

**SASS III**

**ELABORATION OF OPERATIONAL RECOMMENDATIONS  
FOR A SUSTAINABLE MANAGEMENT OF THE WATER RESOURCES  
OF THE NORTH WESTERN SAHARA AQUIFER SYSTEM  
July 2010 – June 2014**

# **AGRICULTURAL DEMONSTRATION PILOTS IN THE SASS BASIN**

**Towards a Sustainable and Profitable  
Agriculture in the Sahara**



**SAHARA AND SAHEL OBSERVATORY**



# AGRICULTURAL DEMONSTRATION PILOTS IN THE SASS BASIN

## Towards a Sustainable and Profitable Agriculture in the Sahara

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# Table of Contents

<b>GENERAL INTRODUCTION</b>		<b>11</b>
1. General Issue of the SASS		13
2. Local variations of the SASS general issue		17
3. Objectives of the SASS III Project		17
3.1. General objective of the project		17
3.2. Specific objective of the “Demonstration Pilots” component		19
4. Concept of “demonstration pilots” and approach to their implementation		21
4.1. Concept of the demonstration pilot		21
4.2. Approach to the implementation of the pilots		24
4.3. The process of implementing the pilots		27
<b>RESULTS OF THE PILOTS</b>		<b>33</b>
<b>ALGERIA</b>		<b>35</b>
<b>P1</b>		
1. General context of the pilot	36	
2. The local issue of irrigation	37	
3. Theme of the Ksar Ait Messaoud pilot	39	
4. Pilot location and characteristics	39	
5. Action plan of the pilot	43	
6. Evaluation of activities carried out	44	
7. Main results	47	
8. Evaluation of results	52	
9. Conclusion and recommendations	53	
<b>P2</b>		
1. General context of the pilot		57
2. Local issue of irrigation		59
3. Theme of the pilot		59
4. Location and characteristics of the pilot		60
5. Action plan of the pilot		62
6. Evaluation of activities carried out		63
7. Main results of the 2 consecutive years of the Pilot Implementation		63
8. Evaluation of results		73
9. Conclusion and recommendations		74
<b>LIBYE</b>		<b>77</b>
<b>P3</b>		
1. General context of the pilot	80	
2. Local issue of irrigation	80	
3. Theme of the pilot	80	
4. Location and characteristics of the pilot	80	
5. Action plan of the pilot	81	
6. Evaluation of activities carried out	83	
7. Results	83	
8. Dissemination of the pilots results	91	
9. Conclusion and recommendations	91	
<b>P4</b>		
1. Local issue of irrigation		95
2. Conclusion and recommendations		96

## TUNISIE

98

### P5

1. General context of the pilot	101
2. Local issue of the pilot	102
3. Theme of the pilot	102
4. Location and characteristics of the pilot	102
5. Action plan of the pilot	106
6. Evaluation of activities carried out	107
7. Results	107
8. Conclusion and recommendations	111

### P6

1. General context of the pilot	119
2. Issue of the pilot	120
3. Theme of the pilot	121
4. Objective of the pilot	121
5. Location and characteristics of the pilot	121
6. Action plan of the pilot	121
7. Evaluation of activities carried out	126
8. Results	130
9. Results of the second agricultural year	137
10. Conclusion	140

### P7

1. General context of the pilot	143
2. Local water issue	144
3. Theme of the pilot	144
4. Objective of the pilot	145
5. Location and characteristics of the pilot	145
6. Action plan of the pilot	148
7. Evaluation of activities carried out during the 1 <sup>st</sup> agriculture year (2011-2012)	148
8. Results and their evaluation	151
9. Conclusion	156

## **SYNTHESIS OF THE RESULTS OF THE PILOTS OF THE THREE COUNTRIES GENERAL CONCLUSION**

**158  
163**

## **OPERATIONAL RECOMMENDATIONS for an efficient management of irrigation water in the SASS zone**

**165**

I. Introduction	167
1. Objective of the operational recommendations	167
2. Recipients of the operational recommendations	167
3. The targeted areas of action	168
4. Capitalization of results	168
5. Lessons learned from the results	168
II. Operational recommendations	171
1. Recommendations at the institutional level	171
2. Recommendations in the technical field	173
3. Recommendations on the socioeconomic issues	176
4. Recommendations in the environmental field	176

# List of Figures, Graphics and Tables

## FIGURES

Figure 1. Map of the SASS exploited water points in 2010 in the three countries.	21
Figure 2. Map of the irrigated areas in the SASS zones of the three countries.	21
Figure 3. Pilot localization map in the SASS zones of the three countries.	21
Figure 4. Spatial image of the geographical location of Ksar Ait Messaoud oasis.	40
Figure 5. Location of the set of surface wells in parallel to the eastern periphery of the oasis.	40
Figure 6. Satellite image of the line of vertical wells of one foggara in the pilot zone.	41
Figure 7. Ground view of the mouths of the vertical wells of the Tamentit foggara under rehabilitation on the Adrar-Reggane road.	41
Figure 8. Restoration of a vertical well of the Tamentit foggara under rehabilitation.	41
Figure 9. Vertical cross section of the Tamentit foggara gallery at the level of its mouth at the old periphery of the oasis with the same name south of Adrar on the road to Reggane.	41
Figure 10. Divider of a foggara at the entrance of an oasis.	42
Figure 11. What remains of the water quota of a cropper of the foggara pilot after an important decrease in its flow.	42
Figure 12. A farm totally abandoned following the decrease of the flow of the foggara supplying this oasis.	42
Figure 13. Traditional cropping system using flooded irrigation.	43
Figure 14. Ruins of the old village of Tamentit entirely abandoned together with its oasis after the drying up of its foggara.	43
Figure 15. Project team with the oasis farmers around a drilling for the validation of the choice of this new resource and its use for the restoration of the initial flow of the foggara.	45
Figure 16. Visit to the pilot plots with OSS consultants together with the pilot farmers.	45
Figure 17. Connecting a well to an individual storage basin for the pressurization of the new localized irrigation network.	45
Figure 18. Installing an electric discharge pump at the exit of the storage basin for the pressurization of the localized irrigation network.	45
Figure 19. Intercropping area unexploited because of lack of water before the project.	46
Figure 20. Intercropping (zucchini using localized irrigation, 2011-2012).	46
Figure 21. Old distribution and flood irrigation channel (séguia) and its replacement by localized irrigation adapted to the palm tree.	46
Figure 22. Winter tomato crop with localized irrigation 2011-2012.	46
Figure 23. Potato crops at two levels of development.	53
Figure 24. Zucchini crops at two levels of development.	53
Figure 25. Tomato crops at two levels of development.	53
Figure 26. Pepper crop in its beginning.	53
Figure 27. Main collection channel of the valley of Oued Righ.	58
Figure 28. Satellite image of the Oued Righ valley oasis map.	61
Figure 29. Satellite image of the pilot's site.	61
Figure 30. Spatial image of the palm grove of the pilot.	61
Figure 31. Intra-plot open draining ditch that has become non-operational due to a lack of maintenance.	61
Figure 32. Secondary collecting channel sealed with reed.	61
Figure 33. A plot of the oasis before renovation by the project.	64
Figure 34. The water distribution channel at the entrance of the farm.	64
Figure 35. Laying the drainage pipe.	64
Figure 36. Filling the drainage ditch after laying the drainage pipe.	64
Figure 37. Sandy amendment to remedy to what is left of the open drainage ditches and elevation of the soil surface.	64

Figure 38. Setting an electrical pump for the pressurization of irrigation water.	64
Figure 39. Efficient operation of the drainage network as soon as the buried channels were installed.	65
Figure 40. The Algerian National Consultant, M. Lamine Hafouda supervising the extension of the localized irrigation network.	65
Figure 41. Manhole at the entrance for evacuation of drainage water.	65
Figure 42. Diagram of the apparatus for the monitoring and evaluation of the hydrosaline results.	69
Figure 43. A plot for the intercropping cultivation of garlic in the palm grove.	75
Figure 44. Location map of the pilot farm (green square).	82
Figure 45. The two pilot's irrigated plots during the agricultural seasons (2012 et 2013).	82
Figure 46. The two plots, general view of the pepper plot.	87
Figure 47. The first crop ready for harvest.	87
Figure 48. General view of the tomato and zucchini crops.	87
Figure 49. General view of the zucchini crop.	88
Figure 50. General view of a cucumber crop.	88
Figure 51. All the damaged production of zucchini after a virus attack.	88
Figure 52. Sweet pepper crop damaged by sun.	88
Figure 53. Damaged tomato crop by a cryptogammic disease.	88
Figure 54. Panels of the nurseries for multiplication of cabbage and cauliflower and tomatoes.	90
Figure 55. A plot being prepared for tomato cropping.	90
Figure 56. A cauliflower plot.	90
Figure 57. A tomato crop under tunnel started.	90
Figure 58. Visit for the evaluation of the pilot results by GWA technicians.	92
Figure 59. Visit for joint evaluation by OSS team and GWA directors.	92
Figure 60. Agricultural croppers on visit to the pilot (May 2013).	92
Figure 61. Session to explain and evaluateThe pilot's results with croppers from the region.	93
Figure 62. Overall evaluation session of the pilot and discussion of perspectives of replication in Libya among the OSS team and GWA managers.	93
Figure 63. A geothermal water resource whose water is cooled in a lake in Tawergha in Libya.	97
Figure 64. The drill made available to the project by the GWA.	97
Figure 65. Visible salinization of the soil.	103
Figure 66. The drainage water collection channel of the closed pilot.	103
Figure 67. Spatial image of the location of the Jedida oasis in its saline environment of the Chott.	104
Figure 68. Spatial image of the pilot's plots.	104
Figure 69. Location of the pilot in the Jedida oasis with its infrastructure.	105
Figure 70. Digging the ditches for drains.	112
Figure 71. Laying the drains.	112
Figure 72. Connecting the drains at the level of the manholes.	112
Figure 73. Cross section of the soil at the level of the drains covered in gravel.	112
Figure 74. The concrete perforated cylinder used as manhole.	112
Figure 75. Manhole in place.	113
Figure 76. The manhole for reception of electric pump for evacuation of drainage water and their discharge to the external collecting channel.	113
Figure 77. The solar panel for the pumping of the drainage water.	113
Figure 78. The drainage water pumping device.	113
Figure 79. Location map of the piezometers.	114
Figure 80. Piezometer soil monitoring.	114
Figure 81. Discharge pipe of the drainage water through the solar pumping station to the external collector.	114
Figure 82. Groves of Zarzis region developed on sandy soils.	122



Figure 83. Olives dried during droughts (September 2010 just before the first autumn rains).	122
Figure 84. One of the many shallow wells and a small pool that mark the landscape of the region.	122
Figure 85. A plot of food crops irrigated in summer Irrigated using brackish water.	123
Figure 86. Illustration of summer fashion flood irrigation. (Note that the olive trees are irrigated directly but indirectly benefit from irrigation of vegetables with their powerful lateral root system).	123
Figure 87. A culture of watermelon with brackish water mid-summer. (Note the difference in the development of the olive tree irrigated land with olive groves in the non-irrigated land in the 2nd plan).	123
Figure 88. An olive tree benefiting from irrigation of intercropping, highly productive and saved from the impact of draught. It provides a yield of more than 200 kg of olives that is 10 times the average production/tree in this region. However, irrigation using brackish water affected the soil through the salinization process.	123
Figure 89. Location of the pilot site in relation to the city of Medenine (yellow arrow).	124
Figure 90. Location of the pilot site on the right fringe of Oued Smar (yellow arrow).	124
Figure 91. Borders of the pilot's plot.	124
Figure 92. Some members of the local team of actors.	130
Figure 93. The surface wells of the pilot rehabilitated ; with shelter for the desalination station.	130
Figure 94. A water tower for the storage of desalinated water.	130
Figure 95. The desalination plant with a processing capacity of 40 m <sup>3</sup> /day of water at 4 g/l with a yield of 50%, that is 20 m <sup>3</sup> /day of water at less than 0,2 g/l of total soluble salts.	130
Figure 96. The mixing basin of brackish water and desalinated water to obtain different water qualities.	130
Figure 97. Site plan of the farm for the first agricultural season (2011-2012).	131
Figure 98. The plot of the pilot before and after the start of the first crops in March 2012.	132
Figure 99. The pilot's plot after establishing the crops (March 2012)).	132
Figure 100. Launch of a tomato crop under one of the greenhouses.	132
Figure 101. One of two greenhouses installed in the intercropping area of the olive tree lines.	133
Figure 102. The tomato crop in greenhouses in full production on 5 June 2012.	133
Figure 103. (a & b) The cucumber crop on the day of the visit to the pilot by participants from the three countries to the workshop for the dissemination of pilots results (5 June 2012).	133
Figure 104. Season potato crop in June 2012 at the harvest.	134
Figure 105. Croppers from the Smar community participate in the workshop for the dissemination of results of the « Pilots » component of the three countries accompanied by the SASS II project coordinator.	134
Figure 106. Plot plan of the farm of the pilot during the second agricultural season.	137
Figure 107. Land cover of the pilot by the end of March 2013 (after the harvest of intercropping crops in the open field).	138
Figure 108. Excellent development of an early pepper crop under greenhouse.	138
Figure 109. Satellite image of the Pilot 7 farm in Tunisia (Chenchou, Mgacem, El Hamma de Gabes).	146
Figure 110. Basins for the preparation of the stock solution of liquid fertilizers.	152
Figure 111. One of the two osmoses for the desalination of brackish water.	152
Figure 112. General view of the cultivation using the heating network.	152
Figure 113. Side view of the tomato plants under greenhouses.	153
Figure 114. Details of crops on the flange of the artificial substrata.	153
Figure 115. Side view of the eggplant crops on artificial substrata.	153
Figure 116. Cherry tomatoes, Cocktail variety at two levels of maturity.	153
Figure 117. Equipment for the manufacture and printing of the carton paper packages for produce to be exported.	154
Figure 118. Weighting and ticketing produce for exportation.	154
Figure 119. Tomato and eggplant boxes packaged and ready for export.	154
Figure 120. State of crops during monitoring visit Evaluation by Mrs. Kerry West from the GEF to the pilot on 26 May 2013.	157

## GRAPHICS

Graphic 1. Forecasts of the evolution of irrigated areas in the SASS zone of the three countries (in ha).	13
Graphic 2. Demographic forecasts (SASS region and by country).	13
Graphic 3. Areas of cultivated plots (ha) per farmer.	51
Graphic 4. Total area of various intercropping cultivations of all the pilot farmers.	51
Graphic 5. Estimates of yields (q/ha) obtained by cropper per crop.	52
Graphic 6. Productions sold (kg) per crop per cropper, selling price of produce (in Algerian dinars/kg, knowing that 100 DA = 1 €) and revenue (AD) by cropper without those obtained from the sale of crops, dates and family livestock which are not declared.	54
Graphic 7. Areas and dates of sowing of annual crops in intercropping (2012-2013).	70
Graphic 8. Hydrosaline balance at the scale of the plot - Period (1/1/2013- 31/3/2013).	73
Graphic 9. Revenue from vegetables grown and the balance sheet of the pilot during the agricultural season 2011-2012.	86

## TABLES

Table 1. The two phases of the agricultural and technical progress creation and dissemination process.	23
Table 2. Les deux étapes de validation des « pilotes de démonstration agricole ».	23
Table 3. Interactions between decision centers, irrigation development partners at local level.	26
Table 4. Evaluation of the activities in implementing pilot 1.	50
Table 5. Evaluation of activities carried out in pilot 2.	68
Table 6. Areas, yield and incomes of the cultivated varieties.	71
Table 7. Drainage water and exported salt of the pilot during the period 1/1/13 to 31/3/13.	72
Table 8. Efficiency of the irrigation water.	73
Table 9. Economics of the pilot (agricultural campaign fall 2012/winter-spring 2013).	74
Table 10. Evaluation of results.	74
Table 11. Evaluation of completed activities.	86
Table 12. Produce, receipts and balance of the agricultural pilot's 2nd year (2013).	91
Table 13. Evaluation of completed activities.	111
Table 14. Evolution of the depth of the sheet (in centimeters) before drainage ; I: after irrigation of the pilot and L: after irrigation of the neighboring plots.	116
Table 15. Evolution of drainage water (g/l) in the manholes.	116
Table 16. Results of the monitoring of the soil's salinity.	117
Table 17. Analysis sheet of the pilot's well (Analysis conducted by CITET).	125
Table 18. Evaluation of activities completed.	129
Table 19. Agricultural performance and income of the first agricultural season 2011-2012.	135
Table 20. Economic balance of the pilot's first year.	136
Table 21. Evolution of the water and soil salinity.	136
Table 22. Economic balance of the pilot's 2nd year.	139
Table 23. Components of the well water desalination costs.	140
Table 24. Comparaison des performances économiques du pilote avec les systèmes de culture traditionnels.	141
Table 25. Évaluation des activités réalisées au pilote 7.	151
Table 26. Performances techniques et économiques du pilote 7.	155
Table 27. Summary of achievements and constraints.	159
Table 28. Evaluation of the performance of the pilots.	160
Table 29. Evaluation of the technical, economic and environmental results of the pilots.	161

# Acronyms

ANRH	Agence nationale des ressources en eau ( <i>National Water Resources Agency</i> )
CLSP	Comité local de suivi du pilote (Local Pilot Monitoring Committee)
CRDA	Commissariat régional au développement agricole, Tunisie (Regional Commission for Agricultural development, Tunisia)
DG	Directeur général (Director General)
DGGREE	Direction générale du génie rural et de l'exploitation des eaux, Tunisie (General Directorate of Rural Engineering and Water, Tunisia)
DGRE	Direction générale des ressources en eau, Tunisie (General Water Resources Directorate, Tunisia)
DRANRH	Direction régionale de l'ANRH (Regional Directorate of the ANRH)
DSA	Direction des services agricoles, Algérie (Directorate of Agricultural Services, Algeria)
FFEM	Fonds français pour l'environnement mondial
GEF	Global Environmental Facility
INRAA	Institut national de la recherche agronomique d'Algérie (National Agricultural Research Institute, Algeria)
IRA	Institut des régions arides de Médenine (Arid Regions Institute, Medenine)
MAE	Ministère de l'Agriculture et de l'Environnement, Tunisie (Ministry of Agriculture and the Environment, Tunisia)
NC	National Consultant
ONID	Office national de l'irrigation et du drainage, Algérie (National Irrigation and Drainage Office, Algeria)
OSS	Observatoire du Sahara et du Sahel (Sahara and Sahel Observatory)
PC	OSS Project Coordinator
RC	Regional Consultant
SASS	Système aquifère du Sahara septentrional (North-Western Sahara Aquifer System)
URERMS	Unité de recherche en énergies renouvelables en milieu saharien, Algérie (Research Group on Renewable Energy in the Sahara Environment, Algeria)





# GENERAL INTRODUCTION

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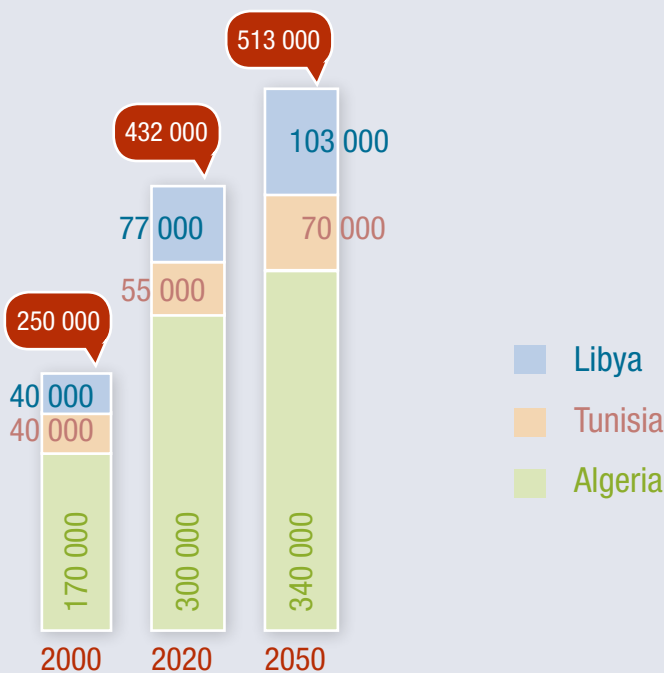
- 13** GENERAL ISSUE OF THE SASS
- 17** LOCAL VARIATIONS OF THE SASS GENERAL ISSUE
- 17** OBJECTIVES OF THE SASS III PROJECT
  - 17** General objective of the project
  - 19** Specific objective of “Demonstration Pilots” component
- 21** CONCEPT OF THE “DEMONSTRATION PILOTS” AND APPROACH FOR THEIR IMPLEMENTATION
  - 21** Concept of the demonstration pilot
  - 24** Approach to the implementation of the pilots
  - 27** Process of implementing of the pilots



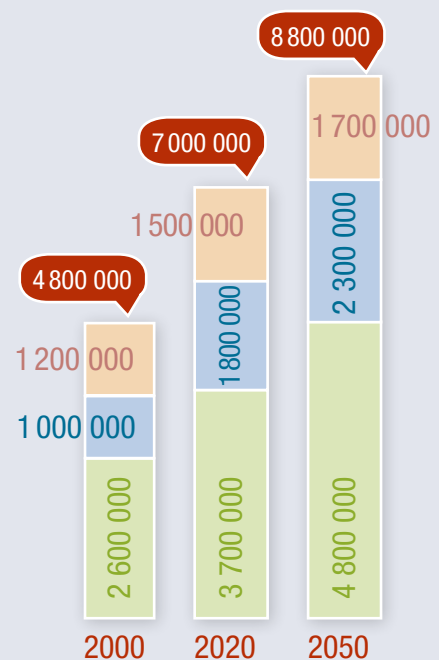
# 1. GENERAL ISSUE OF THE SASS

The North Western Sahara Aquifer System (SASS), a common groundwater resource shared by Algeria, Libya and Tunisia, contains considerable yet little renewable water resources. This system extends over a vast area of more than one (1) million km<sup>2</sup> with seven hundred thousand (700,000) km<sup>2</sup> in Algeria, eighty thousand (80,000) km<sup>2</sup> in Tunisia and two hundred fifty thousand (250 000) km<sup>2</sup> in Libya. This aquifer system consists of a complex superposition of layers, with the two main ones located in two different geological formations: the Continental Intercalary (CI or Albian) and the Terminal Complex (TC). The exploitation of this system goes back to many years: first through the direct exploitation of sources and at a later stage through the construction of surface wells and foggaras according to the structural contexts, then through deeper drills, which may exceed thousand meters (1,000 meters) of depth in some cases. For the last half of the century, the intensive exploitation of this resource has continued to increase to meet growing demand for water. Indeed, the demand, according to OSS projections (2000), increased from 0.6 to 2.5 billion m<sup>3</sup>/year in the three countries sharing the aquifer system. Water withdrawal was carried out without any coordination or consultation between the three countries on the possible risks and impacts of the aquifer's overexploitation. Furthermore, projections of increased pressure on this resource in the coming decades are even more alarming. Projections for up to 2050 are provided in Graphics 1 and 2 (OSS, SASS I).

