**
Relationships are changed from:

- Irrigated cropland to Water demand from 3+ (+0.9) to 2+ (+0.6)
- Dry periods to rainfed cropland from 1- (-0.3) to (-0.1).

**Cost estimation**
The cost estimation is based on the following assumptions:

- Encouraging farmers by giving them 10000 trees per year during 15 years.

**Cost elements and cost unit estimation**

| Year | Encouraging farmers by giving plants |
|---|---|
| | Tree |
| 2016 | 10000 |
| 2017 | 10000 |
| 2018 | 10000 |
| 2019 | 10000 |
| 2020 | 10000 |
| 2021 | 10000 |
| 2022 | 10000 |
| 2023 | 10000 |
| 2024 | 10000 |
| 2025 | 10000 |
| 2026 | 10000 |
| 2027 | 10000 |
| 2028 | 10000 |
| 2029 | 10000 |
| 2030 | 10000 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Encouraging farmers by giving plants | DT/tree | 0.350 |

The total discounted cost: 292,834 TND (TND 2016, discount rate: 10%).

## Water Management option7

# Developing financial awareness tools

**Challenge:** Agriculture

**Description**
This option will develop of a grant system adapted to the regional context to encourage farmers to improve their production.
Financial support as well as awareness development can be used to enlighten and educate landowners and land users, and hence let them become more directly involved. Such a commitment can lead to the conception and spreading of interventions that could be understood and streamlined by the local population. Involve Mutual Companies of Agricultural Services who can mentor farmers.

**Reference**
1st stakeholder workshop of 24 June+ report (2), reports PDP, report (3)

**Implementation in cognitive map**
A new factor 'Agricultural grants' is added with relationships to:

- Irrigated cropland 3+ (+0.9)
- Pasture and cattle raising 1+ (+0.3)
- Rainfed crop production 1+ (+0.3)

**Cost estimation**
The cost estimation is based on the following assumptions:

- Dissolving land situation for a total of 12500 ha in 15 years, 2500 in year 2, 2500 in year 4, 2500 in year 7, 2500 in year 10 and 2500 in year 13.

**Cost elements and cost unit estimation.**

| Year | Dissolving land situation |
|---|---|
| | Ha |
| 2016 | 2500 |
| 2017 | |
| 2018 | |
| 2019 | 2500 |
| 2020 | |
| 2021 | |
| 2022 | 2500 |
| 2023 | |
| 2024 | |
| 2025 | 2500 |
| 2026 | |
| 2027 | |
| 2028 | 2500 |
| 2029 | |
| 2030 | |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Dissolving land situation | DT/ha | 120 |

The total discounted cost: 917,555 TND (TND 2016, discount rate: 10%).

## Water Management option8

# Use of water irrigation technologies

**Challenge:**Agriculture

**Description**
Encourage farmers to use water-saving techniques. Based on calculations of the plant water needs, these techniques make it possible to reduce water losses as much as possible towards a better management of water in irrigated land.
Better management of irrigated areas, use of irrigation techniques that save most water, encourage less demanding crops for water and more profitable.

**Reference**
1st stakeholder workshop of 24 June+ report (2), reports PDP, report (3)

**Implementation in cognitive map**
A factor is added with relationships to:
- 'Adoption of irrigation technologies' to Rainfed cropland 1- (-0.3).
- 'Adoption of irrigation technologies' to Irrigated cropland 1+ (+0.3).

Relationship is changed from:
- Irrigated cropland to Water demand from 3+(+0.9) to 1+ (+0.3)

**Cost estimation**
The cost estimation is based on the following assumptions:
- Implementation of 100 Km water saving techniques every year during the first 5 years.
- Maintenance of 30 Km of these techniques every year during 15 years.

**Cost elements and cost unit estimation.**

| Year | water saving techniques | Maintenance costs |
|---|---|---|
| | km | Km |
| 2016 | 100 | 30 |
| 2017 | 100 | 30 |
| 2018 | 100 | 30 |
| 2019 | 100 | 30 |
| 2020 | 100 | 30 |
| 2021 | | 30 |
| 2022 | | 30 |
| 2023 | | 30 |
| 2024 | | 30 |
| 2025 | | 30 |
| 2026 | | 30 |
| 2027 | | 30 |
| 2028 | | 30 |
| 2029 | | 30 |
| 2030 | | 30 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Use of water saving techniques | DT/Km | 5,000 |
| Maintenance costs | DT/Km | 500 |

The total discounted cost: 2,210,433 TND (TND 2016, discount rate: 10%).