In 2011, the socioeconomic and environmental survey, conducted in the Algerian region of SASS within the framework of the present project showed that the irrigated area increased



Graphic 1. Forecasts of the evolution of irrigated areas in the SASS zone of the three countries (in ha).



Graphic 2. Demographic forecasts (SASS region and by country).

from 170,000 ha in 2000 to 270,000 ha in 2012, confirming therefore the similar trend observed in Tunisia during the same period.

Nowadays, the trend of overexploitation of the aquifer is clearly proven by the complete drying up of most sources, reduced artesianism, drawdown of groundwater levels, degradation of water quality due to salinization and the negative interference between the evolutionary trends of this resource in neighboring countries (Algeria/Tunisia on the one side and Tunisia/Libya on the other).

Indeed, the SASS project first phase studies (SASS I) had clearly shown that the North-Western Sahara Aquifer System (SASS) evolved according to a regressive dynamic in quantitative and qualitative terms and that the continuation of water withdrawals under the current growing trend in the three countries will result in future substantial reductions of easily mobilized resources and degradation of water quality. Consequently, their use will become, in most sectors, inappropriate or risky and expensive, particularly in irrigation, which consumes more than 85% of the resource.

Furthermore, within a perspective of boosting withdrawals, the risks are obviously larger and may involve even questioning socio-economic development plans, which have reached an unsustainable level in many parts of the SASS with negative consequences at the social, economic and environmental levels.

Major strategic and political questions concerning the future development of the population of the SASS area and the preservation of the quality of its environment are therefore raised at the local, national and regional levels. This is the general and common problem for all the regions benefiting from the SASS water resources, where socio-economic activities, notably irrigated agriculture, face the current reality of water scarcity and the high threat of its aggravation in the medium and long term.

Several factors control and exacerbate this dynamic. We will cite in particular:

- the social policies of low water pricing that do not encourage the conservation of the resource and the improvement of the efficiency of its use.

For various reasons (cultural, social, lack of awareness of policy makers ...) water resources are still not valorized and its economic value is not taken into consideration. Within this context and in the three countries concerned, water pricing is determined and fixed by water practitioners based on the cost of the maintenance of water distribution networks and equipments and its mobilization (pumping), which does not reflect the real cost of this economic good (water). The result is evidently an important waste of the resource by the primary user, in addition to losses in the distribution networks upstream irrigation terminals...

- The low valorization of irrigation water at the plot level: most cropping systems have little or no performance at the economic level (low yields and low market value of production), social (to the point that many farmers become increasingly multi-



active employees outside their farms), and environmental (loss of soil fertility by salinization and waterlogging, loss of biodiversity).

- The expansion of irrigated areas by creating new areas, both public and private, authorized or not, leads to new drilling and a faster pace of overexploitation of the aquifer.
- The introduction of new cropping systems that are high consumers of water, little or not profitable (cereal crops irrigated by sprinkling or pivot), which, added to that, have no driving effect on the socioeconomic development at the local level.
- Climate change with increased aridity and frequency of droughts is more and more confirmed for these regions already suffering from a severe climatic water deficit. Indeed, the SASS zone covers various eco-regions ranging from outright desert areas (with annual rainfall <100 mm and evapotranspiration > 3000 mm) to arid areas (with annual rainfall of 100-200 mm and evapotranspiration of about 2000-2500 mm). Global warming accompanied by a rise in average and maximum temperatures will result in an excessive increase in water demand, notably the crops need for water. In other words, it will increase the volume of irrigation water/ha. In addition, the extreme maximum temperatures will be an additional major physiological stress in the selection and implementation of cropping systems.
- The transfer of SASS water to areas outside its territory to meet urgent needs for water. Indeed, among the scenarios to overcome water deficits in arid or semi-arid regions north of the SASS, we find the transfer of considerable volumes of water, notably of drinking water, for industry or irrigation. This water transfer could only help to aggravate and accelerate the SASS exploitation process with all its consequences.
- Competition with other socio-economic sectors that can afford the opportunity costs of using these waters better than irrigation. This is the case of tourism or industry.

All these factors can, separately or simultaneously, depending on the case, make this general problem more acute and threaten the achievement of the socio-economic development strategies of local populations.

Faced with these severe risks, two main types of solutions could be introduced:

- bridge the growing gap between water supply and water demand by promoting the increased supply through the multiplication of drillings, including the deepest drilling in the Continental Intercalary(CI). This option is in line with the policies adopted in the three countries for the last few decades.

The concretization of this option would be possible if the prospective studies made by the OSS within the SASS I project showed, through modeling, that it would be possible to remedy current and future water deficit in some region through the

construction of new drillings in new remote areas, like SASS Western Basin in Algeria, where piezometry has not been affected in a significant way so far.

- Control the aquifer's overexploitation in the three countries through the implementation of various actions and measures, including stopping the expansion of irrigated areas and limiting new drillings while promoting technical innovation in efficient performing production systems which favor water saving, valorization and sustainability.

In the first option, it would be necessary to transfer the mobilizable water to areas that have high water needs, namely the large irrigated areas (old and recent oases facing water deficit). Obviously, in this case, the overexploitation of the aquifer would be more strengthened and its negative impacts more aggravated over the long term. Ultimately, the problem of the non-sustainability of irrigation will not be resolved without improving the efficiency of current or future-oriented development plans, given the huge waste of this vital resource and its low profitability. . .

Politically, this option can only be decided by planners at the national level. All other water stakeholders, including primary users, will have to apply and benefit from it, if it is to their advantage, and not to adopt it if it does not serve their interests. That is to say, this first option serves only to delay the time of the failure of development strategies.

The 2nd option is more rational and might be able to improve significantly the value of the resource. However, it could not respond positively to a strong social demand for the creation of new perimeters. In other words, this second option is economically and environmentally much better, but socially unacceptable.

However, it would also be possible to adopt a mixed solution of optimization goals. It is to act simultaneously on two levels:

- enable the creation of new perimeters with new drillings in less exploited areas, away from current irrigated areas, while ensuring the development of new and improved cropping systems at all levels and having a multiplier effect on local development;
- establish a policy of intensification of existing traditional cropping systems through better land management and irrigation (control of losses and waste water) in order to significantly increase the economic value, so that this new agriculture becomes capable of paying exactly the real cost of water. In this perspective, a number of various accompanying measures should be taken (financial, legal, institutional, social...) for the medium and long term.

It is important to note, however, that in any case, the improvement of the situation would be possible only with the involvement of the cropper irrigator in the design and implementation of any irrigation policy.

It is at the farm level that the farmer is, in fact, the main decision-maker on a daily basis and is the only one capable of optimizing water consumption to produce more and better using as little water as possible while improving farm income.

It is within this perspective that the SASS III project proposes itself to act, along with its “socioeconomic and environmental surveys” and “agricultural demonstration pilots” components.

## 2. LOCAL VARIATIONS OF THE SASS GENERAL ISSUE

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The diversity of natural contexts, experiences of local people in irrigation and age of cultivation systems practiced in the vast area of the SASS, makes the water issue manifest itself in multiple forms at local level. Three main types of deficiencies can be at the origin of threats to the aquifer and irrigation. These could include:

- a structural water shortage in the areas of agricultural use: it is manifest in terms of negative water balance at the local level between overall supply and overall demand expressed in by the cultivation areas. In other words, cultivated areas suffer from a lack of water that is detrimental to the local economy and the income of farmers; it threatens the sustainability of irrigation, the integrity of the aquifer and the quality of the soil.
- a serious deficiency in the management of a resource that is theoretically sufficient to cover the total needs of crops. This deficiency may lie in large water losses in the distribution networks to farms and within farms. In some situations, this loss is due to an imbalance between water rights or the farmers /operators rights to use water and the surface area of their plots. The consequences of this mismanagement are ultimately of the same nature as those mentioned above.
- And for the most part, a very low valorization of irrigation at the level of farms (inappropriate irrigation methods and cultivation techniques, water quality unsuitable for practiced cropping) compared to realizable potential.

These deficiencies can often add altogether and local issues then become more complex at the technical, social and economic levels with serious environmental impacts.

## 3. OBJECTIVES OF THE SASS III PROJECT

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### 3.1. General objective of the project

The aim of the inventory of the cropping systems carried out in this area within the SASS II project was to analyze their (systems') technical, economic and environmental, performance and durability and to identify their limitations and constraints. The results obtained were

alarming: a multitude of complex situations evolving towards the gradual disintegration of most systems and the disintegration of the social fabric with multiple forms of adaptation to new contexts reaching land abandonment. That is, initially, agriculture in the SASS zones of the three countries was limited to traditional oasis cropping, which represented an agricultural system specific to the desert context of sedentary or occasionally nomadic population. In this system, the cultures are organized in three stages: the palm trees at the highest level, diverse arboriculture at the middle level and herbaceous crops (fodder and vegetables) at the ground level. Its main goal is to satisfy a good part of the specific dietary needs of the oases inhabitants and their family owned livestock. It is developed on the basis of a group policy rooted into agronomic principles that ensure:

- the development of a more humid microclimate than the desert space buffers the thermal excess of desert environments and their amplitudes, the high brightness for some crops, resulting in a reduction of potential water evapotranspiration, and consequently a decrease in crops' need for water. This is the oasis effect.
- the optimization of the use of sunlight through a maximum capture of solar energy by the aerial parts of the three cultivation levels, on the one hand, and the use of all irrigation water and soil fertility by the root systems of the various structured crops at different depths. It is intensification.
- the integration of arable crops to family animal production which has among other objectives, the production of manure to be recycled on site to maintain the fertility of the land and reconstitute the export of nutrients through the vegetable crops production. This is the logic of the integration of all cultivation practices.
- the rules for community-based management of natural resources, mainly water and soil. The oasis society is indeed solidly organized in the management of both resources with specific functions, rights and obligations for all oasis inhabitants compared to the conduct of irrigation and maintenance of land quality through regular drainage.

So, the production system in question is designed, implemented and developed by communities having specific basic needs produced on site. It is not a closed system, but rather a semi-autonomous one, open on its natural and human environment and brings with it complementary relationships.

This system is characterized by its biodiversity, its relative performance and its weaknesses, and any changes that are an exception to the four principles mentioned above, destabilize the logic of its sustainability and is translated at the farm level by various adaptation forms to the main constraints encountered, in this case, water scarcity and/or degradation. The various forms of adaptation are divided successively as follows:

- progressive simplification of the system by removing one or two inferior levels;
- loss of biodiversity by eliminating less efficient species;

- elimination of summer and winter fodder crops, and thus disintegration of livestock production from fodder production, considered the backbone to maintain soil fertility through recycled manure;
- partial abandonment of operations for the benefit of off-oasis pluri-activity;
- drilling new illegal boreholes outside traditional oases to create new irrigated areas (monoculture palm oases or new specialized open cropping systems such as cereals, fruit trees, vegetables), a measure that only intensifies the SASS overexploitation and consequently increases the local water deficit.

Faced with this alarming diagnosis, a [consultation mechanism](#) has been created by the three countries with a view to pursuing the study of the SASS resource and identifying ways that can help reduce the large area of irrigation on the path to sustainability. It is on this basis that the SASS III project was born to deepen and generalize awareness at all levels of decision making, challenges to meet and prospect appropriate durable solutions to the various local issues related to the agricultural use of water and its socio-economic and environmental impacts.

The SASS III [general objective](#) was to identify and propose [operational recommendations](#) in order to improve the management of this resource in the sense of increasing the efficiency of its use in irrigation. These recommendations are aimed first at policy-makers in the three countries concerned via the consultation mechanism whose main role is to guide them in converging their operation policies and strategies of the SASS within a perspective of sustainability.

This overall objective is to be achieved through the results of two project components. These are two distinct but fundamentally complementary components:

- a “socio-economic and environmental surveys” component whose main focus is the analysis and understanding of the socio-economic dimension of the use of SASS water for irrigation at farm level should enact significant changes in the behavior of operators in relation with the scarce resource used but obviously inadequately valorized;
- an “agricultural demonstration pilots” component for the identification and implementation, on the ground, of various proven performing irrigation technical solutions on farms and with farmers for the purpose of demonstration and extension at local, national and regional levels. This report deals specifically with the results of these pilots.

### 3.2. Specific objective of the “pilots component”

It is expected at the end of this project that the results of these two components are integrated to achieve the [common general objective](#), namely the formulation of [operational recommendations](#) dedicated to the three countries. As for the [specific objective](#) of the

“pilot” component, it consists in demonstrating to the water sector users and other decision makers that there are efficient technical solutions to increase the productivity of one cubic meter of water, while ensuring the profitability of the investment required and improving farmers’ income, without affecting the integrity or quality of natural resources used for this purpose, in various local contexts of the SASS zone in the three countries.

Given the existence of a wide variety of situations, on one hand, and limited financial resources of the project, on the other, only six local issues of unsustainable management of irrigation water have been identified and selected by water authorities in the three countries.

## ALGERIA PILOTS

**P1 :** Restoration and conservation of the foggaras and their agricultural production systems: the case of the de Ksar Ait Messaoud oasis in the Reggane region, Wilaya of Adrar in the South-Western part of the SASS area in Algeria.

**P2 :** Rationalization of land and irrigation water management and improvement of their valorization in terms of irrigation in the South East of Algeria : the case of the Sidi Mahdi oasis in Touggourt in the Oued Righ Valley, Wilaya of Ouargla.

## LIBYA PILOTS

**P3 :** Restoration and conservation of the irrigated agricultural production systems using brackish water in the Libyan Djefara plain: The case of the Souani zone, situated in the South East of Tripoli.

**P4 :** Agricultural valorization of geothermal waters in the irrigation of off-season crops in the oueds area in the Center of Libya (Oued Zemzem).

## TUNISIA PILOTS

**P5 :** Rehabilitation of irrigated lands affected by salinization and hydromorphy and the restoration of oasis cultivation system: the case of Jedida in the governorate of Kebili, Tunisia.

**P6 :** Desalination and use of brackish waters in irrigation in the Tunisian Djefara plain: the case of the Semar region, governorate of Medenine.

**P7 :** Development of irrigation using desalinated geothermal water in the region of Chenchou, El Hamma Gabès, in the governorate of Gabes.

Agricultural demonstration pilot projects have been designed around these local issues, with two units per country. The following is a breakdown of the demonstration themes of these pilots:

These themes can be classified into two categories:

- three themes related to traditional oasis system, two in Algeria and one in Tunisia;
- three themes related to irrigated cropping systems outside the oases: one in Libya and two in Tunisia. These are recent specialized systems that tend to develop outside of the oases, in total rupture with traditional systems, and seeking more economic efficiency.

Each of these topics is based on a particular local water issue and its agricultural use, identified and considered, as well as by the cropper and by policy makers, as a major obstacle to improving the performance of irrigation in certain regions or irrigated areas of the SASS zone. The following is a reminding of the specific problems of these pilots.

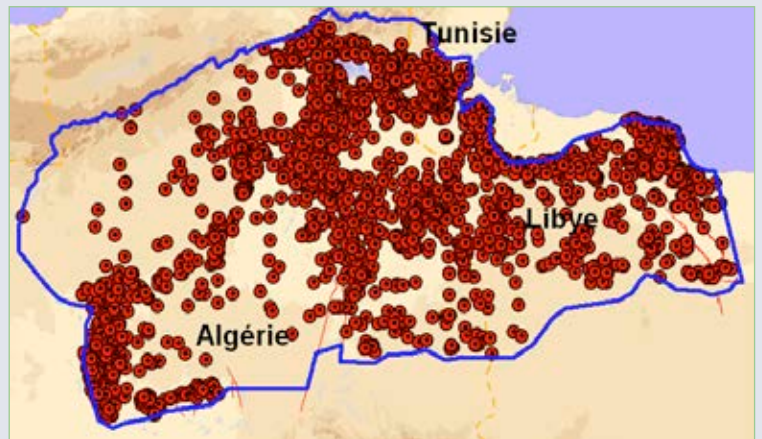


Figure 1. Map of the SASS exploited water points in 2010 in the three countries.



Figure 2. Map of the irrigated areas in the SASS zones of the three countries.

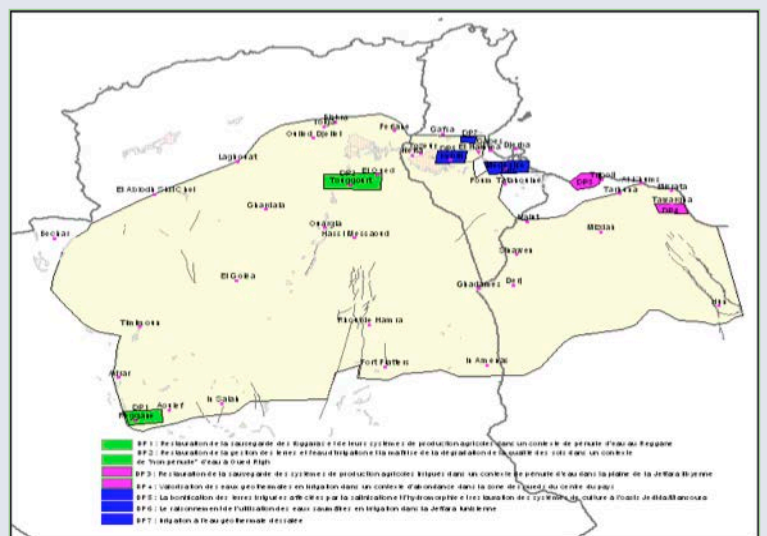


Figure 3. Pilot localization map in the SASS zones of the three countries.

## 4. CONCEPT OF THE PILOTS AND APPROACH FOR THEIR IMPLEMENTATION

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Through its two main components (surveys and pilots), the SASS III project aims at understanding and changing the behavior of the primary users in relation to the efficient use of irrigation water resource. For this reason, all planned activities have focused on the cropper and the agricultural operation of the main current cropping systems. To avoid failures and capitalize lessons, projects and studies realized elsewhere, we opted for a local proximity- method based on the participation of all water stakeholders, at the center of whom we find the farmer. The latter is considered the agent that would be involved in the extension of the expected results in terms of improving irrigation performance. We present in the following two foundations of this adopted proximity method.

### 4.1. Concept of the demonstration pilot

The demonstration pilot concept is borrowed here from the field of industrial technological innovation. Indeed, the research discoveries and inventions in this field are often carried out in a first phase on devices or miniaturized production systems and isolated from large-scale production. The reliability of these discoveries and innovations at the physical, socioeconomic and environmental levels are tested on prototypes or pilot units of a life-scale, close to the actual size of the optimal exploitation of the object of the invention.

The “agricultural demonstration pilot” is considered here as a reliability and demonstration tool of the efficiency of a technology package of an agricultural production applied by the farmers themselves on their own farms, with the supervision of the project. Thus considered, it is a step in the process of creating and disseminating agricultural technology progress among professionals. This process consists of:

- two stages of research (basic and applied);
- two stages for the validation of research results within a systemic approach
  - one stage for the reliability of innovations in an integrated agricultural system at farm scale,
  - a stage for the development of the agricultural system in question within a contextualized production systemh.

These phases are defined in tables 1 and 2.

In many situations, proven technical solutions adapted (or adaptable) to different contexts exist at natural scale, in one of the three countries, or elsewhere in similar contexts that make their transfer conceivable and feasible.

Setting up a package of solutions of various kinds, but mostly technical ones associated



Phase 1	Phase 2
Fact finding in laboratories or on experimental plots	Validation of the results of the first phase in various contexts
Approximate duration : 2-3 years	Duration: 1-2 years
Product : scientific publication	Product : publication or patent

Table 1. The two phases of the agricultural and technical progress creation and dissemination process.

Phase 3 : Reliability of innovations in a cultivation system	Phase 4 : Development of a cultivation system within a n agricultural production system
Demonstration pilot of a cultivation system at farm level (integrated innovative technology package...)	Demonstration pilot on an agricultural production system at the level of many farms: integration of the reliable cultivation system within a socioeconomic and environmental context of a given situation (market, real estate, agricultural services, professional organizations, subsidiaries, state policy...)
Duration: 2-3 years	Duration: 3-4 years
Product: a reliable cultivation system at the technical, economic and environmental levels	Product: a sustainable production system that can be duplicated ensuring local development

Table 2. The two validation phases of the « agricultural demonstration pilots ».

with measures of social and organizational order, aimed at overcoming constraints to the sustainable management of the resource, and their implementation on real production units among farmers (farms, land plots, greenhouses), with their consent, their work and their evaluation, would be the best means of communication to inspire all water users located around these pilots to adopt the necessary changes at the level of the modes of operation and optimization of water and land.

The pilots are thus designed as models for the implementation of these solutions, primed and integrated into the relevant local socio-economic contexts. If conducted properly, they will be able to generate positive results that will have to be disseminated as widely as possible, with some necessary modifications in the SASS zone.

It is important to emphasize, however, that these pilots do not propose to address the structural constraints at the origin of the poor performance of irrigated agriculture, such as structural water shortage (transfer of additional water from another zone) or land issues (fragmentation, reduced area over time) that require deep reforms for the long term. Within

this project, only technical and organizational shortcomings and constraints were addressed, whose solutions could be implemented and appropriated in the short term by users and their associations as well as by the water and agricultural development authorities. So, they will cover a limited number of agricultural development issues related to the optimal use of the resource un nombre limité de problématiques de développement agricole liées à la valorisation optimale.

A brief description of the theme of each pilot would allow defining the scope of actions to be taken for the relevant pilot. This field could cover a multitude of additional actions that may contribute to the restoration of the entire irrigated area within a systemic approach, integrating all segments of the water course (mobilization, distribution, agriculture, draining). However, given the fact that the overall cost of these actions largely exceeds the budget allocated to each of the pilot, there is a need to proceed to a prioritization of actions and consider only those identified as both the most decisive, innovative and having concrete results with significant demonstration impact in the short term.

## 4.2. Approach for the implementation of the pilots

At the local level, pilots should be considered as a new tool for socio-economic development of the areas, capable of reconciling economic growth, human development and social progress while safeguarding natural resources in quantity and quality to transmit to future generations.

This development therefore has three pillars:

- the economic profitability of technical innovations in the management and exploitation of water and mineral resources;
- the acceptance and adoption of these innovations by local people concerned;
- the preservation of natural resources namely the mobilized aquifer and irrigated land against any form of degradation.

This development vision presupposes the design of methods for the agricultural use of natural resources by the irrigators who accept these three foundations. Thus, the approach of the involvement and participation of these users at all stages of the implementation of the pilot becomes a sine qua non condition for the achievement of expected results and their widespread dissemination. In addition, this participatory system takes advantage of local expertise and the experience of the people concerned, taking into account local priorities and integrating them into a strategy that is open to innovations. In this perspective, it is important to:

- begin a decentralization process of decision making. This means delegating to the communities much power and responsibility to encourage and exploit the initiatives of farmers and strengthen existing local organizations or encourage the creation of

other interested groups based on the initiative. It is the application of the subsidiarity principle that allows the transfer of power to the local users of natural resources;

- develop partnership and cooperation between all parties involved (farmer organizations, NGOs, associations, government, local authorities);
- take into account existing initiatives in natural resource management (NRM) and integrate them into a single coherent program of action for sustainable development;
- identify the roles (or obligations) of the relevant partners, including the state and the farmers in the implementation of planned activities and set up a local structure for the monitoring and evaluation of results and their dissemination.

This participatory approach restores to the local community of farmers their water resource management autonomy, but in return requires them to maximize the obligations of high optimization of this resource and the preservation of the land quality. It projects to be a holistic approach (global and integrated). Ultimately, it aims to manage the multiple relationships between development partners around the most coveted resource by partners. These interactions are positive or negative externalities that are expressed differently in time and in space.

Development partners or POLICY CENTRES at the local level are multiple. They are in most cases as follows:

- the user of the irrigation water. He decides on his own socio-economic strategy (in the short, medium and long terms), facilities within own operations and the terms of use of irrigation water (crop selection, techniques, degree of intensification...)
- the farming communities organized as interest groups, NGOs, and groups that manage water resources and certain common services and interests;
- the State, through its central, regional and local governments that manage the economic, social and environmental balances at different spatial scales at local, regional and national levels and ensure the adoption of the participatory approach by the local populations.

The following summarizes the various positive and negative forms of interaction to manage within an equal partnership (Table 3).

Interactions between	Positive externalities	Negative externalities
Farmer-Farmer	Synergy and cooperation for common services	Concurrence for water, real estate issue, various negative impacts
Farmer-Community	Synergy Objective convergence and cooperation for mutual procurement and marketing services	Conflict related to sharing the resource, immediate negative impact or potentials, no payment of joint invoices (energy, water...)
Farmer-Administration	Convergence, improvement of the efficiency of state assistance-subsidies, extension...	Negative impact related to discordance between state strategy and peasant strategies...
Farmer-Community-Administration	Synergy, Convergence of interest Amicable sharing of resources Respect of the sustainable management of resources rules	Non observance of the GS rules, Conflicts in the resource allocation (restriction...) Negative impact of non-maintenance of the general facilities and infrastructures (drainage ditches)
Community-Community	Convergence of interests Cooperation, complementarity of roles	Various types of conflicts about the management of shared resources, common facilities...
Community-State	Complementarity Convergence of interests	Conflict about resources, strategic objectives, roles of partners
Community-Community-State	Coherence of development plans Cooperation, complementarity of roles and facilities	Conflict of interest and roles

Table 3. Interactions between decision centers, irrigation development partners at local level.

Thus, the principles of this participatory approach are as follows:

- voluntary involvement and commitment of all stakeholders at the local level (the water actors) to the three foundations of sustainable local development;
- taking into account the rights and obligations of each party through a consultation

mechanism for the amicable settlement of disputes within the framework of a general consistency of everyone's interests;

- the involvement of all parties at all stages: from setting the goals of a pilot to the development of the action plan for its implementation, the realization of the plan, the monitoring and evaluation of results.

On this basis, all the planned pilots will be designed, implemented and evaluated with the active participation of water users and other stakeholders. The pilot provides irrigation operators with the possibility to transmit their experiences and participate in the creation of a viable model on their own land. They also have the opportunity to see firsthand the results of proposed innovations; and in this respect, they will be the best communicators and disseminators of the introduced innovations.

More than that, beyond the project period, the adoption of the pilot innovations by farmers will oblige both the farmers and the National Water Authority to reflect on the funding arrangements for the duplication of the pilot. A new phase of negotiations on this issue could then begin among stakeholders.

### 4.3. The process of implementing the pilots

This process consists of four successive steps. They are briefly reviewed in the following; they will be detailed later in the presentation of each pilot.

**STEP 1:** Implementation the partnership institutional mechanism for the design, the implementation of the participatory approach and the monitoring and evaluation of the pilot.

To this end, the following actions are performed in succession:

- identification of water stakeholders involved in each pilot and recruitment of a national consultant to be in charge of field management;
- final choice of the theme of the pilot;
- research and selection of the pilot site and farmer;
- organization of a local awareness and information workshop: Constitution of local committee for the monitoring and evaluation of the pilot;
- establishment of partnership agreements between OSS and its development partners and local agricultural research institutions;
- negotiation, preparation and adoption of the action plan for the culture system to be set up;
- assessment of the financial contributions of the project operator and possibly other partners;
- mobilization of the financial contribution of the project.

## **STEP 2:** Implementation of all the dimensions of the Action Plan

- Daily implementation of the Action Plan by the National Consultant, the farmer and the other members of LPMEC;
- completion of a detailed technical study for the implementation of the pilot;
- acquisition and installation of hydraulic and agricultural equipment;
- starting the innovative cropping system according to the action plan approved and adopted by the local monitoring and evaluation committee of the pilot (LMEC).

## **STEP 3 :** Monitoring and evaluation of the implementation of the pilot and its results

This monitoring and evaluation is accomplished throughout the duration of the project. It thus covers:

- the implementation of the action plan initially within the logical framework of the project and updated regularly based on constraints and requirements for the achievement of the objectives of the project, on the one hand; and
- the technical, socioeconomic and environmental results achieved, on the other.

This monitoring is regularly reported through:

- regular quarterly reports by national consultants;
- annual and interim reports by the regional consultant;
- any inspection reports by the central water authorities and external evaluations by international consultants;
- reports of national and regional workshops dedicated to the presentation and dissemination of the results of the pilot;
- reports of the regional consultant relating to the progress of monitoring missions in the implementation of the pilot action plans in the three countries;
- minutes of local, national and regional workshops, discussion and dissemination of results.

The monitoring of the action plans implementation is provided at two levels:

- **that of the operators' at local level.** The Local monitoring Committees of each of the pilots, (LMC) composed of representatives of these operators, including notably water users or their representatives, carry on the ground on a daily basis, the assessment of of the planned activities progress, identify constraints and delays compared to the initial planning and propose remedial solutions.

The findings are submitted to:

- National Water Authority of the relevant country,
- National consultant in charge of the implementation of the pilot,

- Regional consultant in charge of the “Pilots” component at OSS.
- The project coordinator at OSS, in consultation with national water authorities of the three countries, with the assistance of two regional consultants who conduct monitoring and evaluation missions in the field.

The synthesis of these assessments is carried out in the regular reports of the regional consultant. It is validated by the end of term by OSS and forwarded to the OSS project partners.

The overall monitoring and evaluation of the results of SASS III project is completed at two levels:

- a self-assessment that is provided by national and regional consultants in consultation with the National Water Authorities of the three countries and under the supervision of OSS,
- an external assessment entrusted to an I assessor external to OSS.

Self-assessment is regularly carried out for most pilots except Pilot 4 expected to be implemented in Libya but cancelled for security reasons. For each pilot, the evaluation is carried out on the basis of the status indicators (technical, economic performance), and environmental impact indicators that are specific to the pilot and related to its local unsustainability issues. These indicators are identified in advance within the logical framework of the Project.

For instance, performance indicators are available globally as follows:

- improving the value of the use of irrigation water,
- improving the yield of major crops,
- increased farm incomes for farmers,
- job creation,
- the economic viability of the farming system in place
- acceptance of the participatory approach and the results of the pilot by the community of farmers.

As for environmental impact indicators, they cover the main threats to natural resources face. These impacts are:

Strictly hydrogeological impacts, including notably:

- reduction or disappearance of artesianism, which involves a potential recourse to water abstraction through pumping and would result in the loss of traditional catchments such as the “foggaras”
- excessive drawdown of the IC and TC layers, resulting in first a dewatering of shallow

drillings and the need to drill deeper in order to implement new drillings and second in interferences between catchments, including among the three countries;

- the depletion of natural outlets: the Tunisian outlet, which itself feeds a downstream aquifer (The Djeffara); reversal of flows at the chotts and diffusion of salty water into the SASS; increased salinity of the SASS waters.

In fact, the hydrogeological impacts have not been monitored, for the simple reason that they cannot occur in the short term (duration of the project).

Indirect environmental impacts:

- wastewater disposal into groundwater due to rapid urban growth and inadequacy in the management of urban sanitation; this drift contributes to the supply of the water table and results in its chemical and microbiological pollution;
- pollution of groundwater with pesticides and chemical inputs irrationally used in various intensive farming systems;
- degradation of wetlands used as receptacles for waste coming from multiple human activities, threatening their balance and their biodiversity;
- overexploitation of land resources and natural vegetation (used as itineraries, aromatic and medicinal plants...) around the irrigated areas.

**STEP 4 :** The dissemination and extension of results through various means such as:

- the development of regular reports on the pilot's progress and results by the National and Regional consultants;
- the visit of the pilot by other farmers, extension workers and other stakeholders in the local development;
- organization of workshops to report back results at national and regional levels;
- the development of brochures dedicated to pilots.



The final report of the “agricultural demonstration pilots” component of the SASS III project, conducted in Algeria, Libya and Tunisia, covers the achievements and results throughout the duration of the project since its inception in July 2010 until its closing in June 2013, over a period of 36 months. It summarizes all the activities carried out, reviews and evaluates the results, as expected, on the basis of relevant indicators defined in advance. It identifies key operational recommendations to implement the sustainable management of this precious resource. It therefore encloses all the phases of designing and implementing the six pilots, as well as the exploitation of their results at the agricultural, economic, social and environmental levels. To draft the report, all reports and multiform contributions of all the actors who participated in the execution of this component were capitalized. These include:

- operators of realized pilots;
- local technicians of the administrations in charge of water, irrigation and the environment;
- national consultants hired within the framework of this project to supervise the technical and financial management of the pilot;
- the General Directorate of the ANRH at the central level and its regional offices in the Wilayas of Adrar and Ouergla in charge of the development of the water sector, as well as other technical services of the irrigation and environmental protection;
- regional consultant in charge of the realization of the “demonstration pilots” component.

It is through the intersection and combination of the results and expectations of users of this resource that OSS strives to formulate operational recommendations to help these people benefit from a technological and organizational renewal that may lead to new and sustainable systems of irrigated agriculture. These systems would allow to ensure a significant improvement in their incomes through increased economic efficiency of irrigation, while ensuring the conservation of SASS resource.





# RESULTS OF THE PILOTS

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**35**

## PILOTS OF ALGERIA

**36** P1 : Ksar Aït Messaoud Oasis north of Reggane

**56** P2 : Sidi Mahdi Oasis near Touggourt

**77**

## PILOTS OF LIBYA

**79** P3 : Essouani Region, south east of Tripoli

**95** P4 : Oued Zemzem (Zone of the Center oueds)

**98**

## PILOTS OF TUNISIA

**100** P5 : Jedida Oasis near the city of Kebili

**118** P6 : Smar Medenine

**143** P7 : Chenchou near El Hamma de Gabès

**159**

## EVALUATION SUMMARY of THE PILOTS' RESULTS OF THE 3 COUNTRIES'

**164**

## GENERAL CONCLUSION



## I. AGRICULTURAL DEMONSTRATION PILOTS IN ALGERIA

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Algeria is the country where lays the most important part of the SASS territory, approximately 700,000 km<sup>2</sup> of a total of 1 million km<sup>2</sup>. It is also the first user of the SASS resource to cover the water needs of all socioeconomic sectors in the region. Over 85% of the total resource exploitation rate is allocated to agriculture, the rest to potable water, industry and tourism.

Developed in bioclimatic zones, mostly desert, semi-desert and arid in a smaller part, where the climatic water balance (difference between annual rainfall and annual potential evapotranspiration) is largely negative, agriculture there is exclusively irrigated. Initially confined to traditional oases structured socially, culturally and economically; and since the beginning of time, agriculture has been evolving and expanding around this SASS resource, with its openness on the markets, with the adoption of new production systems, outside the oases in open specialized areas that include in particular vegetable crops under shelter and cereal.

Nowadays, there is a great diversity of farming systems that reflect adaptation efforts of farmers to socioeconomic and technological changes they undergo. In this process, some of these systems collapse, others change, while others develop with more or less success. However, most of them suffer from a multitude of structural constraints of social, land and economic orders. In addition, most irrigated systems do not valorize irrigation water adequately and cause negative environmental impacts on the resource and on irrigated land.

As a result, the sustainability of the irrigated agriculture is not assured and faces multiple challenges, often complex, where technical dimensions are intertwined and linked to social and economic constraints. For this project, the focus of the project, namely the National Agency of Water Resources (ANRH) proposed two different major issues affecting irrigated agriculture of two different oasis systems. These are:

- the oasis system of the Great Area of Tuat-Gourara-Tidikelt, exploiting the SASS aquifer through foggaras for irrigation.
- the oasis system of the Oued Righ Great Valley, a large areas devoted mainly to date palm cultivation, Deglet Nour variety.

These issues are analyzed and processed in the following.

## PILOT OVERVIEW

**Geographical location:** Wilaya of Adrar, Reggane region, Ksar Aït Messaoud oasis 10 km north of the Reggane on the Reggane-Adrar road.

**Local issue of irrigation:** Water shortage resulting from the progressive drying up of the foggaras supplying the oasis, having as a consequence, abandoning irrigation over a large area of the developed lands.

**Theme of the pilot:** Restoration of the flow of the foggaras using solar pumping and rehabilitation of the oasis agricultural system.

**Agricultural production :** It is the family oasis system used for the production of foodstuffs for self-consumption or local sale.

**Cropping system:** It is a poly-cultivation family cropping based on date palm cultivation (date palm, local variety) with various subsistence crops.

**Water resources exploited:** A foggara in the process of drying up and overexploited surface wells.

**Availability of water for irrigation:** The oasis suffers from serious water deficit.

**Water quality:** The foggara water is good (total salinity of 2 g/l, while the water from wells has a salinity reaching 3-4 g/l).

**Water resources management:** The foggaras are managed within a community framework and the surface wells are privately operated.

**Threats to this production system:** the total drying up of the foggaras, the continuous dropping piezometric level and increasing salinity of the water from wells.

### 1. General context of the pilot

The Touat-Gourara-Tidikelt region extends over the Wilaya of Adrar on the south east border of the Western Erg Occidental, along a north-west axe from the Timimoun oasis in the north to the Reggane community in the south passing by the city of Adrar. It is an entirely desert region with an annual water deficit higher than 3,000 mm/yr, skeletal infertile land (plateau eroded by the wind...) and a lack of natural vegetation. Thus, in this

context, rainfed agriculture is impossible and climate change during the Quaternary age resulted in the desertification of the whole vast area south of the Saharan Atlas and imposed on the native population the adaptation to the harsh environment. Besides the option to migrate outside the territory, two distinct but complementary lifestyles have been adopted, depending on the availability or absence of water resources that can be mobilized easily:

- the nomadic lifestyle based on pastoralism and cross-border trade,
- the sedentary lifestyle, confined to a string of oases, aligned along the western periphery of the Tadmait plateau and the eastern boundary of the Occidental Grand Erg, thanks to a multitude of natural outlets of the Continental Intercalary layer which sub-flush in this area. It is useful to remember that this table is one of the two aquifers which constitute the SASS.

Thanks to the availability of the IC resource and its easy mobilization, the oases of Tuat-Gourara-Tidikelt developed. In fact, besides the direct use of water sources, the peasant genius innovated in terms of water drainage from the IC by the foggaras systems. This is sub-horizontal tunnels dug shallow (the static water table). The natural drainage of water in these galleries is done by gravity to the lower natural areas for domestic use and irrigation of small oasis. The water is then managed in a community setting through local associations whose functions are:

- distribute, in an equitable manner, water among the beneficiaries;
- resolve conflicts over water resources;
- ensure the contribution of all beneficiaries of water to the maintenance of the state and operation of the foggaras upstream the oases and drainage networks of each oasis.

In these countries, it is around the scarce water resource that communities are intimately structured. In addition, the traditional oasis system that largely feeds these communities is viable only under three conditions:

- the sustainability of water resources in terms of quantity and quality;
- the maintenance of hydraulic structures (foggaras and drainage systems for the evacuation of drainage water from the land);
- the opening of the oasis to its old steppe and desert environment, to exchange some food products produced on the site (dates) against other products such as cereals.

## 2. The local issue of irrigation

The word Ksar (plural ksour) means Castle in Arabic. Traditionally, each oasis is a socio-economic system culturally and socially structured around the water resource. There is therefore locally a local decision authority for the management of this resource as specified

above (the allocation and sharing of water and maintenance of water infrastructure). This authority is held by an elected local structure headed by a beneficiary, usually a notable of the local community. In the largest and oldest oasis of the region, the center of local decision materialized in the Ksar, which is a military-security building for the storage of Community strategic food; by extension, the word Ksar is allocated to the entire oasis. Thus, the word Ksar refers nowadays to the whole entity “oasis resort-community”.

Thus, Ksar Ait Sidi Messaoud is a small oasis with a total area of about 240 hectares divided into two parts:

- Initial oasis irrigated with three foggaras in the process of drying;
- an extension of an area of 120 hectares, of which only 23 hectares are still irrigated and operated by seventy farmers with water from a foggaras that dried up at more than 70% of its initial flow and a set of surface wells being overexploited.

The pilot is established on a few plots of this extension over a total area of about one hectare.

The population of this oasis is 645 residents whose incomes were initially exclusively agricultural, but have diversified their incomes by force of circumstances following the collapse of the oasis agricultural system because of the water shortage. Indeed, under the impact of a combination of several factors, including the expansion of irrigated areas, lack of maintenance of the foggaras galleries and overexploitation of the IC aquifer by deep drilling, the flow of most foggaras has declined steadily over the years. In this region, there were more than 4,000 functional foggaras with rates suitable to the needs of users.

Today, many foggaras have completely dried up and others have seen their rates drop significantly, including the one supplying the pilot (called Foggara of Tadmaït). Its initial continuous flow exceeded five (5) l/s, and which decreased now to only about 1 l/s. It's obviously very inadequate to ensure the survival of the oasis system in place. The situation led the ANRH to allow operators to dig and operate individual shallow wells on the eastern outskirts of the oasis. As the pumping of water is provided with electrical power 24 hours, it has only accelerated the overexploitation of the water tables and the drying up of the foggaras.

This situation is serious in many respects and reflects a deviation from the rules of community management of the aquifer. Indeed, water foggaras were everywhere managed within a consultation framework obeying rules scrupulously observed. The exception to these rules, that is introducing the individual management of surface wells, aggravated the situation and led to a deadlock that threatens the sustainability of irrigation in this locality.

The current issue of this oasis is the generalized important water deficit: the foggaras and wells are no longer able to meet the minimum water requirements of the oasis. Consequently the irrigated area is reduced to its simplest expression (less than a fifth of the extension



area), and operators are encouraged to supplement their income by using a diversified multi-activity outside the oasis, with many cases of total or partial abandonment of irrigation.

In this context, one of the durable solutions to this complex issue could be the restoration of the initial flow of the foggaras provided by a solar energy pump (few hours/day at a rate of about 5 l/s). The pumped water would be injected into the foggaras network, upstream of the distributor to be shared equally among the beneficiaries according to their quotas set within a community framework. This would restore the oasis agriculture, increase household income of the oasis inhabitants and stabilize these indigenous peoples on their farms.

### 3. Theme of the Ksar Aït Messaoud pilot

It consists in showing that this pilot could:

- restore the initial flow of the foggaras using solar pumping upstream the oasis;
- sustainably rehabilitate the oasis agricultural production system, ensuring a significant improvement in the efficiency of irrigation water and increased agricultural income of farmers, without negative impacts on groundwater and land.

This is subject to the support and participation of farmers and their local association in the implementation of the pilot.

Technically, this goal requires:

- the installation of a solar pumping station (a panel of a certain power and pumping equipment);
- the intensification of the cropping system through the use of proven agricultural techniques (appropriate localized irrigation, fertilization and reasonable phyto-sanitation).

### 4. Pilot location and characteristics

The pilot site is located 10 km north of the Reggane city on the road to Adrar, capital of the wilaya with that same name.

Its coordinates are:  $x= 0^{\circ} 05' 43'' 07 E$  ;  $y= 26^{\circ} 46' 32'' 07 N$  ;  $z= 205m$

This pilot is not designed over the entire Oasis. Only a few plots (farms) belonging to different operators are considered.

This is the deadlock situation in which Ksar Ait Messaoud is found, like many other oases in the region.

To restore the foggaras and their endangered oases, the SASS III project assumes that it would be possible to rehabilitate these oases through the introduction of a tested technology package judged capable of increasing the water efficiency and ensuring the stability of farmers on their land.

The purpose of this pilot was to demonstrate the feasibility and effectiveness of this renewal option. The action plan implemented in this demonstration is reported hereafter.

Figure 4. Spatial image of the geographical location of Ksar Ait Messaoud oasis.

Note in particular:

- the typical desert landscape of the zone;
- the irregular length of the cultivated plots because of the water deficit recorded at the level of each farm.

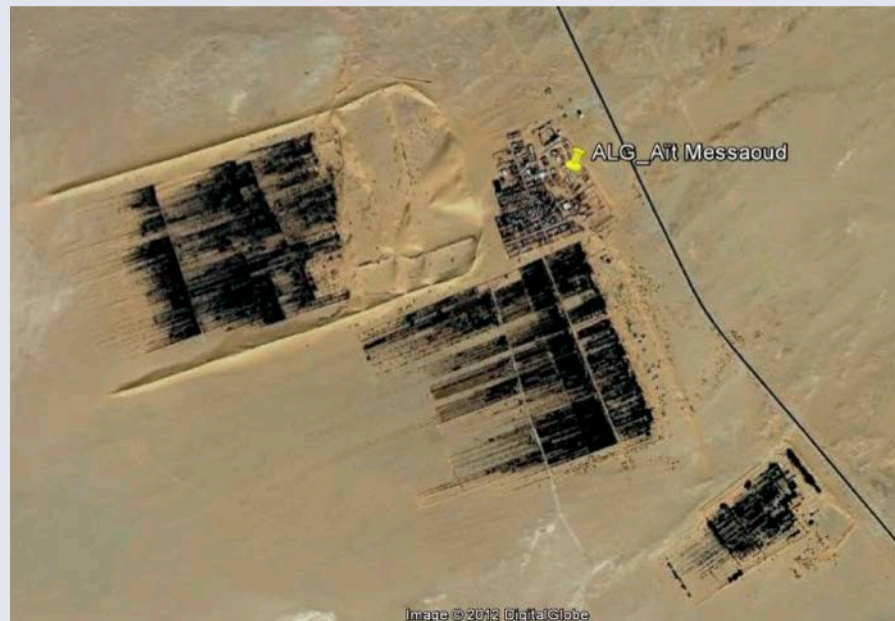


Figure 5. Location of the set of surface wells in parallel to the eastern periphery of the oasis.