## Water Management option9

# Improvement of the treatment of waste water

**Challenge:** Water quality

**Description**
Improve the quality of non-conventional water (treated wastewater + desalinated brackish water) to make it available for crop irrigation. This option includes:

- Creation of mini-stations for the treatment of wastewater (factories, agriculture and homes)
- Control of industrial, domestic and agricultural discharge
- Extension of purging networks in rural agglomerations
- Development of water treatment plants in accordance with the laws in force (brackish waters of magnetization, reverse osmosis, tertiary treatment)

**Reference**
1st Stakeholder workshop 24+ interviews, meeting at the Regional Office of the Ministry of Environment and Sustainable Development.

**Implementation in cognitive map**
A factor is added with relationship to:

- 'Treated water' to Irrigated crops 1+ (+0,3)

Relationship are changed from:

- Industry and tourism to Water quality from 1- (-0.3) to (-0,1)
- Population livelihood and settlements to Water quality from 2- (-0.6) to 1- (-0.3).

**Cost estimation**
The cost estimation is based on the following assumptions:

- The creation of a mini-station for the treatment of wastewater in the first year.
- The maintenance of existing stations for a total of 2 units in 15 years; one in the first year and the second in year 7.

Only activities are included in the cost assessment of which the participants of the third workshop confirm to be implemented in the basin during the next years.

**Cost elements and cost unit estimation.**

| Year | Creation of mini-stations for the treatment of wastewater | Maintenance of existing stations |
|---|---|---|
| | Unit | unit |
| 2016 | 1 | 1 |
| 2017 | | |
| 2018 | | |
| 2019 | | |
| 2020 | | |
| 2021 | | |
| 2022 | | 1 |
| 2023 | | |
| 2024 | | |
| 2025 | | |
| 2026 | | |
| 2027 | | |
| 2028 | | |
| 2029 | | |
| 2030 | | |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Creation of mini-stations for the treatment of wastewater | DT/unit | 500,000 |
| Maintenance of existing stations | DT/unit | 30,000 |

The total discounted cost: 546,934 TND (TND 2016, discount rate: 10%).

## Water Management option10

# Water discharge control

**Challenge:** Water quality

**Description**
This option will promote the control of pollutant releases by improving the application of the regulations and recovering waste, Rehabilitation of spills sites uncontrolled**,** valorisation of olive presses waste by the creation of harvesting units and the creation of new spills sites controlled, the implementation of solid waste management systems (harvesting + transportation + treatment) in the rural agglomerations , Provision of equipment and machinery to the rural population for waste management and the use of agri-waste as fertilizer.

**Reference**
1st stakeholder workshop 24+ interviews, meeting at the Regional Office of the Ministry of Environment and Sustainable Development.

**Implementation in cognitive map**
Relationship is changed from:

- Industry and tourism to Water quality 1- (-0.3) to (-0,1).

**Cost estimation**
The cost estimation is based on the following assumptions:

- Creation of new unit of spills sites controlled in the first year.
- The implementation of unit of solid waste management systems in rural agglomerations in the first year.

**Cost elements and cost unit estimation**

| Year | Creationof new spills sites controlled | Implementation of solid waste management systems in rural agglomerations |
|---|---|---|
| | unit | unit |
| 2016 | 1 | 1 |
| 2017 | | |
| 2018 | | |
| 2019 | | |
| 2020 | | |
| 2021 | | |
| 2022 | | |
| 2023 | | |
| 2024 | | |
| 2025 | | |
| 2026 | | |
| 2027 | | |
| 2028 | | |
| 2029 | | |
| 2030 | | |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Creation of new spills sites controlled | DT/unit | 4,500,000 |
| Implementation of solid waste management systems in rural agglomerations | DT/unit | 500,000 |

The total discounted cost: 4,500,000TND (TND 2016, discount rate: 10%).