Figure 6. Satellite image of the line of vertical wells of one foggara in the pilot zone.



Figure 7. Ground view of the mouths of the vertical wells of the Tamentit foggara under rehabilitation on the Adrar-Reggane road.

Figure 8. Restoration of a vertical well of the Tamentit foggara under rehabilitation.



Figure 9. Vertical cross section of the Tamentit foggara gallery at the level of its mouth at the old periphery of the oasis with the same name south of Adrar on the road to Reggane.





Figure 10. Divider of a foggara at the entrance of an oasis.



Figure 11. What remains of the water quota of a cropper of the foggara pilot after an important decrease in its flow.



Figure 12. A farm totally abandoned following the decrease of the flow of the foggara supplying this oasis.



Figure 13. Traditional cropping system using flooded irrigation.



Figure 14. Ruins of the old village of Tamentit entirely abandoned together with its oasis after the drying up of its foggara.

## 5. The pilot's action plan

According to the project's approach presented in the first part, the pilot's action plan is structured in the form of four types of activities, namely:

- the institutional activities for the adoption and implementation of the participatory approach (mobilization of water and irrigation development stakeholders at local level, establishing a Local Committee for the monitoring and evaluation of the implementation of the pilot and its results, recruitment of a national consultant in charge of the management of the pilot ...).

- technical innovation activities to improve the agricultural, economic and environmental performance of irrigation. These activities are divided into two categories for two objectives:
  - The acquisition and commissioning of a solar pump station comprising a solar panel on the one hand, and an electric pump generator that can provide a water flow rate of 5 l/s from an existing borehole to be made available to the project by the ANRH on the other. This station would work for 6 to 8 hours per day depending on the hours of sunshine.
  - The renovation of the cultivation system by a rational intensification of farming techniques and the use of chemical inputs. To this end, flood irrigation was replaced by two localized irrigation modes. A mode reserved for palm trees with a nozzle controlled by a micro-valves system and a drip irrigation system for annual crops (vegetables, cereals and fodder) in the interlayer space of the palm grove. This required the pressurization of water through small individual pumps.
 

The implementation of this renovation necessitated improved capacities of many operators of the oasis.
- implementation of the monitoring and evaluation activities of the pilot and its results (regular monitoring of outputs and outcomes, regular reporting on progress of the implementation of the pilot and the collection of results, visit to pilots by officials and local farmers with discussion of the results...);
- dissemination activities and extension of the results (organization of dissemination workshops, visit to the pilot by National Water Authority officials..., production of information leaflets and dissemination of results...).

## 6. Evaluation of activities carried out

Drilling available to the project to restore the original flow of the Tademait foggaras is called Ait Messaoud drilling. It is located on the eastern edge of the oasis.

Its coordinates are:  $X = 0^{\circ} 06' 11''\text{E}$  ;  $Y = 26^{\circ}46'45''$  ;  $Z = 213 \text{ m}$

Its depth is 150 m, its static level is 34 meters and its operating speed is 20 l/s.

Figures 16 to 18 illustrate material achievements in the pilot.

Until the installation of solar pumping station is planned, operators have adopted the new drip irrigation system using scarce water resources available from surface well. Thus, with the

water saving achieved using the new method of localized irrigation and rational management, the irrigated area has more than doubled the cultivation of interlining cultivation between palm trees (with the adoption various of food crops).

Thanks to two irrigation networks, water saving has been important and the *Seguias* (highly permeable sandy soil channels, therefore a source of great water loss through infiltration).

Various crops have been implemented by five operators over a total area of about one hectare (date palm and vegetable intercropping). Water availability allowed to restructure operations and to operate the new irrigation mode, but did not make it possible to meet

Figure 15. Project team with the oasis farmers around a drilling for the validation of the choice of this new resource and its use for the restoration of the initial flow of the foggara.



Figure 17. Connecting a well to an individual storage basin for the pressurization of the new localized irrigation network.

Figure 16. Visit to the pilot plots with OSS consultants together with the pilot farmers.



Figure 18. Installing an electric discharge pump at the exit of the storage basin for the pressurization of the localized irrigation network.

Figure 19. Intercropping area unexploited because of lack of water before the project.



Figure 20. Intercropping (zucchini using localized irrigation, 2011-2012).



Figure 21. Old distribution and flood irrigation channel (séguia) and its replacement by localized irrigation adapted to the palm tree.



Figure 22. Winter tomato crop with localized irrigation 2011-2012.

the minimum needs of water crops. Despite this, farmers have made tremendous progress in awareness of the water conservation issue and enhancement of its valuation. They also seized the complexity of the water situation in their oasis and interference between the impacts of the exploitation of shallow wells on the viability of their foggaras.

Ultimately, despite the large water deficit of the oasis, agricultural results obtained reinforced the conviction of operators that increasing the flow of the foggaras using the solar pump station will allow them to restore their oasis and improve consequently their farm income.

The evaluation of activities under this pilot is reported in Table 4 (see next page).



## 7. Main results

The expected results of this pilot were the rehabilitation of traditional oasis system through the restoration of the initial flow of the Foggara using solar pumping on the one hand, and improving the farmers' incomes, on the other. As the solar pumping station is not yet in place, the specific objective of this pilot is not yet achieved. However, the introduction of appropriate techniques for the intensification of crops in the context of water deficit has caused a total conversion of habits and reflexes of the operators in relation to the management of irrigation water. Indeed, the technical results recorded among the five operators were not uniform and had not reached the same level of performance. The following data clarify the performance achieved without the supplement of water expected from the solar pump station.

### 7.1. The cultivated area

The introduction of localized drip irrigation enabled, thanks to water saving achieved, to expand the cultivated area especially the intercropping area between palm lines. The total area of the plots of the pilot's five operators is one (1) hectare. Intercropping activities occupy 0.8 ha or 80%. This helped to achieve an increased rate close to 100%. Figure 3 (page 51) details the areas cultivated by the five operators of the pilot.

### 7.2. The cultivated species

They are very varied. Their selection was undertaken by croppers who take into consideration meeting their food needs first. Yields are not identical and reflect the levels of care provided by farmers, water quotas and the quality of their land.

The potato proved to be the preferred crop for farmers because it does not present a technical problem, or storage or marketing, while beans occupy the smallest area and represent the least successful crop. Vegetative cycles of these crops have the advantage to succeed throughout the cool season, from October to May, and spread their production, allowing to the best the management of the little water available.

As for the palm, it occupies only 20% of the total area of the plots, but its root system spreads outside its foliage, allowing it to take advantage of irrigation dedicated to intercropping. However, given the general water deficit, its production has not changed.

### 7.3. Yields

It was not possible, in the context of this oasis, to weight regularly every harvested produce. A significant part of this produce was for self-consumption, stored or offered without

Planned activities	Degree of realization	Results	Means of verification
Institutional activities			
Mobilization of water actors at the local level	Full	Information provided by the croppers, the regional office of the l'ANRH, the INRAA regional station in Reggane	Report of the 2 <sup>nd</sup> mission of the RC in this region
Recruitment of a national Consultant (NC)	Completed	Contract signed and launching NC activities	Quarterly report of the NC
Organisation d'un atelier de sensibilisation	Completed	Involving many croppers	Quarterly report of the NC
Constitution du Comité du Comité local de suivi-évaluation	Completed	Participation of the croppers in the committee	Structure of the committee according to quarterly report of the NC
Conventions de partenariat	Partnership conventions with INRAA signed and applied	Participation of partners in the development and monitoring of the pilot (INRAA, ANRH, DSA of Reggane)	Partnership conventions with INRAA
Technical activities			
Prospection of the field with the NC and the water authority, agriculture service and croppers and choice of pilot location	Entirely	Pilot site selected Existing drill made available to the project by ANRH to re-establish the initial flow of the foggara	Report of the RC's mission, quarterly report of the NC
Technical study and design of the pilot components	Entirely	Conception of the pilot	Quarterly report of the NC
Identification of necessary facilities and equipments	Completely		Quarterly report of the NC

Development of the Action Plan for the implementation of the pilot projects	Executed	Action Plan is available	Quarterly report of the NC and 3rd quarterly report of the RC
Implementation of the Action Plans	Agricultural equipment provided  Solar powered pumping station ordered, but it has not yet been installed	Agricultural equipments have been partially installed, since there have been some difficulties in procurement  Run-off of the foggara has not yet been re-established, since the station	Quarterly report of the NC
Parcelling Plan and first annual crops	Executed with the water resources available for the time being	The yields of the first harvests have shown net improvements in comparison with the local average, but they are below the envisaged results  The second agricultural season has also been undertaken without the support of the pumping station	Report of the NC  Report of the RC's mission  Communication of the NC during the first regional workshop on the pilot initiatives in June 2012  Report of the NC of the 4th Quarter 2012
Awareness raising activities and distribution of the results			
Information workshops	First awareness raising workshop executed	Involvement of the farmer to implement the pilots in their fields	First quarterly report of the NC
Dissimination of the results	Presentation of the synthesis of the national water strategies of the three countries to the steering committee of the project in Algier in May 2011  Development of a booklet about the pilots	PPT presentation    booklet available	Synthesis report  Mission report of the RC in Algier for the steering committee of the project    the booklet

Visit to the pilot	Activity not launched yet as the solar pumping station has not been installed yet	Positive but insufficient results	
Monitoring and reporting activities			
Quarterly reports of the NC	Reports received and validated	State of progress in implementing the pilot duly described	Reports of the NC
Quarterly and biannual reports of the Regional Consultant	Submitted and received by OSS	Information on the state of progress in the implementation of the pilot component shared	Reports of the RC
Biannual reports of the RC	Reports received and validated	Idem	Reports documents
Annual report of the RC	First annual report (July 2010 to June 2011 of the RC)	Idem	Report document
Mid-term report on the pilot component	Report received in December 2012 and validated	Inventory very well detailed	The relevant report
Final draft reports submitted in June 2013	Reports submitted to countries for validation	Results remain partial pending the setting up of the solar panel	The relevant report
Draft final report on the pilot component	Report received and validated by OSS	Final results drafted by the end of December 2013	This report

Table 4. Evaluation of the activities in implementing pilot 1.

being recognized. Figure 5 provides an estimate of returns on the basis of the marketed production.

Ces rendements moyens sont évidemment faibles par rapport aux moyennes nationales réalisées dans d'autres contextes édaphiques et climatiques, mais ils sont nettement supérieurs aux rendements obtenus traditionnellement dans les oasis.

Graphic 3. Areas of cultivated plots (ha) per farmer.

For some of these crops, such as potatoes and zucchini, the yields obtained are twice those known by the croppers outside the plots of the pilot. There is therefore a great satisfaction of the croppers of the pilot compared to the performances. They plan to do better on the day the solar pump station will be commissioned and provide the additional water expected.

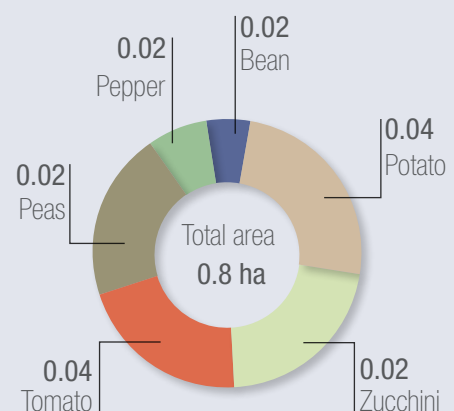
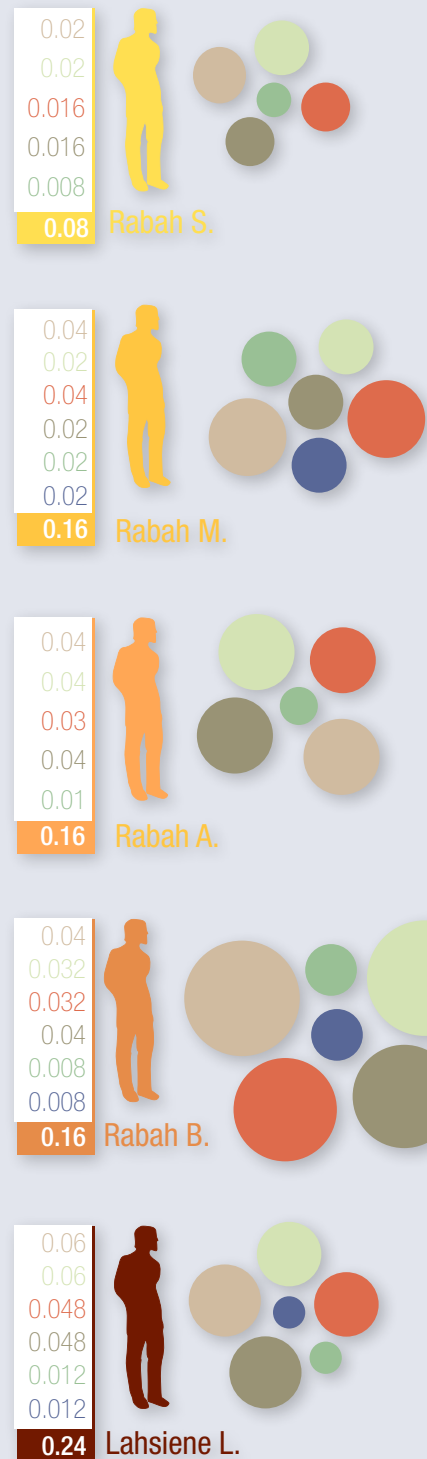
### 7.4. Produce

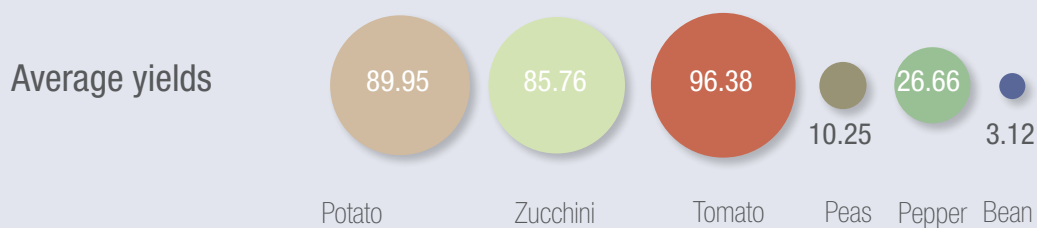
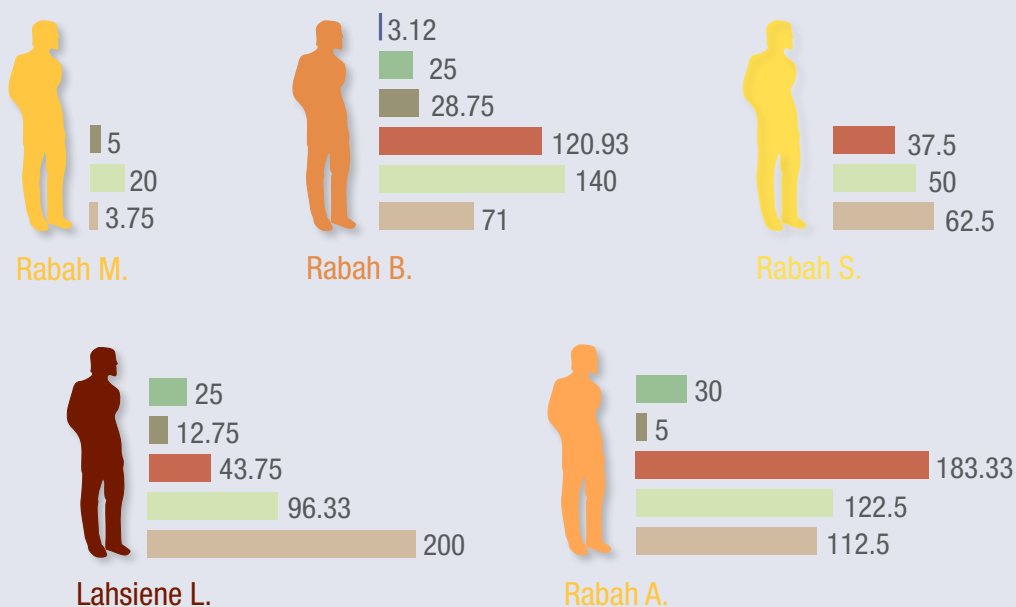
Crops were largely sold on the local market, a total of 5224 kg of all the species combined. Selling prices were highly variable and depended on several factors including the availability of croppers to sell the produce on market day (Graphic 6).

These data demonstrate that the introduction of the intensification technology package accompanying the localized mode suitable for irrigation crops has:

- better valorized the little water available on a larger area for further production;
- got rid of the labor allocated to the management of irrigation;
- explored issues related to intensification such as the selection of the most suitable species and varieties in a desert environment, the supply of necessary chemical inputs (soluble fertilizers used in fertigation and various pesticides ...) and the issue of market access outside to sell the produce at reasonable prices;

Graphic 4. Total area of various intercropping cultivations of all the pilot farmers.





Graphic 5. Estimates of yields (q/ha) obtained by cropper per crop.

- significantly improved farm income, according to the majority of farmers who have adopted the technology package.

All the work realized by the community of farmers even before the commissioning of the pumping station has significantly contributed to the increase of productions.

## 8. Evaluation of results

It is obvious that this assessment is only temporary as the centerpiece of this pilot has not been installed. The results must be taken in their context, they focused only on changes of various kinds caused by the project:

- change in the behavior of the croppers with respect to the resource: they now include the concept of saving water and optimum water efficiency. They discovered that they are able to produce more with the little water available, and they are seekers of innovation and coaching to address the new requirements of the crop intensification

system (supply of chemicals, flow of production, adaptation of introduced varieties...);

- a technical change: the transition from surface irrigation to drip irrigation adapted to the context of the oasis has resulted in a significant increase of crops and extending them throughout the cool season, which improved the supply of households in various fresh or preserved products (dried tomatoes, garlic, cereals, forage...);
- social change: the success of this demonstration sparked a new social dynamic in the community's management of oases;
- the adoption by many farmers (over 60%) of the oasis of the new techniques introduced and the manifestation of a strong demand for close supervision.

All these changes are expected to be confirmed the day farmers have access to additional water to meet the water needs of the palm and integrate annual crops. This is to be confirmed with the establishment of the solar pumping station.

## 9. Conclusion and recommendations

This pilot is implemented in its agricultural component only. Financial, commercial and logistic constraints have not allowed until today the installation and commissioning of the solar pumping station already acquired. It should be installed in the near future to start the new agricultural season with additional supply of water as expected. In this perspective, its impact on the water balance of the pilot and the irrigation efficiency will be correctly evaluated in the coming years.



Figure 23. Potato crops at two levels of development.



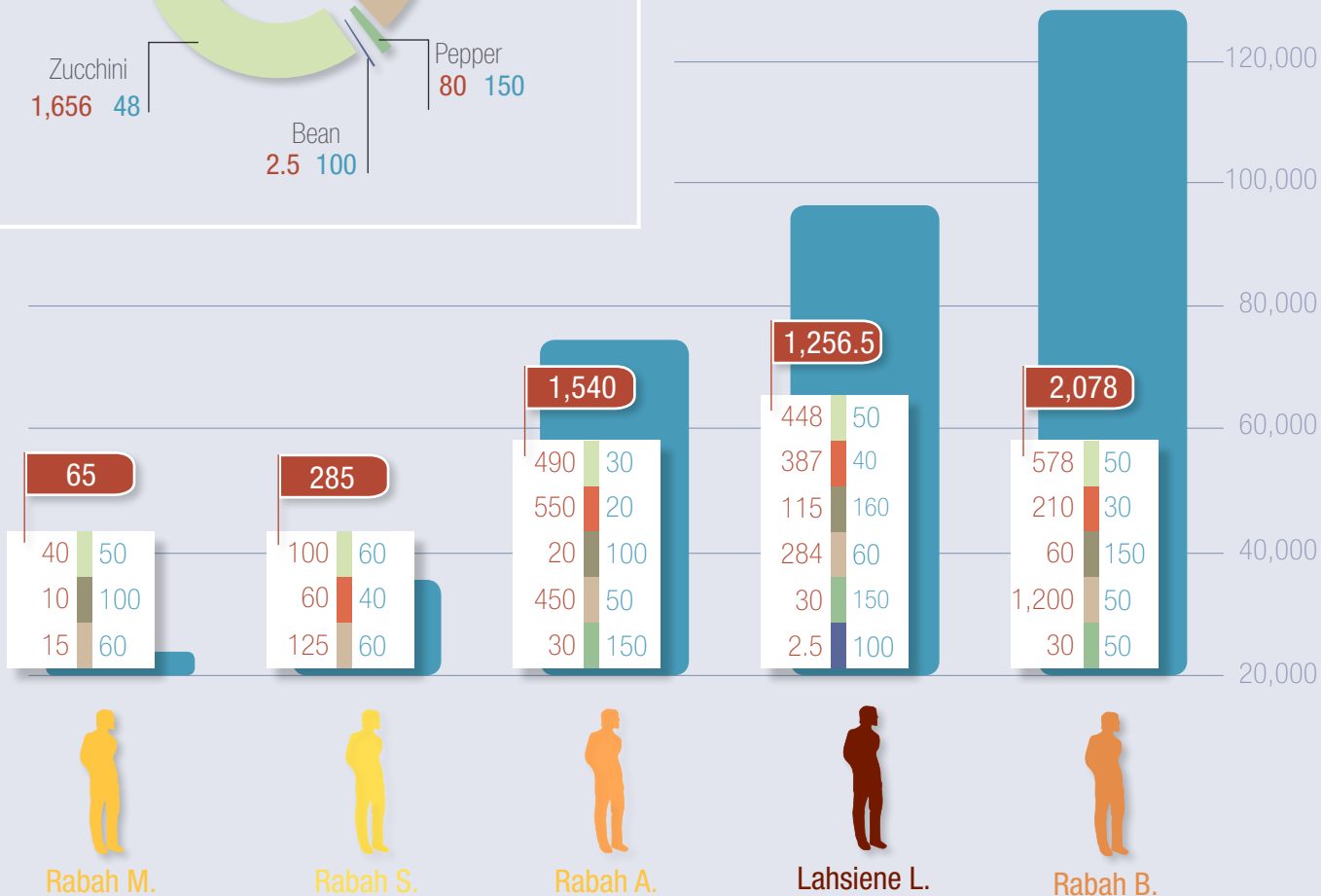
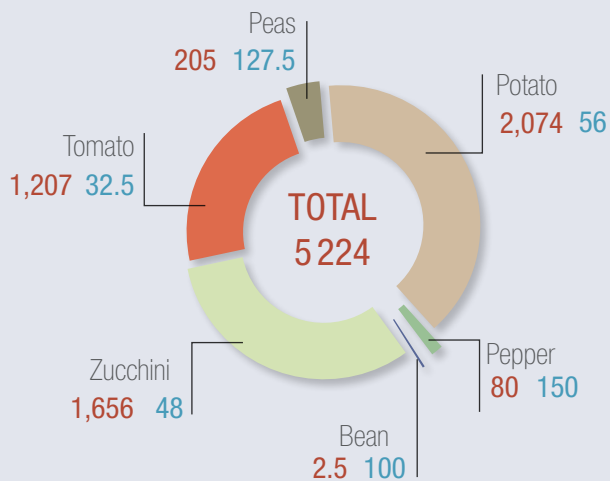
Figure 24. Zucchini crops at two levels of development.



Figure 25. Tomato crops at two levels of development.



Figure 26. Pepper crop in its beginning.



Graphic 6. Productions sold (kg) per crop per cropper, selling price of produce (in Algerian dinars/kg, knowing that 100 DA = 1 €) and revenue (AD) by cropper without those obtained from the sale of crops, dates and family livestock which are not declared.

The technical results obtained with the little water available, but with a new method of water-saving irrigation, opened up promising prospects for the conservation of this decaying oasis. The plot croppers are convinced of the relevance and efficiency of introduced innovations and most of their neighbors have adopted drip irrigation and intensive intercropping. Farm income has been significantly improved. It led to a strong social demand for the extension of the project to the whole oasis. Unfortunately, meeting this demand is hardly possible without the solar pumping station and the restoration of the original flow of the foggaras.

Therefore, it is important to mobilize all partners in the project at all levels of decision



making to set the pumping station the earliest possible as the latter represents the major component of the strategy adopted to safeguard the foggaras and the community oasis system.

## PILOT OVERVIEW

**Geographical location:** Wilaya of Ouargla, Touggourt region (Oued Righ valley), Sidi Mahdi oasis, 5 km south east of Touggourt.

**Local issue of irrigation:** In a general context of no water shortage, the bad management of irrigation networks results in an increase in the level of the groundwater table, having as a consequence the development of hydromorphy in most irrigated lands as well as their salinization ; hence serious socioeconomic and environmental impacts.

**Theme of the pilot:** Land Restoration through better land and water management and the intensification of the cropping system.

**Agricultural production system:** It is a family oasis system based on the date palm cultivation, Deglet ennouar variety, as a major crop and subsistence crops mainly for self-consumption.

**Cropping system:** It is a poly cropping system based on date palm cultivation (date palms, local variety) with various subsistence crops.

**Water resources exploited:** There are two layers drilled in this region: The Continental Intercalary (IC) with its geothermal waters and the Complex Terminal (CT).

**Availability of water for irrigation:** Overall, the available water resources could cover the crops needs. However, the inappropriate and inadequate management of these resources results locally in conflicts and water shortage.

**Water quality:** The water resources of both layers have a salinity of 3-4 g/l, hence the evident risk of salinization of the irrigated lands.

**Water resources management mode:** The irrigation water resources are managed by associations of the croppers at local level. As for the open drainage network located outside the farms, it is managed by the National Irrigation Bureau (Office national de l'irrigation et du drainage (ONID)).

**Threats to the production system:** The aggravation of the hydromorphy and salinization of the lands as a result of the shortcomings of irrigation and drainage that represent a heavy threat to the oasis system and Oued Righ valley, one of the major zones producer of Deglet Nour in Algeria.

**Evolution trends of the system:** In the absence of integrated and coordinated intervention of all the water stakeholders for the rationalization of the water management, irrigation will be abandoned progressively according to the degradation of the lands, and therefore the agricultural production system.

## 1. General context of the pilot

The pilot site is located in the Upper Valley of Oued Righ. This valley stretches north-east of the Sahara, along the Oriental Grand Erg and south of the Saharan Atlas. It extends over a north-south axis along about one hundred and fifty (150) km. It is defined by the following coordinates:

$$X1 = 04^{\circ}58'55'' \quad - \quad X2 = 06^{\circ}28'41''$$

$$Y1 = 32^{\circ}45'22'' \quad - \quad Y2 = 34^{\circ}33'47''$$

This valley forms a broad elongated depression with a peak in the south, 80 m of altitude in Touggourt and a downstream point to the north, with 0 (zero) m in the vicinity of El Mghaïer along Chott Mérouane. There are even negative scores around the center of the Chott. Its overall slope is therefore 1 for one thousand. This exposes most of the land in the valley to poor drainage with all its consequences. It begins in the south at Goug located about 30 km south of Touggourt and ends in the town of Umm Ettieur along the National Highway No 3. Administratively, the valley is covered by two Wilayas (Ouargla and El Oued) and the pilot is located in the Wilaya of Ouargla in the Touggourt region, specifically in the Sidi Mahdi oasis.

This valley represents a very special large socio-economic development zone, which has developed since old times date palm cultivation based on a single crop variety Deglet Nour in over 50 oasis with a total area of about 20 000 ha, on both sides of a central axis, the channel Oued Righ. This channel is used as a general collector of runoffs, agricultural drainage and urban sanitation.

At climate level, it is a desert region, receiving less than 100mm/yr. of rainfall, with a negative climatic water balance during all the months of the year, making rainfed agriculture inconceivable. Hence the importance of the SASS resource in this region for all socio-economic activities, especially for irrigated agriculture.

The Oued Righ Valley Drainage system is provided by the open channel over a length of 150 km from the town of Goug (Daira Temacine) to chott Mérouane to Melghir (El Oued Province). This channel was originally built in 1924, its flow slope is about 0.1% (for one

thousand), the third southern section of this channel is of natural origin, while the northern two-thirds were dug and recalibrated.

Following the deterioration of this channel, the State had carried out major works for redevelopment between 1980 and 1984. The objectives of these works were:

- the drawdown of the water table;
- drying of the valley through the evacuation of excess irrigation water;
- evacuation of sanitation waters of urban areas located on both sides of the channel, along all its course.

Figure 27. Main collection channel of the valley of Oued Righ.



The channel collects and evacuates drainage water in the Chott Mérouane through Oued Khrouf. Its hydrologic characteristics are as follows:

- Total length = 136 km
- Average width = 10 m
- Average depth = 4 m
- Average flow speed = 0.7 m / s
- Average Salinity = 15 g / l
- Slope flow = 1/1000
- The upstream flow (Touggourt) is 2.6 m<sup>3</sup> / s.
- The average maximum rate downstream (Chott Merouane) > 5m<sup>3</sup>/s

This center channel plays a vital role for all the communities developed along its route and in protecting the quality of oases land, the main source of food in the region.

As for groundwater resources, there are three main tables:

- water table with depths ranging from 0 to 50 m, with water containing salts (up to 13 g/l). The power of this sheet is essentially maintained by irrigation surpluses. It is rarely used for irrigation;
- water sheet of the Terminal Complex, located at depths between 65 and 416 m, the spot rate varies from 25 to 45 l/s; it provides water that has a saline load of 3 11 g/l;
- water sheet of the Continental Intercalary, located at depths up to 2200 m north of the valley. Its quality is much better than the previous one. It is mobilized especially for potable water.

These resources are increasingly called upon to respond to an uncontrolled growth of water demand by all socio-economic sectors. But it is still agriculture that is most demanding. The total number of drillings of the two main aquifers increased from 318 in 1975 to 848 in 2004. This number has certainly exceeded 1000 now, not taking into account the number of illegal boreholes.

## 2. Local issue of irrigation

The issue of P2 concerns t most of the oases of Oued Righ Valley in Algeria, as well as several other oases in Tunisia and Libya. Indeed, many traditional and modern oases in this region are suffering the impacts of improper management of irrigation water and land drainage. Including large areas in irrigation within a general context of non-water shortage and the rise of the water table has resulted in the development of an intense hydromorphy causing salinization of land. The extension of an efficient drainage system outside the farm failed to decrease sufficiently the level of the water table. This results in a low efficiency of irrigation water, degraded plantations and even their degeneration in certain situations. Thus, sustainability of such farming is certainly under threat given the changing trends in the incomes of farmers. Increasingly, small farmers are encouraged to use multiple activities to improve their income.

## 3. Theme of the pilot

This theme focuses on improving the efficiency of irrigation water and control of land degradation in the context of non-water shortage.

It therefore implies remedying to deficiencies in the quality of the land using buried drainage

within the farms, then the improved management of irrigation water for both the desalination of upper soil horizons and the renovation of the culture system. The ultimate goal is the intensification of this culture system, increasing farmers' income and improving their living conditions.

#### 4. Location and characteristics of the pilot

The coordinates of the pilot are:  $x= 6^{\circ} 06' 01'' 20'' E$  ;  $Y= 33^{\circ} 04' 39'' 13'' N$  ;  $Z = 205$ .

The Sidi Mahdi oasis pilot is five kilometers south of Touggourt (wilaya of Ouargla), opposite Touggourt airport and close to the regional INRAA station.

This is a palm grove with a total area of 5 ha created in 1959, with two parcels P1 and P2, initially flood irrigated with water from a borehole drilled in the Complex Terminal. The panels have a length of 108 m and a width of 1.5 m. The palm trees are planted on the edge of the panels 9m apart on the line and 15 m between the lines. The panels are also used for various annual food crops and fruit, so their flood irrigation benefits all species. The intermediate space, rarely cultivated, is occupied by open drainage ditches, often poorly maintained, non-operational and invaded by indicator plant species of strong hydromorphy.

The initial distribution network of the irrigation water is reduced to a main concrete pipe, the remainder being séguias (earthen ditches). Irrigation is then performed in series; it requires the mobilization of manpower and time, with large water infiltration. Given the low price of water paid by the cropper, the volumes of irrigation water are often excessive and contribute to the leaching of soluble nutrients, the increasing level of the water table and the development of waterlogging. The entire farm suffers from the proximity of the table of the palm root system.

The low overall slope of the Valley does not facilitate the natural drainage of excess water. This results in waterlogging that affects the various levels of the land of the successive compartments of the Oued Righ valley.

The open ditches inside the farms, poorly maintained, eventually collapse, clog quickly and lose their effectiveness.

This is also the case of the side drainage channel systems constructed outside the farms. Hydrophilic reeds (*Phragmites*) rapidly developed there and at high density and ended up clogging the discharge of drainage water from the farms.

Hence the urgent need to address all forms of degradation of all the components of the drainage network.

In addition, agricultural drainage water is contaminated by untreated discharges of municipal

Figure 28. Satellite image of the Oued Righ valley oasis map.

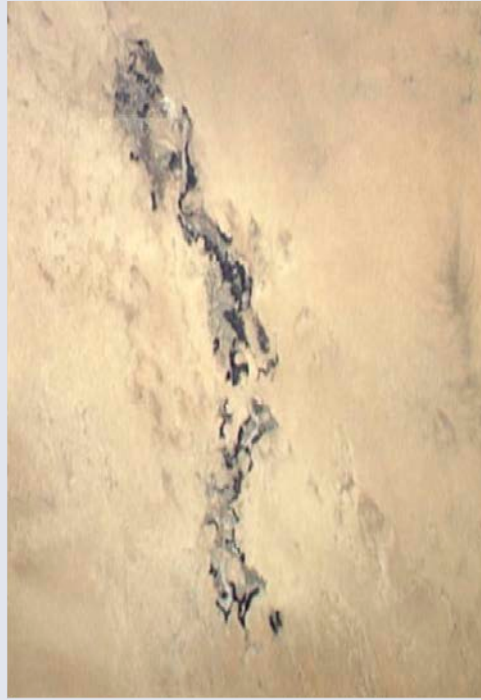


Figure 29. Satellite image of the pilot's site.



Figure 30. Spatial image of the palm grove of the pilot.



Figure 31. Intra-plot open draining ditch that has become non-operational due to a lack of maintenance.



Figure 32. Secondary collecting channel sealed with reed.



and industrial wastewater coming from many towns and cities of the Valley of Oued Righ. Irrigated areas thus suffer from three major soil constraints:

- hydromorphy (rise in the shallow surface water table causing crop asphyxiation);
- progressive salinization associated with it, resulting from poor management of irrigation and drainage waters;
- contamination of the water table and soil by biological and chemical pollutants from industrial wastewater and household.

The site of the pilot selected in Sidi Mahdi oasis offers all the features of this problem, the planned actions have two basic objectives:

- remedy to the poor drainage and cause a gradual desalination process surface horizons of the land and the restoration of fertility;
- Improve agricultural and economic performance of irrigation through a reasoned intensification of the oasis production system.

## 5. Action plan of the pilot

To achieve the objectives, an action plan was developed and adopted with the farmer and the other project partners. This plan, in line with the overall approach of the project, is structured around four areas:

- institutional axis integrating the participatory approach with the involvement of all water stakeholders around the objectives of the SASS III project, the creation of a local monitoring and evaluation committee of the pilot and adoption of the Action Plan . Partnership agreements have therefore been established between OSS and various actors at the local level, including National Institute of Agronomic Research of Algeria, the Regional Directorate of ANRH and ONID.
- A technical component that includes all land development activities, intensification technical innovation and crop management:
  - the development works consist in the establishment of a buried drainage system of 1.4 m deep, the sandy amendment to the soil surface, the establishment of two local irrigation networks adapted to palm trees (high flow nozzle controlled by micro-valves) and various annual crops located in the space in-between the palm lines (drip irrigation network for low flow market gardening);
  - the intensification of farming techniques (local species and varieties chosen selected by the cropper according to its strategy, the use of chemicals...).

It is noteworthy that the farm was divided into two parcels of the same area P1 and P2. P1 is the pilot plot that has benefited from various development works, agricultural



equipment and innovative farming practices, while P2 was managed as a sample, that is to say, according to past practices in the project.

The initial work related to the establishment of an underground drainage network with significant technical and material contribution by ONID (National Board of Irrigation and Drainage), the national organization in charge of irrigation networks and drainage of all the Valley areas.

In the pilot plot, flood irrigation has been replaced by waterproof plastic pipes where the water is pressurized by means of a pressure electrical pump (Figures 38 to 41).

- A monitoring and evaluation axis for the implementation of the pilot and its results on the basis of economic performance indicators, predefined technical and environmental indicators; this monitoring is being provided locally by the CLSEL by local technical services and OSS consultants under the supervision of the Project Coordinator.
- An axis for dissemination of results through pilot visits and platelet production and presentation of results to local and regional workshops.

## 6. Evaluation of activities carried out

This evaluation is summarized in table 5.

## 7. Main results of the 2 consecutive years of the Pilot Implementation

### 7.1. Main agricultural results of the first year (2011-2012)

The main agricultural achievements during the first year (2011-2012) are as follows:

- the first harvest date (November 2011) obtained after completion of drainage and irrigation network showed an increase of more than 50% of production in the pilot plot compared to the reference plot;
- a significant improvement in the quality of dates;
- a doubling of revenues from the sale of the crops of the entire farm;
- an improvement of income for the cropper following the immediate success;
- absence, unfortunately, of annual crops harvest in place that have not completed their cycles following stopping irrigation due to a labor dispute.

As far as the environmental impacts of the local irrigation network and the buried drainage is concerned, a protocol for monitoring changes at the level of the water table, salinity of drainage water and that of the sheet (in the piezometers) and soil was implemented and



Figure 33. A plot of the oasis before renovation by the project.



Figure 34. The water distribution channel at the entrance of the farm.

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Figure 35. Laying the drainage pipe.

Figure 36. Filling the drainage ditch after laying the drainage pipe.

Figure 37. Sandy amendment to remedy to what is left of the open drainage ditches and elevation of the soil surface.

Figure 38. Setting an electrical pump for the pressurization of irrigation water.



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Figure 39. Efficient operation of the drainage network as soon as the buried channels were installed.

Figure 40. The Algerian National Consultant, M. Lamine Hafouda supervising the extension of the localized irrigation network.

Figure 41. Manhole at the entrance for evacuation of drainage water.

Planned activities	Degree of realization	Results	Means of verification
Institutional activities			
Mobilization of water actors at local level	Entirely	Voluntary involvement of the croppers to adopt innovative techniques on their farms	Report of the 2nd mission of the RC in the region
Recruitment of the National Consultant (NC)	Completed	Contract signed and mission assigned	Quarterly reports of the RC
Holding an awareness workshop	Completed	Involving many croppers	First quarterly report of the RC
Setting up the local monitoring/evaluation committee	Completed	Participation of croppers in the committee	Structure of the committee in the quarterly report of the RC
Partnership conventions	Conv. with INRAA, ANRH, ONID and croppers	Participation of partners in the development and monitoring of the pilot	Conventions signed with partners and quarterly reports of the RC and NC
Technical activities			
Prospecting the field with the NC and water authority, agricultural services and croppers, selection of the pilot site	Entirely	Pilot site selected	Mission report of the RC Quarterly report of the NC
Technical study and design of the pilot components	Entirely	Design of the pilot and action plan	Quarterly report of the NC
Identification of required works and equipment	Entirely	List of equipment and estimates of the cost of the pilot	Quarterly report of the NC
Adoption of the action plan and implementation of the pilot	Entirely	Action plan adopted	Quarterly report of the NC and 3 <sup>rd</sup> quarterly report of the RC

Implementation of the action plan	Completed	Drainage and irrigation networks developed and operational ; annual crops set up with localized irrigation for annual crops and cuvette for palm trees ; fertilization and phytosanitary treatment.  However, the suspension of water supplies and the negative impact on annual yields during the spring of 2012. This constraint has been solved only during the fall of 2012.	Mid-term report of the RC  Communication of the NC to the 1st regional workshop on the pilots June 2012, Medenine Tunisia  New convention between water administrators, OSS and the cropper
Extension activities and dissemination of results			
Information workshop	1 <sup>st</sup> awareness workshop	Committing croppers to receive the pilot in their farms	1 <sup>st</sup> quarterly report of the NC
Dissemination of results	Presentation of the summary of national water strategies of the three countries to the Project Steering Committee of the project	PowerPoint presentation  Visit by students and teachers of the INA in Harrach	Summary document  Mission report of the RC in Algiers to the Project Steering Committee  Presentation by the NC on the P2 during a regional workshop on the pilots in June 2012, Medenine Tunisia
Visit to the pilot	In Algiers in May 2011	Approbation. Assignment of 3 MA students on composting waste of the available crops	Report of the NC, protocol of research on composting and list of students
Activités de suivi évaluation et de reporting			
Quarterly report of the National Consultant	Report of the Algerian NC in charge of the available pilot, received and validated	State of progress in implementing the pilots duly described	Documents of progress reports on the design of the pilot by the NC

*continued on next page*

Quarterly reports of the RC	Submitted and accepted by OSS	Information shared on progress in implementing the pilot component	Documents of the RC reports
Biannual reports of the RC	Report of the first semester (July to December 2011) submitted to OSS and validated	Same as precedent	Report document
Annual reports of the RC	Report submitted to OSS and validated	Same as precedent	Report document
Mid-term report	Report submitted and validated	Same as precedent	Project document
1st Phase report on pilots	Report submitted and adopted	Same as precedent	Project document
Final draft report on the pilots of Algeria (June 2013)	Report submitted for validation	Final results were presented to the Steering Committee in May 2013	This report
Draft final report on the entire pilots component (December 2013)	Report submitted for validation	All the results with their general guidelines on operational recommendations	Document of this draft final report
Final report on the pilots component	Submitted to OSS for validation	All the results and operational recommendations	This final report

Table 5. Evaluation of activities carried out in pilot 2.

executed over 24 hours during irrigation. Similarly, the volume of water for irrigation and drainage were estimated as from the establishment of crops and the start of irrigation (twice a week). The results are as follows:

- concerning the efficiency of the drainage system, the drainage water flows recorded a consistent evolution trend with the occurrence of irrigation and the dynamics of the sheet. A peak flow almost concomitant with the supply of irrigation water is observed, followed by a downward phase characterized by a gradual drying rate,
- the salinity of irrigation water is of the order of 4.2 g/l and the drainage water ranged between 9 and 10 g/l of total soluble salts, proof of good drainage efficiency on desalination soil.
- 24 hours after irrigation, a slight increase of the surface sheet is recorded followed by a gradual lowering of its level.
- after two months of irrigation-drainage, the water sheet has dropped by about 20 cm.
- preliminary results of soil analysis in the vicinity of 9 piezometers installed in the pilot show a stabilization of the average salinity of the soil solution of the soil profile,

around 5-6 g/l. This reflects a good irrigation efficiency and balance between the salinity of the irrigation water and soil.

Thus, the results of the first winter season of 2012 clearly show a positive impact of the drainage system on the quality of the soil and the drawdown of the initial level of the sheet. This result was confirmed during the summer season during which the irrigation system and the operation of hydro-saline soil were more intense. The first objective of the pilot is fully achieved.

As for the economic assessment, it was not possible due to the suspension of irrigation following a social dispute, resulting in the loss of all annual crops that started in the fall of 2011 and winter 2012. The conflict was solved thanks to the intervention of technical Services and the supply of water has been restored at the end of the summer of 2012. Thus, the second agricultural year could be started in the fall and continued until to its end in May 2013.

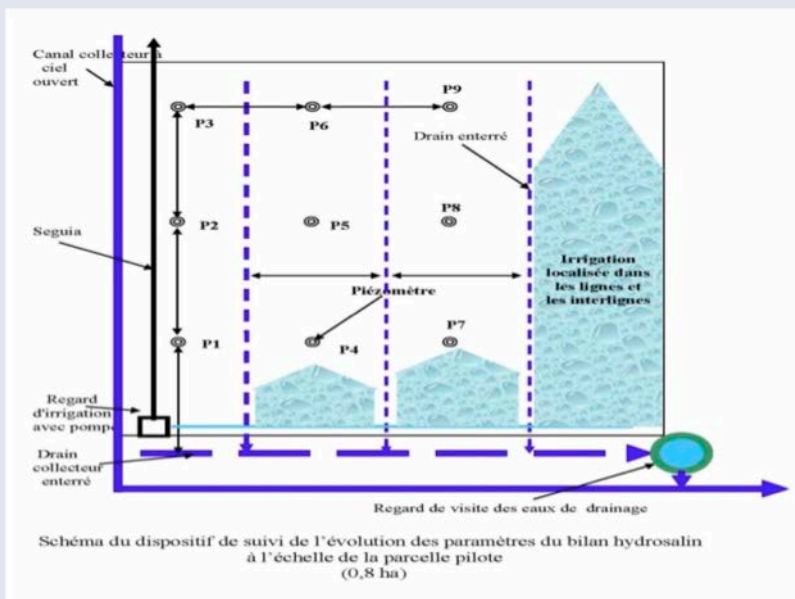


Figure 42. Diagram of the apparatus for the monitoring and evaluation of the hydrosaline results.