## Water Management option11

# Reduction of society pressure on forests

**Challenge:** Forest resources

**Description**

Forest will be protectedby implementing prevention and control measures in order to reduce overgrazing. Users will be involved and integrated in the management and protection of forests and private forest owners will be compensated for the resulting costs or the losses in production. This option includes:

- Integration of civil society in forest conservation
- Organization of the local population in groups of agricultural development
- Pathways by pasture species
- Revision and implementation of management plans for state forests
- Development of income generating activities for forest users (ecotourism)
- Strengthening agricultural development group.

**Reference**

1st stakeholder workshop 24 June+ interviews, reports PDP, report (3), associations.

**Implementation in cognitive map**

Relationships are changed from:

- Pasture and cattle raising to Forest resources from 1- (-0.3) to (-0.1)
- Population livelihood and settlements to Forest resources from 2- (-0.6) to 1- (-0.3)

**Cost estimation**

The cost estimation is based on the following assumptions:

- Creation of an ecotourism project in the second year and the revision of one of the developments plan at the same year.
- Pastoral involvement for a total of 250 ha during the first 5 years.

Only activities are included in the cost assessment of which the participants of the third workshop confirm to be implemented in the basin during the next years.

**Cost elements and cost unit estimation.**

| Year | Revision of developments Plans | Ecotourism Project | Pastoral improvement |
|---|---|---|---|
| | unit | unit | ha |
| 2016 | | | 50 |
| 2017 | 1 | 1 | 50 |
| 2018 | | | 50 |
| 2019 | | | 50 |
| 2020 | | | 50 |
| 2021 | | | |
| 2022 | | | |
| 2023 | | | |
| 2024 | | | |
| 2025 | | | |
| 2026 | | | |
| 2027 | | | |
| 2028 | | | |
| 2029 | | | |
| 2030 | | | |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Revision of developments Plans | DT/unit | 50,000 |
| Ecotourism Project | DT/unit | 60,000 |
| Pastoral improvement | DT/ha | 1,200 |

The total discounted cost: 350,192 TND (TND 2016, discount rate: 10%).

## Water Management option12

# Protection against forest fire

**Challenge:** Forest resources

**Description**

The protection of forests against fires will be achieved by implementing appropriate techniques and providing the required equipment, as well as by involving users in forest management to make them aware of the importance of conserving these resources to improving their income. This option includes:

- Equipment of forests by trenches firewall
- Creation and improvement of access roads to facilitate the access for fire fighters
- Organization of supervision by creating lookouts and fly patrols
- Maintain and expand the existing trenches in forests particularly at Aleppo pine
- Organization of awareness campaigns related to the exploitation of forests.

**Reference**

1st Stakeholder workshop 24 June + interviews, reports PDP, report (3).

**Implementation in cognitive map**

A factor is added with relationship to:

- 'Prevention of forest fire' to Forest fire 2- (-0.6)

Relationship is changed from:

- Forest fire to Forest Resources from 2- (-0.6) to 1- (-0.3)

**Cost estimation**

The cost estimation is based on the following assumptions:

- The Creationof forest pistes/ firewalls trenches at a rhythm of 20 Km every year during the first 5 years,
- Maintenance of 5 Km of forest pistes / firewalls trenches every year during 6 years and 10 Km per year during the 9following years
- Maintenance of 2 unit of of lookouts every year during 10 years and 3 Km per year during the following 5 years
- Organization awarenesscampaigns at the rhythm of one session every year during 15 years.

**Cost elements and cost unit estimation**

| Year | Creationof forest pistes/ firewalls trenches | Maintenance of forest pistes / firewalls trenches | Maintenanceof lookouts | Organization awarenesscampaigns |
|---|---|---|---|---|
| | km | Km | Unit | Session |
| 2016 | 2 | 5 | 2 | 1 |
| 2017 | 2 | 5 | 2 | 1 |
| 2018 | 2 | 5 | 2 | 1 |
| 2019 | 2 | 5 | 2 | 1 |
| 2020 | 2 | 5 | 2 | 1 |
| 2021 | | 5 | 2 | 1 |
| 2022 | | 10 | 2 | 1 |
| 2023 | | 10 | 2 | 1 |
| 2024 | | 10 | 2 | 1 |
| 2025 | | 10 | 2 | 1 |
| 2026 | | 10 | 3 | 1 |
| 2027 | | 10 | 3 | 1 |
| 2028 | | 10 | 3 | 1 |
| 2029 | | 10 | 3 | 1 |
| 2030 | | 10 | 3 | 1 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Creationof forest pistes/ firewalls trenches | DT/km | 70,000 |
| Maintenance of forest pistes / firewalls trenches | DT/km | 30,000 |
| Maintenanceof lookouts | DT/unit | 10,000 |
| Organization awarenesscampaigns | DT/session | 5,000 |

The total discounted cost: 2,600,413 TND (TND 2016, discount rate: 10%).

## Water Management option13

# Introduction of new agro forestry species and enrichment of existing forest

**Challenge:** Forest resources

**Description**
Good management of forest resources by introducing new species for agroforestry purposes as well as enriching and preserving existing species in order to preserve and develop the forest. This option includes:

- Reforestation and increased planted areas
- Introduction of various species (eucalyptus, argon...) that improve natural products, and respect for phytosociological plants.

**Reference**
1st stakeholder workshop 24 June + interviews, reports PDP.

**Implementation in cognitive map**
A factor is added with relationship to:

- 'Forestation' to Forest resources 1- (-0.3)

**Cost estimation**
The cost estimation is based on the following assumptions:

- Introduction of various species and increase planted areas at a pace of 30 km every year during 15 years.

Cost elements and cost unit estimation.

| Year | Increased planted areas |
|---|---|
| | ha |
| 2016 | 30 |
| 2017 | 30 |
| 2018 | 30 |
| 2019 | 30 |
| 2020 | 30 |
| 2021 | 30 |
| 2022 | 30 |
| 2023 | 30 |
| 2024 | 30 |
| 2025 | 30 |
| 2026 | 30 |
| 2027 | 30 |
| 2028 | 30 |
| 2029 | 30 |
| 2030 | 30 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| increased planted areas | DT/ha | 2,000 |

The total discounted cost: 502,001 TND (TND 2016, discount rate: 10%).

## Water Management option14

# Better governance of forest resources

**Challenge:** Forest resources

**Description**
Protect forest resources by giving more importance to the application of adapted harvesting practices and to the sustainable use of these resources by local communities. This option requires the support of the government through regulations and laws..

**Reference**
1st stakeholder workshop 24 June+ interviews, reports PDP

**Implementation in cognitive map**
A factor is added with relationship to:
- 'Forest laws' to Forest resources 1+ (+0.3)
- 'Forest laws' to Forest fire 1- (-0.3)

Relationship is changed from:
- Pasture and cattle raising to Forest Resources from 1- (-0.3) to (-0.1)

**Cost estimation**
The cost estimation is based on the following assumptions:
- Strengthening agricultural development groupby creation of two new agricultural development group in the first year.

**Cost elements and cost unit estimation.**

| Year | Strengthening agricultural development group |
|---|---|
| | unit |
| 2016 | 2 |
| 2017 | |
| 2018 | |
| 2019 | |
| 2020 | |
| 2021 | |
| 2022 | |
| 2023 | |
| 2024 | |
| 2025 | |
| 2026 | |
| 2027 | |
| 2028 | |
| 2029 | |
| 2030 | |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Strengthening agricultural development group | DT/unit | 50,000 |

The total discounted cost: 100,000 TND (TND 2016, discount rate: 10%).

## Water Management option15

# Awareness campaign and learning

**Challenge:** Awareness of civil society

**Description**

Raising awareness and improving the degree of information of the civil society concerning the importance of natural resources and the necessity to protect them for better management and exploitation. These actions must be initiated at the school and be continued for relevant results. This option includes:

- Integration of association
- Awareness campaigns
- Facilitate the work of associations by public authorities.

**Reference**

1st stakeholder workshop 24 June + interviews, reports PDP,report (3).

**Implementation in cognitive map**

Relationship are changed from:

- Population livelihood and settlements to Forest Resources from 2- (-0.6) to 1- (-0.3)
- Population livelihood and settlements to Water demand from 2+(0.6) to 1+ (+0.3).

**Cost estimation**

The cost estimation is based on the following assumptions:

- Organizing one session awareness campaigns for civil society every year during 5 years and 2 sessions per year during the next following 5years and 3 sessions per year during the last following 5 years.