## 7.2. Results of the second year (2012-2013)

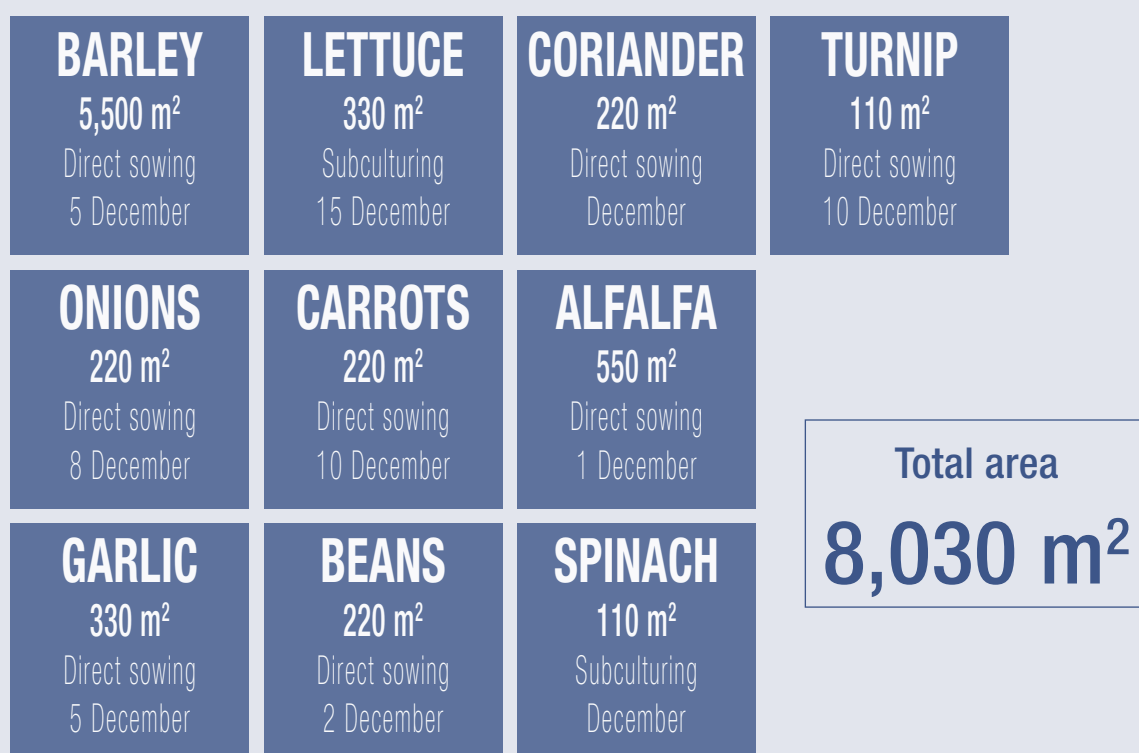
The action plan developed during the second agricultural year, drafted in consultation and with the approval of the cropper, comprises:

- continuing the monitoring of the impacts of drainage on groundwater and soil;
- the application of intensification cultivation techniques of date palm cultivation and intercropping;

- the introduction of annual food varieties selected by the cropper for their profitability with the strict application of recommendations on intensification techniques (drip irrigation and proper fertilization);
- the introduction of poultry farming, considered very profitable by the cropper, because it provides all the manure required for the operation. This represents significant savings for the pilot, given the very high cost of sheep manure used and the difficulties in the supply of fertilizers in this region. This innovation was suggested by the cropper, discussed and approved by the local pilot monitoring and evaluation Committee, the national and regional consultants of the project.
- monitoring water consumption and water table depth, and the establishment of water and salt balances of the plot equipped with a buried drainage network;
- monitoring revenues and expenditures.

The numerical results are provided in charts and tables on the following page:

Based on these results, although the drainage is efficient, soil desalination is not complete yet, since the salt balance in the soil remains positive. The total evacuation of salts caused by irrigation water is not complete. During this follow up time to water drainage, there was an accumulation of 3,274 tons, which represents about 25% of the contributed salts.



Graphic 7. Areas and dates of sowing of annual crops in intercropping (2012-2013).



Given the fact that the desalination process is still in its beginning, these results must be considered very positive, in comparison with the initial situation where all brought salts accumulate in the soil and groundwater. The dissolution of the least soluble salts (sulfates in particular) accumulated in the soil and their evacuation outside the operation can only be gradual and at different speeds depending on the nature of the chemical elements. It is therefore important to continue monitoring and evaluating the annual salt balance to describe the evolutionary trend of groundwater level, its salinity and that of the soil, the volume and the salinity of drainage water exported outside the farm for several years. We note, however, that this result remains approximate as the surface sheet is open laterally. The circulation of this sheet by natural drainage is at the origin of more or less important transfer of soluble salts.

Technically, the average yields/ha are approximately the double or quadruple of those obtained in the whole area. This performance is the result of efficiency in irrigation water use for the practiced cropping.

Cultivated areas	Area (m <sup>2</sup> )	Date of sowing or subculturing	Harvested quantities	Unit	Observation
Date palm	10,000 (100 trees)		8,000	Kg	Average yield of 80 Kg/palm tree
Barley cultivated for its grains	2,750	5 December 2012	550	Kg	Average grain yield of 20 Q/ha
Barley harvested green (fodder)	2,750	5 December 2012	11,000	Stack of 1 kg	Two harvests per year
Onion	220	8 December 2012	465	Stack of 1.5 kg	
Garlic	330	9 December 2012	320	Stack of 1 kg	Average yield in bulbs of 7,580 stacks/ ha
Lettuce	330	15 December 2012	350	Stack of 0.5 kg	5.1 tons/ha
Carrot	220	10 December 2012	350	Stack of 2 kg	30 tons/ha
Beans	220	2 December 2012	880	Kg	16 tons/ ha (green pods)
Coriander	220	December 2012	1,022	Stack of 0.25	11 tons/ha (leaves)
Alfalfa	550	1 December 2012	898	Stack of 1 kg	16 tons/ha
Spinach	110	December 2012	416	Stack of 1 kg	37 tons/ha
Turnip	110	10 December 2012	230	Stack of 2 kg	20 tons/ha

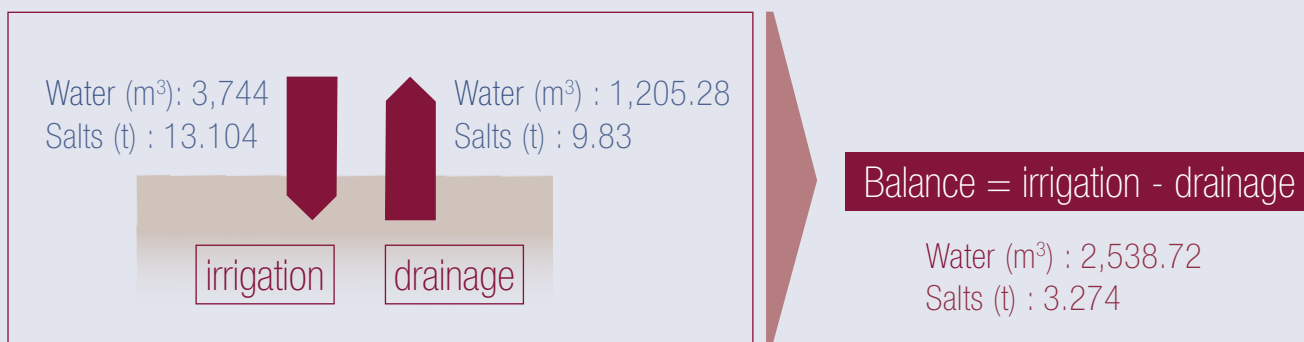
Table 6. Areas, yield and incomes of the cultivated varieties.

Water Turn	Number of days	Average flow (l/s)	Volume of drainage water (m <sup>3</sup> )	Total concentration of salt (g/l)	Total export of salt (tons)
Turn (1)	3	0.18	46.66	9.85	0.46
Turn (2)	4	0.13	44.93	8.76	0.39
Turn (3)	3	0.19	49.25	6.49	0.32
Turn (4)	4	0.13	44.93	8.86	0.40
Turn (5)	3	0.16	41.47	7.51	0.31
Turn (6)	4	0.15	51.84	6.53	0.34
Turn (7)	3	0.19	49.25	6.50	0.32
Turn (8)	4	0.12	41.47	9.32	0.39
Turn (9)	3	0.19	49.25	6.34	0.31
Turn (10)	4	0.18	62.21	6.58	0.41
Turn (11)	3	0.15	38.88	8.51	0.33
Turn (12)	4	0.13	44.93	6.65	0.30
Turn (13)	3	0.16	41.47	7.85	0.33
Turn (14)	4	0.18	62.21	10.40	0.65
Turn (15)	3	0.15	38.88	9.91	0.39
Turn (16)	4	0.16	55.30	8.91	0.49
Turn (17)	3	0.19	49.25	8.76	0.43
Turn (18)	4	0.14	48.38	6.43	0.31
Turn (19)	3	0.19	49.25	9.50	0.47
Turn (20)	4	0.16	55.30	8.34	0.46
Turn (21)	3	0.14	36.29	9.39	0.34
Turn (22)	4	0.19	65.66	7.95	0.52
Turn (23)	3	0.13	33.70	8.95	0.30
Turn (24)	4	0.19	65.66	7.42	0.49
Turn (25)	3	0.15	38.88	9.65	0.38
Total period (1/1/2013-31/3/2013)	1,205.28		9.83		

Table 7. Drainage water and exported salt of the pilot during the period 1/1/13 to 31/3/13.

The economics of this campaign is also very positive (Table 9).

The comparison of total revenue (3,138,650 DA) achieved during this campaign with the average revenue of the farm (347,340 DA) before the project can measure the positive impact on the income of the pilot's cropper; which highlights the relevance of the efficiency and sustainability of this demonstration management of the SASS resource in Algeria. It certainly opens up new prospects for the future of the oases of the entire Valley of Oued Righ.



Graphic 8. Hydrosaline balance at the scale of the plot - Period (1/1/2013- 31/3/2013).

Crops	Area (m <sup>2</sup> )	Produce harvested Kg	Total volume of consumed water (m <sup>3</sup> )	m <sup>3</sup> of water consumed per kg of fruits or vegetables	Efficiency rate of m <sup>3</sup> of water = Kg produce/m <sup>3</sup> water
Grain barley	2,750	550	1,318.31	2.40	0.2
Green barley (fodder)	2,750	11,000	1,318.31	0.12	4
onions	220	697.5	105.46	0.15	3.12
Garlic	330	320	158.20	0.12	0.96
Lettuce	330	175	158.20	0.90	0.53
Carrots	220	700	105.46	0.15	3.18
Beans	220	880	105.46	0.12	4
Coriander	220	255.5	105.46	0.41	1.16
Alfalfa	550	898	263.66	0.29	1.6
Spinach	110	416	52.73	0.13	3.78
Turnip	110	460	52.73	0.11	4.18

Table 8. Efficiency of the irrigation water.

## 8. Evaluation of results

This evaluation is carried out on the basis of indicators selected among the objectives of the project. Table 10 sums up this evaluation.

Production	Receipts	Total charges	Net margin
Vegetable production	1,038,650 DA or 10,386 euros	350,000 DA or 3,500 euros	688,650 DA or 6,886 euros
Poultry	2,100,000 DA or 21.000 euros	1,600,000 DA or 16,000 euros	500,000 DA or 5,000 euros
Total	3,138,650 DA or 386 euros	1,950,000 DA or 19,500 euros	1,188.650 DA or 11,886 euros

Table 9. Economics of the pilot (agricultural campaign fall 2012/winter-spring 2013).

Results	Appreciation	Commentary
Efficiency of drainage	Very positive	The share of leaching is 32% of the volume of irrigations
Evacuation of salts from irrigation water	Positive	Positive dynamic that should improve over time after dissolution of the most soluble chemical elements such as chlorides and sulfates
Improving yields	Very positive	It can improve with a better control of organic and mineral fertilization
Efficiency of irrigation water	Very positive	Can still be improved
Improving the cropper's income	Very highly significant	The cropper reinvested initial benefits in poultry production
Environmental impact	Very positive	significant decrease of the layer and avoiding the accumulation of salts imported by irrigations

Table 10. Evaluation of results.

## 9. Conclusion et recommandations

The pilot is implemented in its hydraulic and agricultural components. The cultivation plan is executed and the results obtained are considered very positive by all partners, including the cropper. They exceed the planned objectives.

- Technically, increasing the efficiency of the date palm plantation with an important improvement in the quality of the fruit. An obvious success in carrying out food crops in the interspace after filling the open drainage ditches and replacing them with an underground drainage system. Achieving higher yields than the traditional system (at least 30-50% more).
- Environmentally, the success of the underground drainage network, with 30-40 cm of dropping water level of the surface table within few weeks of irrigation,

Figure 43. A plot for the intercropping cultivation of garlic in the palm grove.



accompanied by a drop in the salinity of drainage water and soil. Failure of delivery of irrigation water for social reasons led to the failure to develop a cultivation plan for the first year, but the restoration of the water supply has helped achieve the second year until completion and confirmed the results on the efficiency of drainage and its positive impacts on crops

- Economically, the agricultural income of the operator has improved significantly with a quadrupling of revenue from exploitation and doubling the gross margin. The success is such that the cropper has undertaken, on his own initiative, setting up a small industrial poultry unit. This breeding has proven very beneficial to the cropper by generating significant additional profit and production of sufficient quantities of manure to cover the needs of the pilot. Moreover, under the supervision of INRAA, the cropper has learned to value the vegetation of *Phragmites* (reed in drainage channels) transformed into compost mixed with manure. The compost is of excellent physical and chemical quality.

These positive results of a new [cultivation system](#) of intensive irrigated family farming should be made reliable through a [system of production](#) on several farms of several acres of the same oasis within the same farming community; these farms benefit from a socio-economic environment and a similar environmental context. It is because the technical success of a cultivation system in a small area by one cropper does not necessarily guarantee its success on several farms, for several reasons:

- technical reasons: the underground drainage was effective because the pilot site

has a slight slope sufficient to ensure the evacuation of exploitation drainage to the outside collecting duct **by gravity**. It is therefore important to ensure that the **slope** of the land for all future croppers of the future pilot production system. Also, it is essential to ensure the technical feasibility of achieving an efficient drainage system integrated on all farms of the pilot.

- economic reasons: increasing irrigated areas by intercropping and improved performance will result in a considerable increase in production that will be sold on the local market in the first phase. Within this perspective, it is important to ensure the local market capacity to absorb these products at acceptable prices for farmers. Otherwise, the search for new markets is needed, and operators will have to organize themselves, always in a community setting to identify new business sectors and adapt their products accordingly.

It is therefore recommended to replicate this pilot cultivation system on a **pilot production system** on a sufficiently large spatial scale to test the feasibility of the introduced technical innovations (input supply and various technical services) on the one hand, and the ability of farmers to organize themselves to make viable the management model and valorize SASS, and to control the entire food production chain.

- social reasons: the success of the new cultivation system will remain conditioned by the restoration of community structures that will ensure the proper management of irrigation water and maintenance of drainage systems, both within and outside the farms. It is within this community framework that croppers undertake to authorize the realization of development work and the installation of irrigation works on their farms as part of integrated management of water and soil resources.

Furthermore, it is important to remember that the issue addressed in this pilot concerns all the Valley of Oasis of Oued Righ. Eventually, the drainage of these oases should be addressed in the context of an agro-hydro-soil systems approach, taking into account all the parameters (soil salinization and change in groundwater level soil water balance of the crops and saline balance land at various spatial scales, farm). The future pilot production system should be designed using this approach.

## II. AGRICULTURAL DEMONSTRATION PILOTS IN LIBYA

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Libya is the poorest North African country in terms of renewable water resources. Its main resources are underground and most of these resources come from the SASS or SASS related layers. They are mobilized and overexploited to cover the needs of all socio-economic sectors. Faced with the growing deficit between water supply and demand, recourse to the desalination of sea water to meet part of the demand for drinking water becomes the ultimate solution, despite its relatively high cost.

Based on the information collected and analyzed by specialists from both countries operating the same resource of the great Jeffara plain, namely Libya and Tunisia, a mathematical model was designed and developed to simulate the future behavior of the aquifer system and develop forecasts of its medium-term behavior (50 years). Simulations gave the following conclusions on Libya:

- continuing current withdrawals until 2050 will result in significant additional drawdowns and a continuous progression of seawater intrusion in the Tripoli area: this scenario inevitably leads to the disappearance of part of the water resources of the central Libyan Jeffara zone, by physical drying or by excessive degradation of water quality (increased salinity);
- an additional increase in withdrawals in the Jeffara areas already exploited is inconceivable;
- the hypothesis a significant reduction in levies, politically difficult to implement, would have positive impacts on resource conservation and quality.

In this situation of shortage, irrigated agriculture is the most affected. The drawdown of the aquifer levels and salinization caused by sea water intrusion led to the abandonment of irrigation over large areas and, consequently, the degradation of water infrastructure and irrigation networks in the western part of the Libyan Jeffara.

Furthermore, the Central Zone (zone wadis of Merdoun, Zemzem) has important geothermal water resources that are not valorized for irrigation.

Everywhere and in all cases, the irrigation efficiency is extremely low and were it not for the low price of water paid by farmers, irrigated agriculture would not be maintained, even in areas with water resources. Physical productivity of one cubic meter of water is very low and its economic profitability is not guaranteed given the competition of imported food.

Thus, irrigated agriculture is heavily threatened by restriction under the influence of multiple local constraints such as the drying up of wells, the significant drawdown of the layer, excessive water salinization making it inappropriate for irrigation. Among these various issues, the Libyan Water Authority had retained two major situations to be addressed in the context of the “pilot” component of this project. This choice is justified by the spatial

extension and socio-economic impacts of these issues. These are:

- [shortage in good quality water](#) for irrigation across the vast plains of the Libyan Jeffara, given the drawdown of the groundwater and contamination by intrusion of sea water;
- [non-valorized geothermal water resources](#) for intensive irrigation in the area of the wadis of the country's central area.

These are two major issues that lend themselves relevant to the analysis and resolution within the SASS III project. They were selected to be the [two Libyan pilots P3 and P4](#).



## PILOT OVERVIEW

**Geographical Location:** This pilot is located in the region of Essouani, about twenty kilometers south of Tripoli. Its geographical coordinates are WGS 84 are: Long: 13°.0677 - Lat : 31°.6525.

**Local issue of irrigation:** An important drop in the layer with the degradation of soil quality (salinization), as a result of overexploitation of the aquifer using multiple illicit drills.

**Theme of the pilot:** The rationale behind the use of brackish water in the irrigation of intensive cropping.

**Agricultural production system:** In this zone, irrigated agriculture is in the process of being abandoned. However, some croppers practice a system of winter or summer vegetable cropping inside the old olive plantations. The produce is for the Tripoli market, but the efficiency of water used is poor and the soil is salinized over time.

**Water resources exploited:** A private drill exploiting the layer of Jeffara at over one hundred and sixty meters of depth and whose static level is decreasing under the effect of increasing pressure on this resource.

**Availability of water for irrigation:** Water available is likely to cover the needs of the pilot area, with an increasing real cost of pumping.

**Water quality:** The drill water used has a salinity of 1,6 g/l of total soluble salts with a chloride-sodium geochemical facie.

**Water resources management mode:** The cropper manages his drill privately and individually. He ensures the maintenance of the drill and pays for the electricity highly subsidized at national level.

**Threats to this irrigation system:** Overexploitation of this layer continues to aggravate the situation of irrigated agriculture. The dropping level of the layer is reflected in the cost of drainage water and the degradation of its quality with as a result the salinization of the land and the decrease of the crops yields.

**Evolution trends of the system:** with the absence of an intervention to Control in a significant way the overexploitation of this resource, irrigation will be abandoned in the medium term because of the shortage of good quality water. The quest for alternative solutions is opting for the rational use of brackish water in irrigation or recourse

to the desalination of these waters. There is also the question of the imperative of intensification of crops to increase the efficiency of water and make profitable the required investments.

## 1. General context of the pilot

For two decades (1980-2000), irrigated agriculture in the plain of Jeffara experienced a boom as part of a proactive agricultural policy aimed at the country's food security. For this purpose, large irrigated areas were created and many boreholes dug by the state. This policy was echoed later by private investment around multiple wells and boreholes, which eventually triggered a frantic overexploitation of the resource, accompanied by the drawdown and the intrusion of sea water. Crop yields were quick to fall and profitability of irrigation projects has been questioned, hence, the gradual abandonment of irrigation.

## 2. Local issue of the pilot

The problem of the P3 is representative of those of all irrigated areas of the great plain of the Libyan Jeffara. It is the scarcity of good quality water, hence the search for alternative solutions to this shortage to save irrigated agriculture within a sustainable development perspective.

## 3. Theme of the pilot

Within the context of the shortage and poor quality of water, the project aims to demonstrate that it is possible to adopt the results of agricultural research on irrigation using brackish waters. These solutions are known and have been practiced for several decades in many Mediterranean countries. These solutions concern the setting up, with the cropper's agreement, on his own and with the assistance of the project, a technology package for the sustainable use of available brackish water in intensive irrigation, both profitable and without negative impact on land quality. This is subject to the validation of the results of another pilot implemented in Tunisia, with the aim of demonstrating the viability of brackish water desalination and use in irrigation.

## 4. Location and characteristics of the pilot

The farm that hosts the pilot is in the region of Essouani in the southern suburbs of Tripoli (see the location map of this farm in the next page). This area was originally cultivated

by rainfed olive plantations conducted as part of a dry farming system. Irrigation was introduced at large-scale by the end of the last century under the encouragement of the State to mobilize water and irrigation.

This farm extends over 5 hectares of which only three have been developed for irrigation.

The rest of the area is maintained under rainfed conditions, it is considered a resting soil that will be irrigated alternately with three ha irrigated currently. This allows time for the desalination of soil by natural leaching random storms that occur sporadically in this arid region. If needed (in droughts period), one or two flood irrigations could be performed to help ensure desalination before returning to irrigation.

The 3 l/s flow of water available can properly cover the water needs of the three hectares of the pilot, however, the water salinity is of 1.6 g/l, which represents a constraint for crops selection. The most demanding of them, like strawberries or beans will not be cultivated. All Solanaceae (peppers, eggplant, tomato, potato ...), cruciferous (cauliflower, turnip cabbage) cucurbits (melon, watermelon, cucumber, squash, zucchini...) and all other salt-tolerant species (onion, garlic, winter vegetables such as beans and bersim) could be integrated into the rotations of cultivation plans according to the farmers' needs. This is possible provided their vegetative cycles end no later than the end of May in order to fully suspend annual crops throughout the summer and avoid excessive heat and their negative impacts on crops. In July and August, the climate water demand is very high indeed and daytime temperatures can reach extreme levels that cause tremendous damage to crops. The total suspension of irrigation from June to August is an absolute rule to observe and will allow substantial saving of water, control of salinization risk and avoid the risk of damage to crops.

As for the quality of the soil, its texture is sandy; of alluvial origin affected by the wind, it is highly permeable and deep, and therefore enables vertical drainage, leaching of salts and without risk of soil degradation.