Cost elements and cost unit estimation.

| Year | Organizing awareness campaigns for civil society |
|---|---|
| | session |
| 2016 | 1 |
| 2017 | 1 |
| 2018 | 1 |
| 2019 | 1 |
| 2020 | 1 |
| 2021 | 2 |
| 2022 | 2 |
| 2023 | 2 |
| 2024 | 2 |
| 2025 | 2 |
| 2026 | 3 |
| 2027 | 3 |
| 2028 | 3 |
| 2029 | 3 |
| 2030 | 3 |

Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Organizing awareness campaigns for civil society | DT/session | 5,000 |

The total discounted cost: 70,856 TND (TND 2016, discount rate: 10%).

## Water Management option16

# Improved decision making

**Challenge:** Awareness of civil society

**Description**

This option aims to improve the decision-making process with the civil society. The civil society will participate in different types of projects at various stages, but primarily in the decision phases. The government can incite a reorientation of the existing institutions. Financial support as well as awareness development can be used to enhance coordination between the public authorities and civil society, create integrated companies between graduates and farmers to manage state lands (science + experience), consider co-creation of the whole nexus of education, research, society, and policy ; research needs to adopt transdisciplinary methods to work together with society in the development of solutions and innovations for sustainable agriculture and sustainable water use, revision of the incentive code of investment, working on developing an incentive background for a good management of natural resources.

**Reference**

1st stakeholder workshop 24 June + interviews, reports PDP,report (3).

**Implementation in cognitive map**

A factor is added with relationship to:

- 'Participatory approach' to Population livelihood and settlements 1+ (+0.3)

**Cost estimation**

The cost estimation is based on the following assumptions:

- Consultation of meeting on the management of the watershed at the rhythm of one meeting every year during 15 years.

Cost elements and cost unit estimation.

| Year | Consultation meeting on the management of the watershed |
|---|---|
| | meeting |
| 2016 | 1 |
| 2017 | 1 |
| 2018 | 1 |
| 2019 | 1 |
| 2020 | 1 |
| 2021 | 1 |
| 2022 | 1 |
| 2023 | 1 |
| 2024 | 1 |
| 2025 | 1 |
| 2026 | 1 |
| 2027 | 1 |
| 2028 | 1 |
| 2029 | 1 |
| 2030 | 1 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Consultation meeting on the management of the watershed | DT/meeting | 5,000 |

The total discounted cost: 41,833 TND (TND 2016, discount rate: 10%).

## Water Management option17

# Promote projects that generate more income

**Challenge:** Human Resource and employment

**Description**
This option aims to improve livelihoods through job creation and encouragement of the launch of income generating projects. This option incudes:

- Create jobs in various fields
- Encourage ecotourism projects
- Introducing craft activities for rural women
- Promote new productive activities
- Promoting improvement income and / or preserving environment, such as biologic Agriculture development
- Amend investment incentive code by integrating mechanisms that endow the mutual Agricultural Services by necessary means for coaching and upgrading the small operations.

**Reference**
1st stakeholder workshop 24 June + interviews, reports PDP, report (3)

**Implementation in cognitive map**
A factor is added with relationship to:

- 'Stimulation of new projects' to Job Creation 1+ (+0.3)

**Cost estimation**
The cost estimation is based on the following assumptions:

- Introducing Agricultural micro projects of 12 projects every year during 15 years.
- Introducing craft micro-projects for rural women of 8 projects every year during 15 years.

**Cost elements and cost unit estimation.**

| Year | Agricultural micro projects | Craft micro projectsfor rural women |
|---|---|---|
| | project | project |
| 2016 | 12 | 8 |
| 2017 | 12 | 8 |
| 2018 | 12 | 8 |
| 2019 | 12 | 8 |
| 2020 | 12 | 8 |
| 2021 | 12 | 8 |
| 2022 | 12 | 8 |
| 2023 | 12 | 8 |
| 2024 | 12 | 8 |
| 2025 | 12 | 8 |
| 2026 | 12 | 8 |
| 2027 | 12 | 8 |
| 2028 | 12 | 8 |
| 2029 | 12 | 8 |
| 2030 | 12 | 8 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Agricultural micro projects | DT/project | 10,000 |
| Craft micro projectsfor rural women | DT/project | 5,000 |

The total discounted cost: 1,338,670 TND (TND 2016, discount rate: 10%).

## Water Management option18

# Encourage investments

**Challenge:** Human Resource and employment

**Description**
Facilitate funding by encouraging investment in various fields (agriculture, industry and tourism), taking into account the profiles of the area. It aslo includes the facilitation of obtaining short-term loans and grants for small farmers and young people.