## 5. Action plan of the pilot

This plan was designed according to the four areas (institutional, technical, monitoring, evaluation and dissemination of information) presented in the first part of the report. It aims to achieve the technical objectives (increased water efficiency), socioeconomic (improving farmers' incomes) and environmental (control of negative environmental impacts: drawdown and salinization of groundwater and land). To do so, it was important to choose an intensive cropping system, consuming as little water as possible, likely to ensure return on investment needed and responding to local and national demand for foodstuffs. This system was a market gardening system practiced throughout the cool season (fall, winter and spring). Some off-season crops are produced under small tunnels, others are grown in the open.

This system was carried out using intensive cropping and localized irrigation (drip irrigation), with a mixed fertilizer (organic and inorganic) and plant protection treatment, mostly preventive.

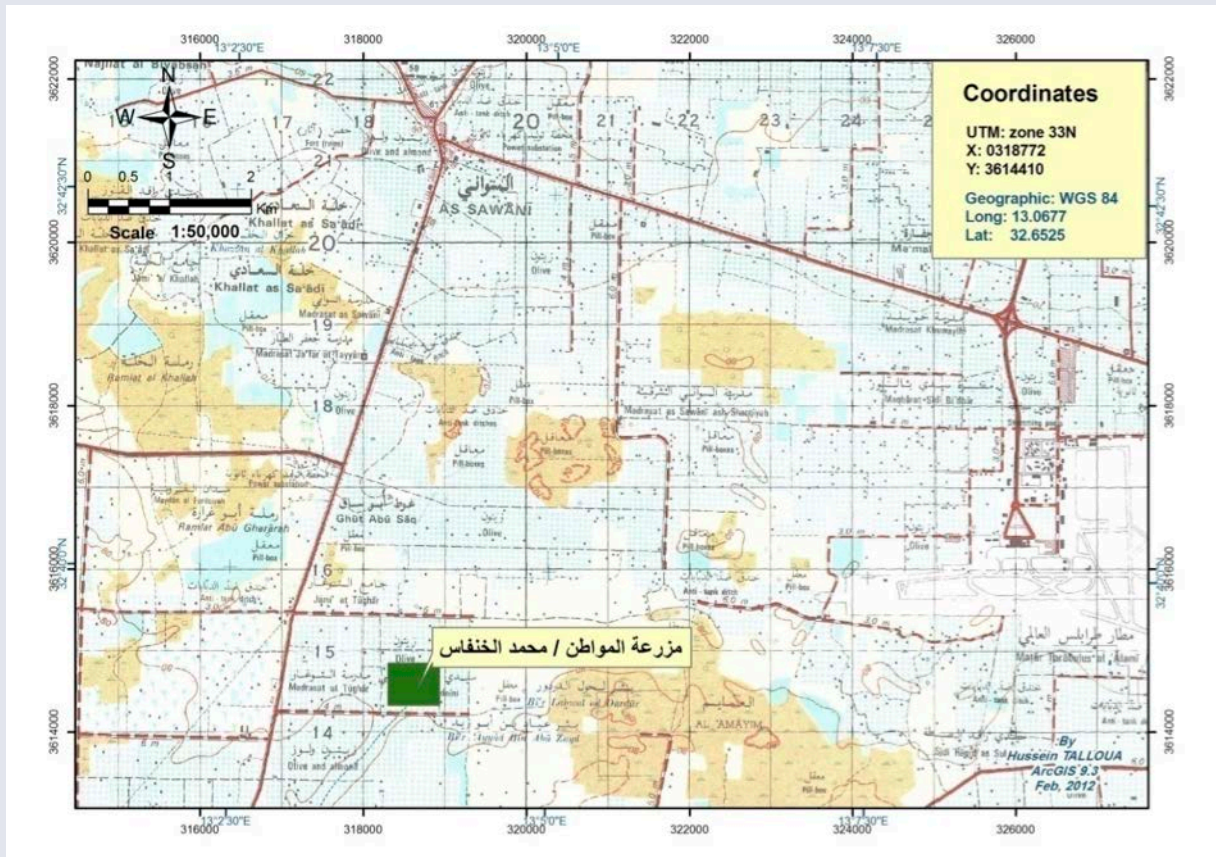


Figure 44. Location map of the pilot farm (green square).

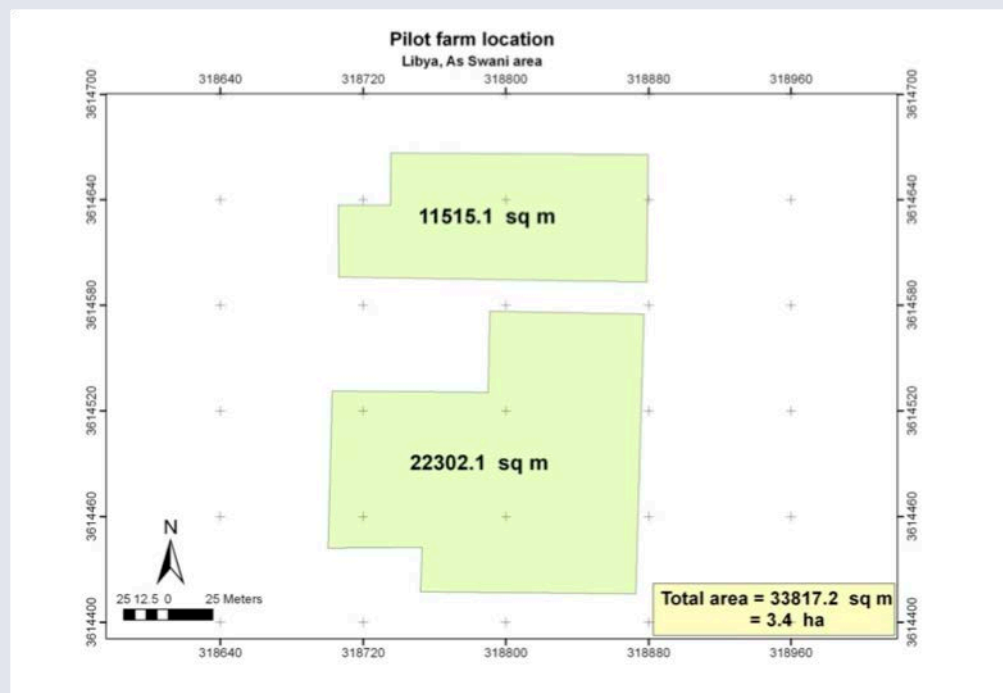


Figure 45. The two pilot's irrigated plots during the agricultural seasons (2012 et 2013).

For various reasons, including the severity of the winter, crops during this first year were started only in April 2012 and the harvest continued during the summer. The crops grown were pepper, tomato, eggplant, zucchini, squash and cucumber.

## 6. Evaluation of activities carried out

This evaluation is summarized in Table 11.

## 7. Main results

### 7.1. Results of the first agricultural season (2011-2012)

The crops were cucumber, zucchini, squash, sweet pepper, eggplant, tomatoes and hot pepper.

Figures 46 to 50 illustrate the production of these crops.

Most unfortunate, the crops did not all reach the end of their growth cycles. The cultivation of squash was affected by a virus attack that caused the loss of the entire harvest, at least 10 tons of fruit and tomatoes were partially damaged by sunburn, with significant losses of the fruit quality. Likewise for the sweet pepper (Figures 51-53).

This damage confirms the importance of the risks for summer vegetables in these desert regions. They support one of the principles of the strategy adopted in the design of this pilot, namely banning summer irrigated crops because of the risk of diseases, excessive high temperature and excessive sun heat.

The financial results are reported in Graphic 9.

The financial results for the first planting season were therefore virtually null. It is important to remember that the cropper was obliged to delay the start of the first growing season because of the exceptionally harsh winter 2012, which affected the timing of the harvest.

Moreover the total volume of irrigation water consumed throughout the season was 24.100 m<sup>3</sup> for a total net area of 2.8 ha, an average of 8,707 m<sup>3</sup>/a. This consumption can be considered remarkably low in the climate context of this region and compared to the consumption of summer crops. Because the three crops (squash, tomato and pepper) were damaged, they did not enjoy all the planned irrigation during the end of the crop cycle.

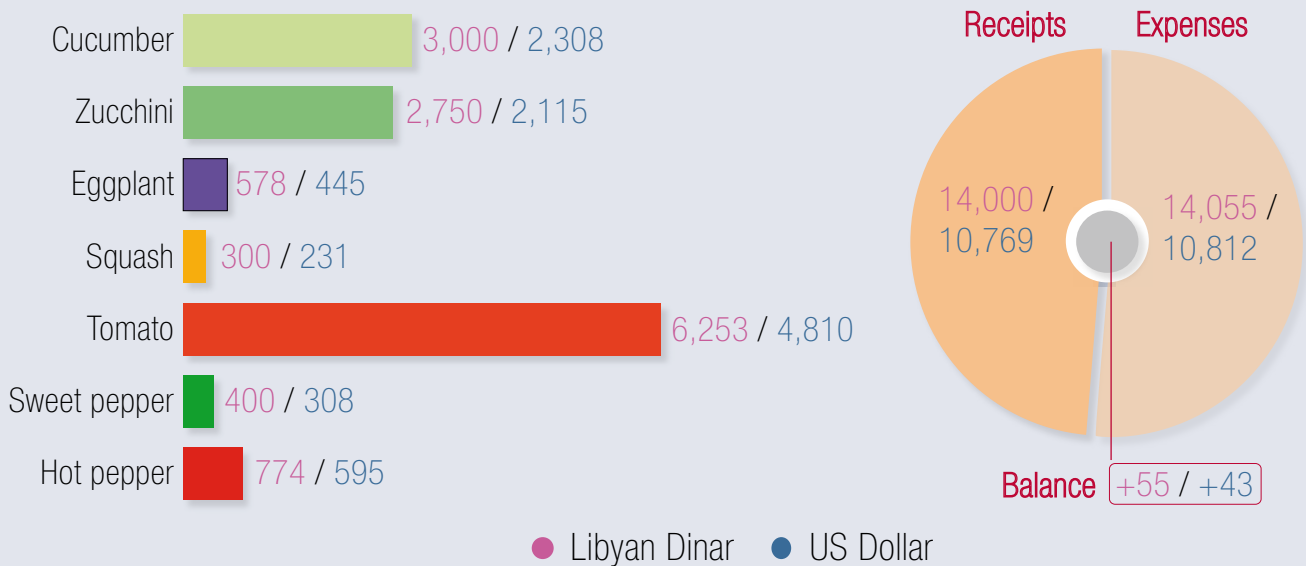
Regarding the impact of irrigation on soil, increasing salinity in the soil profile was moderate (up to 5 mS/cm). Projected desalination under irrigation at the start of the next growing season should bring soil salinity to its original level.

Planned activities	Degree of completion	Results	Means of verification
Institutional activities			
Mobilization of water actors at the local level	Entirely	Information of the cropper, the Libyan water authority and agricultural Service of the Tripoli region	Report of the 2nd mission of the RC in the region
Recruitment of the National Consultant (NC)	Completed	Contract signed and kick off of activities of the NC	Monthly report of the NC
Holding an awareness workshop	Completed	Committing all the water stakeholders	Quarterly reports of the RC
Setting up the local monitoring/evaluation committee	Completed	Participation of water actors in the committee	Structure of the committee according to the quarterly report of the RC
Technical activities			
Prospection of the field with the NC and the Water Authority, agricultural service and croppers for the choice of the pilot site	Entirely	Pilot site selected Existing drill made available to the project by cropper	Mission report of the RC
Technical study and design of the pilot components	Entirely	Pilot design	Monthly report of the RC
Identification of necessary works and equipment	Entirely	List of equipment and estimates of the pilot cost	Monthly report of the RC
Elaboration of the action plan and implementation of the pilot	Completed	Action plan available	Monthly report of the RC, and 3rd quarterly report of the RC
Implementation of the action plan	Agricultural equipment completed	Equipment installed	Quarterly report of the RC
Site plan of the first and second planned agricultural seasons	Completed	The first agricultural season was a technical success but with economic results that were below objectives set because of climate accidents and parasite attacks. The second agricultural season started in good condition with positive results	Report of the RC Mission report of the RC Presentation of the NC to the 1st regional workshop on the pilots June 2012 Monthly Reports of the NC 4th term 2012

Extension activities and dissemination of results			
Information workshop	1st awareness workshop held	Committing croppers to implement the action plan and receive visitors	1st report of the RC
Dissemination of results	Presentation of the summary of national water strategies of the three countries to the Project Steering Committee in Algiers in May 2011	PowerPoint presentation	Summary document Mission report of the RC in Algiers to the Project Steering Committee
	Other regional workshops	Presentation, discussion and adoption of results	Minutes of the workshops
Visit to the pilot	Activities carried out by the local technicians and consultants  Open doors day to croppers of the zone held in May 2013	Positive results  Very positive results that triggered social demand for the replication of the cropping system among other croppers	Mission report of the RC
Monitoring and evaluation activities and reporting			
Monthly report of the National Consultant	Report received and validated	Progress in the implementation of the pilot very well detailed	Reports of the NC
Quarterly reports of the RC	Submitted and accepted by OSS	Information shared on progress in implementing the pilot component	Reports of the NC
Biannual reports of the RC	First semester (July to December 2010)	Same as precedent	Report document
Annual reports of the RC	First annual report of the RC (July 2010 to June 2011)	Same as precedent	Report document
Mid-term report on the pilots component	Report received and validated	Inventory very well detailed	This report

Quarterly report January-June 2012	Report submitted and received	Evaluation of results carried out and shortcomings are reported and suggestions made	The relevant report
Final draft report December 2013	Report submitted to OSS and validated	Technical economic and environmental results are satisfactory	The relevant report
Report on the pilots of Libya, September 13	Report submitted to OSS and validated	Results confirm the targeted objectives	The relevant report
The final report on the SASS III pilot component (march 2014)	This report	The results obtained and lessons learned	This report

Table 11. Evaluation of completed activities.



Graphic 9. Revenue from vegetables grown and the balance sheet of the pilot during the agricultural season 2011-2012.



Figure 46. General view of the pepper plot.



Figure 47. The first crop ready for harvest.



Figure 48. General view of the tomato and zucchini crops.





Figure 49. General view of the zucchini crop.



Figure 50. General view of a cucumber crop.

Figure 51. All the damaged production of zucchini after a virus attack.



Figure 52. Sweet pepper crop damaged by sun.



Figure 53. Damaged tomato crop by a cryptogammic disease.



## 7.2. Results of the second cropping season (Fall 2012-Winter/Spring 2013)

The crops grown were cabbage, cauliflower, tomatoes, watermelon, melon and cucumber which had been grown in nurseries in the pilot. Figures 54-57 illustrate some crops developed.

The technical and economic results are shown in Table 12. The following conclusions are highlighted by this table:

- the total market output, around 85 tons per 2.8 ha, or around 29 tons/ha for all varieties, is much higher than the results of the first year, but remains relatively low compared to the achievable potential for off-season crops, with more care to crops. However, this overall assessment should be modulated according to the species: the best performance is achieved for tomatoes and melon with yields of 55.5 tons/ha and 32 tons/ha respectively.
- The total revenues were very satisfactory given the high local market prices of the produce obtained. Hence, the relevance of this cropping system in satisfying the strong local demand for out of season vegetables and fruit products.
- The economics of this second year, with very positive results, gave a gross margin of 33,900 Libyan dinars, representing a gross margin per hectare of 11300 DL. This is the equivalent of US \$ 9,400/ha, which corresponds to the annual salary of a senior Libyan official.
- The environmental balance is the same as that of the previous year. The average salinity of the soil remains controllable by means of a leaching irrigation with the start of the cropping at the beginning of each fall.
- Water consumption was lower than in the previous year, resulting in saving water, on the one hand, and an increase in the efficiency of the resource, on the other.

Overall, these results are objectively very positive with respect to the objectives and messages to be transmitted to all decision makers.

- For farmers potentially interested in this cropping system, these results open obvious perspectives for the replication of the pilot in the same area using brackish water of comparable quality. The general trend of disinterestedness among Libyan farmers in the agricultural sector could be reversed thanks to a targeted policy aimed at both improving the conservation and enhancement of the water resource, on the one hand, and the Libyan national contribution to the satisfaction of domestic demand for commodities produced by this culture system.
- For policy makers, these results need to be made reliable on many farms [to validate them within a production system](#) that integrates the market dimension upstream and downstream of the production into the cropping system. Once the system is validated, the public authorities could consider developing a policy to encourage the development of this system.



54



55



56



57

Figure 54. Panels of the nurseries for multiplication of cabbage and cauliflower and tomatoes.

Figure 55. A plot being prepared for tomato cropping.

Figure 56. A cauliflower plot.

Figure 57. A tomato crop under tunnel started.

Crop	Area m <sup>2</sup>	Production Kg	Receipts LD	Expenses LD	Balance LD
Cucumber	3,760.12	4,000	3,000		
Zucchini	2,063.30	4,000	3,000		
Eggplant	1,100.94	2,000	500		
Watermelon	924.27	3,000	1 500		
Tomatoes	8,734.83	47,600	35,700		
Pepper	2,032.74	1,000	1,250		
Melon	6,310.82	20,000	14,000		
Cabbage	2,177.12	3,000	1,200		
Total	27,104.14	84,600	60,150 LD 50,125 US\$	26,250 LD 21,875 US\$	+ 33,900 US\$ + 28,250 US\$

Table 12. Produce, receipts and balance of the agricultural pilot's 2<sup>nd</sup> year (2013).

## 8. Dissemination of the pilots results

The results of the second year of the pilot have been the subject of multiple evaluations and dissemination activities with various project partners, including farmers in the pilot area, the technicians of the Libyan Water Authority, its successive directors general as well as water stakeholders in Algeria and Tunisia during regional workshops held outside of Libya. The following photos illustrate these activities.

Finally, while being positive, these results are still improvable at the agricultural and economic levels through local technical assistance in the management of production. This assistance could be considered as part of the adoption and replication of this irrigation development program model.

At the end of the second year, the overall result of the evaluation of the results is very positive, bolstered by strong social demand for the replication of the pilot expressed at all levels of decision making. It is up to the Libyan authorities to develop a strategic vision for the development of this farming system into a sustainable production one taking into account all the dimensions of the initial problem.

## 9. Conclusion and recommendations

This pilot has been implemented in accordance with the action plan prepared within a participatory approach with all the project partners. This action plan has incorporated the cropper's expertise into technical innovations introduced in the intensification of cropping system. Despite the late start, because of political events in Libya, all the dimensions of



58

Figure 58. Visit for the evaluation of the pilot results by GWA technicians.



59

Figure 59. Visit for joint evaluation by OSS team and GWA directors.



60

Figure 60. Agricultural croppers on visit to the pilot (May 2013).

the pilot were carried out. The irrigated intensive cropping system using available brackish water has given excellent technical results during the second cultivation season. Those of the first year were inconclusive due to the loss of harvests for three crops attacked by parasites and damaged by sunburn. The losses are estimated at more than 15,000 Libyan dinars that could be the benefits of this first year.

However, the balance of the second year is very positive. It generated a gross margin of 11,300 Libyan dinars/ha (approximately US \$ 9,400/ha), which shows a very significant improvement in the economic productivity of irrigation water in this cropping system.



61

Figure 61. Session to explain and evaluate the pilot's results with croppers from the region.

Figure 62. Overall evaluation session of the pilot and discussion of perspectives of replication in Libya among the OSS team and GWA managers.



62

More than that, this performance is undoubtedly still improvable to achieve a higher level of water use efficiency, while preserving the soil against irremediable salinization. These improvements could be made in the future after overcoming multiple constraints imposed by security conditions (difficulties in the supplies, labor recruitment constraints...).

Given the large interest shown by all water stakeholders in Libya in the performance of this pilot (administrations and ministries, many farmers in the Essouani region and other neighboring areas), it is highly recommended to replicate this pilot in the short term at a spatial scale of a few dozen acres in a similar context to ensure reliable technical and economic results in the context of the Libyan local market. This would be a pilot demonstration of the efficiency and sustainability of any agricultural production system.



Libya is highly rich in geothermal water resources in the central area of Merdoum Zemzem wadis... (southern Mesrata). These resources are still emerging in some areas in the form of hot springs, and in others they are mobilized by artesian wells ... these waters are currently air-cooled then used in conventional irrigation oases or areas outside the irrigated oasis. This geothermal water valorization method has certainly contributed to increased agricultural production (crops and livestock), but the physical efficiency and economic valorization of this water are extremely low. In addition, the natural and free heat energy (geothermal) of that water is not exploited and enhanced technically and economically in any way whatsoever. Instead, this energy is considered a constraint that must be solved in order to use the water.

Yet there is proven expertise in the SASS in valorizing these hot waters for off-season greenhouse crop irrigation, first to provide heat, then for irrigation after cooling. This expertise is well established in the SASS area in Tunisia, particularly in the area of the Chott (Gabes, Kebili and Tozeur regions).

The purpose of pilot 4, planned in the central area of Libya, was to transfer technology and know-how of Tunisian croppers in the field to a farm rich with geothermal water resources.

## 1. Local issue of irrigation

The problem of the P4 could be summarized in the availability of abundant geothermal water resources non-valorized in irrigation in comparison to the operation model in Tunisia.

Indeed, the added value provided by these resources through their high temperatures could easily be capitalized in an agricultural demonstration pilot.

To this end, the project selected, with the technicians of the General Water Authority of Libya, the suitable area to implement the planned pilot, namely the area of Wadi Zamzam where two farmers, who meet the criteria determined in advance, agreed to implement the pilot in their farms. Meanwhile, the GWA has made available an existing drill project for the implementation of the pilot.

Unfortunately, the pilot has not been established for security reasons. The Libyan revolution started a few days after the mission of site and croppers selection was completed. To date, the central region of the wadis is not accessible without risk to direct farmers on the ground.

Following consultations, it was decided to replace it by another pilot with the same theme in the region of El Hamma of Gabes in Tunisia. This pilot is already operational and functional and, with the agreement of the cropper, a partnership agreement was reached to allow visits by Libyan technicians and farmers. This new pilot called P7 is mainly dedicated to their awareness and training.

## 2. Conclusion

Apart from pilot 4, which has not been established, the results obtained in the pilot 3, dedicated to the degradation (salinity) of the water resources quality of the Libyan Jeffara and its impacts on the quality of irrigated land, are very positive. They open serious prospects for rehabilitation of irrigated agriculture with brackish water in specific technical conditions that ensure both the conservation of water resources, preservation of soil fertility and a substantial improvement in income operators. These promising results obtained in an intensive [cropping system](#) should now be reliable and validated in large [pilot production systems](#) that integrate the major structural constraints, not addressed in this project.

In any event, the adoption of these results should not be made on the basis of a [simple dissemination of agricultural technologies](#) proven in the pilot, but through a new vision for the modernization of intensive irrigated agriculture within a [systemic approach](#) that addresses all dimensions (economic, community organization of water management and agricultural services ...) and the various segments of the relevant chains of production. This vision, negotiated and shared by all the players of the mentioned sectors, should then be realized by implementing programs where the state will have a key role in the mobilization and sustainable management of groundwater resources, while farmers, on their side, should ensure a significant improvement in the efficiency of irrigation and the preservation of soil fertility on their farms.