**Reference**
1st stakeholder workshop 24 June + interviews, reports PDP, report (3)

**Implementation in cognitive map**
A factor is added with relationship to:
- 'Investment' to Industry and tourism 1+ (+0.3)
- 'Investment' to Irrigated cropland 1+ (+0.3)

**Cost estimation**
The cost estimation is based on the following assumptions:
- Facilitate the obtaining of short-term loansfor20loans every year during 15 years.
- Facilitate the obtaining of grantsfor20grants every year during 15 years.

**Cost elements and cost unit estimation.**

| Year | Facilitate the obtaining of short-term loans | Facilitate the obtaining of grants |
|---|---|---|
| | loans | grants |
| 2016 | 20 | 20 |
| 2017 | 20 | 20 |
| 2018 | 20 | 20 |
| 2019 | 20 | 20 |
| 2020 | 20 | 20 |
| 2021 | 20 | 20 |
| 2022 | 20 | 20 |
| 2023 | 20 | 20 |
| 2024 | 20 | 20 |
| 2025 | 20 | 20 |
| 2026 | 20 | 20 |
| 2027 | 20 | 20 |
| 2028 | 20 | 20 |
| 2029 | 20 | 20 |
| 2030 | 20 | 20 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Agricultural micro projects | DT/ loans | 5,000 |
| Craft micro projectsfor rural women | DT/ grants | 1,000 |

The total discounted cost: 1,004,002 TND (TND 2016, discount rate: 10%).

## Water Management option19

# Developing skills for young people

**Challenge:** Human Resource and employment

**Description**
This options aims to organize training sessions to facilitate the integration of young people into working life and thus a generation of skilled technicians for proper use of different techniques. It aslo includes the training of young people about modern specialties, development and activation of institutional environment,improve employability.

**Reference**
1st stakeholder workshop 24 June + interviews, reports PDP, report (3).

**Implementation in cognitive map**
A factor is added with relationship to:
- 'Youth empowerment' to Population livelihood and settlements 1+ (+0.3)
- 'Youth empowerment' to Job creation 1+ (+0.3)

**Cost estimation**
The cost estimation is based on the following assumptions:
- Organization of agricultural training sessions for 20beneficiaries every year during 15 years.
- Organization of Craft training sessions for 15 beneficiaries every year during 15 years.
- Organization of Youth training sessions for 15 beneficiaries every year during 15 years
- Organisation of training sessions for personnel of the regional commissariat of zaghouan with one session every year during 15 years

**Cost elements and cost unit estimation.**

| Year | Agricultural training | Craft training | Youth training | Training of personnel ofregional commissariatof zaghouan |
|---|---|---|---|---|
| | beneficiaries / days | beneficiaries / days | beneficiaries / days | session |
| 2016 | 20 | 15 | 15 | 1 |
| 2017 | 20 | 15 | 15 | 1 |
| 2018 | 20 | 15 | 15 | 1 |
| 2019 | 20 | 15 | 15 | 1 |
| 2020 | 20 | 15 | 15 | 1 |
| 2021 | 20 | 15 | 15 | 1 |
| 2022 | 20 | 15 | 15 | 1 |
| 2023 | 20 | 15 | 15 | 1 |
| 2024 | 20 | 15 | 15 | 1 |
| 2025 | 20 | 15 | 15 | 1 |
| 2026 | 20 | 15 | 15 | 1 |
| 2027 | 20 | 15 | 15 | 1 |
| 2028 | 20 | 15 | 15 | 1 |
| 2029 | 20 | 15 | 15 | 1 |
| 2030 | 20 | 15 | 15 | 1 |

**Unit cost of different actions in the option (Source: CRDA/PDAI Zaghouan 2014)**

| Infrastructure /action | unit | Unit cost |
|---|---|---|
| Agricultural training | DT/ beneficiaries / days | 120 |
| Craft training | beneficiaries / days | 100 |
| Youth training | DT/ beneficiaries / days | 120 |
| Training of personnel ofregional commissariatof zaghouan | DT/session | 10,000 |

The total discounted cost: 131,357,670 TND (TND 2016, discount rate: 10%).

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| Rapport | Year | Author | Title |
|---|---|---|---|
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