These prospects should be the subject of a Libyan national debate to reach a consensus, then a consultation with the Sahara and Sahel Observatory could possibly help to support the Libyan Water Authority to develop the path towards sustainable renewed management of SASS water resources of the Libyan Jeffara for the agricultural development of this great region.



63



64



Figure 63. A geothermal water resource whose water is cooled in a lake in Tawergha in Libya.

Figure 64. The drill made available to the project by the GWA.

### III. AGRICULTURAL DEMONSTRATION PILOTS IN TUNISIA

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The problem of water in the SASS area in Tunisia is particularly severe for many reasons, including in particular:

- the important local water deficit in the absence of any other significant water resources that can help meet the growing demand for water for all socio-economic and environmental sectors;
- the location of the area around the Chotts region, suffering more than elsewhere of drawdown of SASS groundwater levels with both its CT and CI layers and announced degradation of their qualities;
- increased human pressure on this resource to accompany proactive policy development.

For these reasons, all the farming systems are in crisis and at risk of water shortage in more or less maturity.

In the field and at the local level, this problem arises differently in different natural and socio-economic contexts. Compared to agricultural use (irrigation), three main forms of expression of this issue should be highlighted:

- a water shortage that threatens more and more the future and sustainability of local development based mainly on irrigation, with a deterioration in the quality of available resources, resulting in a serious decline in yields and 'incomes, and consequently increasing economic and social vulnerability;
- mismanagement and poor sharing of available resources, that jeopardize the interests and rights of certain croppers and triggers the principle of solidarity/equity on which is built traditional agriculture in these dry regions;
- a very low valorization of this resource through irrigation at the farm.

It is also rare to find that these three expressions can be combined in multiple situations, which does not fail to make local water issues even more complex in the light of the urgent requirement to establish a process of sustainable development.

The primary cause of the water shortage is structural. The SASS area of Tunisia is the least endowed with potential, compared with Algerian and Libyan areas; a factor that is also true of the geological and hydrogeological characteristics of the subsurface of southern Tunisia.

Other factors exacerbate this shortage include the terms of its use in irrigation (area expansion, waste, low technical and economic efficiency) and current institutional and legal frameworks dedicated to water management.

In this context, among the many local water issues identified by the studies carried out in Tunisia in the SASS II project, DGRE and DGGREE selected two, considered highly constraining and most frequent in this area.

These are:

- degradation of land quality by waterlogging (water stagnation) and salinization of land as a result of two joint essential factors, namely an inappropriate irrigation method and the use of poor quality waters in a topographical context resulting in poor natural drainage of the land. This phenomenon is very common in most of the oases of the Chott El Jerid area (oases of Jerid and Nefzaoua),
- overexploitation accompanied by increased salinity of the surface layer of the Jeffara plain and the deadlock to which irrigated family farming has committed itself in this plain.

After consultation with the water authorities at regional and local level, these two issues have been validated and adopted for the implementation of their respective agricultural demonstration pilots. In addition to the pilot dedicated to promoting geothermal water for irrigation, which replaced the one that could not be started in Libya because of the Libyan revolution.

These are:

- P5: Jedida Oasis pilot near the town of Kebili;
- P6: Smar Medenine pilot;
- P7: Chenchou pilot near El Hamma of Gabes.

## PILOT OVERVIEW

**Geographical location:** In the governorate of Kebili, 5 km from the city with the same name on the road to Souk El Ahad.

**Local issue of irrigation:** A degradation of the quality of the soil under the effect of brackish waters used for irrigation of an oasis situated on the fringe of the Chott, under edaphic topographic conditions that do not enable the natural drainage of the land. The development of a hydromorphy of the land salinization resulted in the degradation of the land quality, dropping productivity of the irrigation water and questioning the sustainability of agriculture.

**Theme of the pilot:** The restoration of the quality of the land by artificial drainage (underground network inside the plots) and pumping the surplus water using solar energy, with intensification of the agricultural production system.

**Agricultural production system:** It is a family oasis system destined initially for production around the date palm, the Deglet Ennour variety, and various intercropping whose produce is largely for self-consumption. This system is being abandoned for other non-agricultural activities. Livestock is no more integrated into the farm.

**Cropping system:** It is a traditional oasis based essentially on the date palm tree, with two levels of fruit arboriculture and annual crops (market gardening and fodder).

**Water resources exploited:** A drill of more than 900 meters deep tapping the Continental intercalary supplies geothermal water at a temperature higher than 55 °C. This water is cooled before it is distributed for irrigation.

**Availability of water for irrigation:** The resources are available but croppers are not satisfied with its exploitation manner. The irregularity and poor frequency of water turns do not enable salt leaching, namely in the absence/insufficiency of external collecting channels.

**Water quality:** the water of the borehole is brackish with a dry residue of 3,5-4 g/l. This water is used for irrigation of the date palm on condition of providing the salt leaching using a leaching irrigation fraction. However, the water quotas provided do not allow the croppers to cover leaching needs. Besides, natural drainage is highly defective.

**Water resources management mode:** Water is managed within

a community framework by a local Agricultural Development Association (Groupement de Développement Agricole (GDA) assisted by CRDA Kebili.

**Threats to the production system:** The intensification of the hydromorphy and salinization of the land threaten the sustainability of the oasis over time.

**Evolution trends of the system:** The system is actually showing a progressive move to abandon the oasis as an integrated socio-economic system.

## 1. General context of the pilot

Over the past four decades, the oasis regions in Tunisia, including that of the governorate of Kebili, had benefited from a number of development strategies and programs from the Southern Water Master Plan (PDES). It consisted in many regional development programs aimed at the mobilization and recovery of SASS groundwater in several areas, including irrigated agriculture. The Jedida oasis was created as part of the implementation of PDES. Twenty-five years later (2005), 23.000 ha of oasis benefited from a new irrigation improvement program in much of the southern oasis (APIOS Project), including Mansoura/Jedida Oases near Kebili. This program was to replace the water distribution pipes by concrete pipes to control the high water losses during the transport and distribution of water to the entrance of the farm.

Following the development and expansion of irrigated areas, overexploitation of deep groundwater in these areas, particularly that of the Terminal Complex, has resulted in a continuous salinity of the water resource and at the same time as a drawdown of the piezometric level of the exploited aquifer and its contamination by intrusion of the Chott salt water. Also, located on the edge of the Chott Jerid with a low slope, with sometimes located in depressions and irrigated with brackish water, most Nefzaoua oases (Governorate of Kebili) suffer from continuous soil degradation reaching sometimes the level of "soil fatigue", especially in the old oasis. Indeed, the use of this salt water for irrigation has led to serious problems of degradation and soil salinization due to inadequate drainage and poor maintenance, and therefore inefficiency. Given the importance of the physico-chemical properties of soil in agriculture and the negative impact of the rise of the water sheet and soil salinity on the behavior of oasis crops, including date palms, the adoption of agricultural techniques that allow improving physical and chemical qualities of the soil of the oases has finally been imposed on decision makers. It is in this context that the creation of a drainage system in the plots of the selected pilot has become a top priority to combat the increasing salinization, allowing leaching and preventing the rise of the sheet. In addition, this operation should be supported by other interventions, particularly in terms of water management and irrigation techniques for crop intensification.

## 2. Local issue of the pilot

In its topographical context and location on the edge of Chott (hypersaline basic level), the pilot lands suffer from two major constraints, namely waterlogging and salinization. These constraints are intensifying over the years with the rise of the layer. The latter has less than 70 cm medium depth, with soil salinity of more than 8 g/l (electrical conductivity of 10-15 ms/cm) which severely limits the ability of the soil for intensification and reduces yields on existing plantations. All this within a socio-economic dynamics of gradual abandonment of intensive land use and the search for alternative sources of income.

## 3. Theme of the pilot

It focuses on land rehabilitation with the installation of a drainage system buried inside the plots and its connection to the collecting duct of the outside public network. This connection is made by pumping and discharge using solar energy. This action is intended to lead to a new dynamic drawdown of groundwater and desalination of the soil, especially in the 120 cm of arable layer of the soil surface. The second action planned is the intensification of the cropping system by rational fertilization and control of phytosanitation problems through the use of preventive and curative treatments and some biological treatments for palms parasite.

## 4. Location and characterization of the pilot

The pilot is located in Jedida oasis that is part of Mansoura oasis. It is located on the road to Souk Lahad 5 km northwest of Kebili.

Its geographical coordinates are:  $X= 8^{\circ} 55' 59'' E$  ;  $Y= 33^{\circ}42' 56'' N$ .

It consists of several adjacent small farms (micro-plots) forming a common terminal area receiving irrigation water. It is a good real estate situation representative of the farm land fragmentation arising from successive inheritances and sharing of initial properties. These were already of the order of 1 to 3 ha on average in their creation. Indeed, the pilot comprises 13 plots belonging to 15 farmers 4 of which are associated in pairs. Its total area is 16,201 m<sup>2</sup> and the size of the plots varies from 315 m<sup>2</sup> to 3,116 m<sup>2</sup>, with an average of 1,246 m<sup>2</sup>. This land aspect reflects the complexity of the difficulties involved, namely at the level of hydrogeological involvement.

Having benefited in 2005 from a project to improve the irrigated areas of the oases of the South (APIOS project), the pilot area, like the rest of the Jedida oases, was endowed with a main network of irrigation that is 340 meters long, in the form of concrete seguias. Irrigation is carried out using water towers and conducted by submersion panels of variable sizes according to the land use with herbaceous layer. These panels are connected to the





Figure 65. Visible salinization of the soil.

Figure 66. The drainage water collection channel of the closed pilot.



main network of earthen ditches. One can imagine the importance of the quantity of water lost by infiltration in these channels (*séguías*). They are valued at 20-30% depending on soil texture, and contribute more to raising the level of the water table and the accentuation of waterlogging.

It should be noted that the drainage realized within the APIOS project did not involve the inner parts of the oasis farms where the traditional open drainage ditches (*khendeg*) are managed individually and are supposed to ensure the evacuation of excess irrigation water by gravity to the external collector channel. However, following the breakup of the original social fabric, the function (duty) to ensure the maintenance of these drainage ditches by the farmers, each in his own land, is no longer carried out by many among them. This is



Figure 67. Spatial image of the location of the Jedida oasis in its saline environment of the Chott.

Figure 68. Spatial image of the pilot's plots.

not without negative impact on the flow and discharge velocity of drainage water with as a consequence a rise in the water table and soil salinization throughout the oasis.

The water flow supplied to the entire Jedida oasis is 104 l/s for 138 ha, corresponding to a fictitious continuous flow rate of 0.75 l/s per hectare. This water is supplied 12 to 15 hours per hectare and in turn (20 days). Theoretically, this situation is likely to enable an



Figure 69. Location of the pilot in the Jedida oasis with its infrastructure.

acceptable level of intensification, at least for arboriculture and forage crops. In practice, this is not the case for several reasons. To improve the management and efficiency of this water, the transition to drip irrigation requires the construction of individual storage ponds for water quotas to be used according to crop needs. This will easily allow the intensification of the three levels of the traditional cropping system.

## 5. Action plan of the pilot

In its general design and approach, this plan is consistent with the one designed for all pilots. It is structured in four areas:

- institutional axis, consisting in mobilizing all water stakeholders, to recruit a national consultant and set up the local Committee for the monitoring and evaluation of the implementation of the action plan and the results of the pilot;
- a technical component, including the actions taken involving:
  - ... the preparation of documents, including maps required for the project:
    - ▶ geographical location of the pilot map;
    - ▶ general map of the pilot;
    - ▶ map of the irrigation system;
    - ▶ land cover map of the herbaceous layer;
    - ▶ land cover map of the arboreal level;
    - ▶ land cover map of phœnicicole level;
    - ▶ land surveys and tracing the profile of the drainage network and location of piezometers;
  - ... installation of the underground drainage network (trenching, laying pipes, installation of manholes, pipe coating, backfilling of trenches ...)
  - ... installation of piezometers,
  - ... installation of the solar panel,
  - ... installation of pumping equipment for the drainage water (solar panel and electric pump)
  - ... soil preparation: weed control, tillage, soil amendment (manure and sand);
  - ... exploitation of the herbaceous cover through vegetable and fodder crops;
  - ... exploitation of the arboreal floor (increase biodiversity index by the introduction of several tree species adapted to the oasis).
- an axis for monitoring and evaluation. Given the collapse of the borehole providing irrigation water that occurred during the spring of the first year of the project, technical monitoring was limited to the impacts of drainage and solar pumping during the launching of the project. The impacts of these developments on agricultural production could be assessed only later after the commissioning of the new drilling replaced recently created (2014).

- an axis of dissemination of agricultural results whose actions were planned to help the three countries benefit from the results obtained and the conditions for their implementation will be implemented after the return of the water to the farm.

## 6. Evaluation of activities carried out

This evaluation is summarized in Table 13.

## 7. Main results

The establishment of the Local Pilot Monitoring and Evaluation Committee in consultation with the central and local water authorities facilitated the negotiations with many croppers of the pilot, especially to carry out the work of setting up the drainage system and installation of the solar pumping station. Figures 70 to 78 illustrate the technical achievements.

Moreover, monitoring the evolution of groundwater levels and soil salinity under the effect of the buried drainage has been achieved through a set of five piezometers three meters deep along the pilot (figure 79).

The evolution of the water table at the pilot level is monitored by piezometer measurements during the first period of 21/2/2012 to 3/3/2012. It is marked by a rapid drop in the level of the water table. The first measurement was made a few days after irrigation. During the period from 8/3 to 16/3/2012, there has been a rise in the level of the water table due to irrigation of neighboring plots. During the following period from 22/3 to 30/4 following irrigation of the pilot plots, there was a rise of the water table level followed by a gradual and significant decrease. These results prove the efficiency of the drainage network and herald a positive impact on lowering the accumulated salinity in the surface layers for several years. The monitoring of changes in the salinity of the drainage water was provided by the sample taken at the level of manholes.

Thus, it is clear from the results that the salinity of the drainage water before the installation of the drainage system was high, i.e. about 10.66 grams of total soluble salts per liter. This salinity has dropped sharply just after the first irrigation down to an average of 6.5 g/l and a decrease of 40% of the total salinity since the first irrigations. The salinity of the drainage water remained stable throughout the first four months after the installation of the drainage system. It could decrease the pace of irrigation to stabilize at a level correlated with doses and the salinity of the irrigation water.

The results obtained are shown in Table 14.

Regarding the soil salinity, it was measured using samples at different depths before the introduction of the drainage system. The results showed that the soil was in the beginning very salty. Samples distributed throughout the pilot area and at different depths in five different points located next to the piezometers were taken three times in succession after

Planned activities	Degree of completion	Results	Means of verification
Institutional activities			
Mobilization of water actors at local level	Completed	Voluntary commitment of the agricultural croppers and other actors in the realization of the pilot	Report of the 1st mission of the RC in the region
Recruitment of the National Consultant (NC) for the period April 2011- June 2012	Completed	Contract signed and kick off of activities of the NC	Contract of the NC Quarterly report of the NC
Holding an awareness workshop	Completed	Committing a large number of croppers achieved	Quarterly report of the NC
Setting up the local monitoring/evaluation committee	Completed	Setting up the Committee completed	Minutes of the meeting for the setting up of the Committee Quarterly report of the NC
Partnership convention	Multipartite partnership convention with IRA, CRDA of Kebili, the president of GDA and the croppers	Participation of partners in the realization and monitoring of the pilot	Convention signed by the partners Quarterly report of the NC
Technical activities			
Prospecting the field with the NC and the Water Authority, the agricultural croppers and selection of the pilot site	Completed	Pilot site selected	Mission report of the RC Quarterly report of the NC
Technical study and design of the pilot components	Completed	Action Plan of the pilot	Quarterly report of the NC
Identification of the necessary works and equipment	Completed	List of equipment and cost estimate of the pilot	Quarterly report of the NC Estimates of the equipment

Implementation of the action plan of the first year involving the extension of the underground drainage network, the acquisition and installation of the solar pump, kick off of the agricultural practices	Completed	The drainage network operational, solar pump installed and operational	Biannual report of the RC
Agricultural results	No results because of the collapse of the borehole supplying the Jedida oasis	Annual crops were not carried out until their end because of the absence of irrigation water	Mission report of the RC on the first regional workshop on the pilots June 2012
Measuring the indicators of the impact of drainage : salinity and depth of the water table and soil salinity	Done	Positive impact of the drainage : decreasing level of the table and salinity	Mid-term report of the RC
Extension activities and dissemination of results			
Information workshop	1 <sup>st</sup> local awareness workshop held  1 <sup>st</sup> regional workshop on the pilots June 2012	Commitment of the croppers to host the pilot on their farms  Presentation of the NC on the pilot and its results	1 <sup>st</sup> quaterly report of the NC  Mission report of the RC on the 1st regional workshop on the pilots June 2012
Dissemination of results	Presentation of the synthesis of the national water strategies of the three countries to the Project Steering Committee, Algiers May 2011  Regional workshop May 2012  National workshop Jerka September 2013  Regional workshop, Algiers May 2014  Developing the pilot's leaflet	P o w e r P o i n t presentation of the synthesis  Leaflet  Minutes of these workshops	Synthesis document  Mission report of RC in Algiers for Steering Committee Meeting  The leaflet itself  Annual reports, mid-term report of the RC

Visit to the pilot	<p>Visit to the pilot by the CRDA Kebili general director in the company of collaborators</p> <p>Visit to the pilot by participants to the first regional workshop on the pilots in June 2012 (Libyan, Algerian and Tunisian, namely the DG DGRE et DGGREE and DGCRDA Médenine</p> <p>Visit by large number of local and regional technicians</p>	<p>Great satisfaction</p> <p>Observation of the destruction of the borehole supplying the oasis and decision to develop a new one</p> <p>Validation of the efficiency of drainage and solar pumping</p>	<p>Biannual report of the NC</p> <p>Mission report of the RC on holding the first regional workshop on the pilots</p> <p>Mid-term report</p>
Quarterly report of the National Consultant	Reports of the NC in charge of this pilot received and validated.	Progress in the implementation of the pilot very well detailed	Le document du rapport national
Quarterly reports of the regional Consultant	Submitted and accepted by OSS	I n f o r m a t i o n on progress in implementing the pilot component shared	Regular reports of the RC
Biannual report of the regional Consultant	First semester report (July to December 2011) submitted to OSS and validated	Same as precedent	Document of quarterly report
Annual report of the RC	Report submitted to OSS	Same as precedent	Document of the report
Mid-term report of the project	Completed	The report is shared	Document of the report
Monitoring the evolution of the sheet and salinity	Completed	Dropping levels of the sheet and its salinity	Report of the NC
Biannual report of June 2012	Completed	Inventory is detailed and the list of achievements completed	Document of this report
Biannual report of December 2012	Completed	List of achievements and shortcomings set	Document of this report
Final report on the pilots in Tunisia (March 2013)	Completed	Validation of results	Report submitted to OSS
Report submitted to the Steering Committee (May 2013)	Completed	Validation of results	This report submitted to OSS



Evaluation of the pilots' results workshop in Tunisia (Jerba, September 2013)	Report of the results of the workshop	The results are validated with recommendations to replicate the pilots	PowerPoint presentations
Draft final report December 2013	Submitted to OSS and validated	Results and recommendations under discussion	The relevant report

Table 13. Evaluation of completed activities.

the installation of the drainage system: One in February, one in March and a third in April.

The results obtained show that the difference between the electrical conductivities of the various points and depth of the samples is not significant. However, the difference between the electric conductivity of the pilot soil before and after drainage is highly significant. This shows that with a well-functioning drainage system, two successive irrigations allow good leaching.

These results perfectly illustrate the efficiency of the drainage and pumping-discharge of water outside the oasis. This resulted in a very significant drawdown of the sheet by 30-40 cm in a few weeks, that is to say, better than the target, the decrease in the salinity of water by 40% compared to the initial salinity and a significant decrease in soil salinity. This performance should be improved and stabilized through permanent irrigation to allow the operation of the entire soil profile soil healthy.

## 8. Conclusion and recommendations

Pilot 5 has been implemented in its hydro-agricultural (drainage) and agricultural components. The underground drainage system, the solar pumping and discharge of drainage water station have been installed according to the rules of art and commissioned. The first results on the efficiency of drainage obtained during the first half of 2012 and its impact on the drawdown and initiation of a soil desalination process were excellent. Unfortunately, suspension of water supply to all of the oasis after the collapse of the borehole serving this area harmed annual crops introduced in early 2012. This affected the economic impact of improved drainage on crop yields, including in particular the date palm. The pilot is currently not operational. The Water Authority has renewed drilling, it is being currently equipped. It is expected to be operational and supply the whole oasis with water in 2015. The agricultural activities of the pilot should then be able to resume soon and it is important that the CRDA undertake following the monitoring of the pilot and its irrigation, agricultural and economic performance results during the coming years.

Notwithstanding the incomplete results, and pending confirmation by the CRDA after the



70



71



72

Figure 70. Digging the ditches for drains.

Figure 71. Laying the drains.

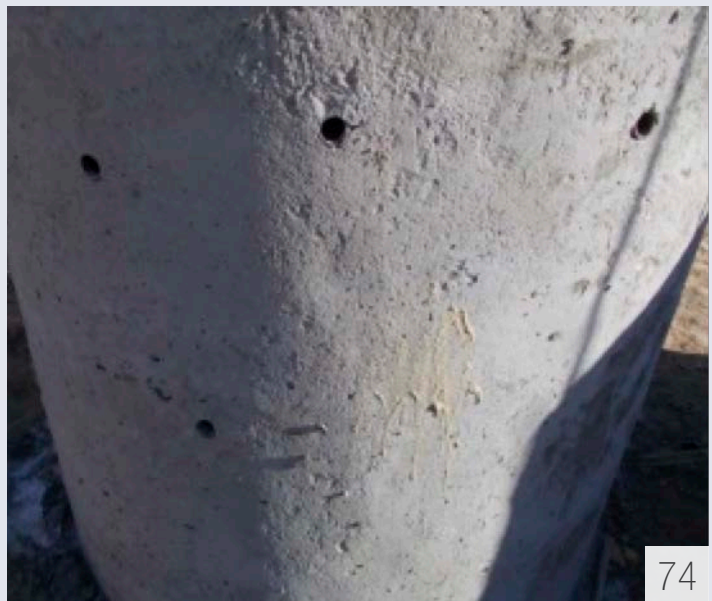
Figure 72. Connecting the drains at the level of the manholes.

Figure 73. Cross section of the soil at the level of the drains covered in gravel.

Figure 74. The concrete perforated cylinder used as manhole.



73



74



Figure 75. Manhole in place.



Figure 76. The manhole for reception of electric pump for evacuation of drainage water and their discharge to the external collecting channel.



Figure 77. The solar panel for the pumping of the drainage water.



Figure 78. The drainage water pumping device.

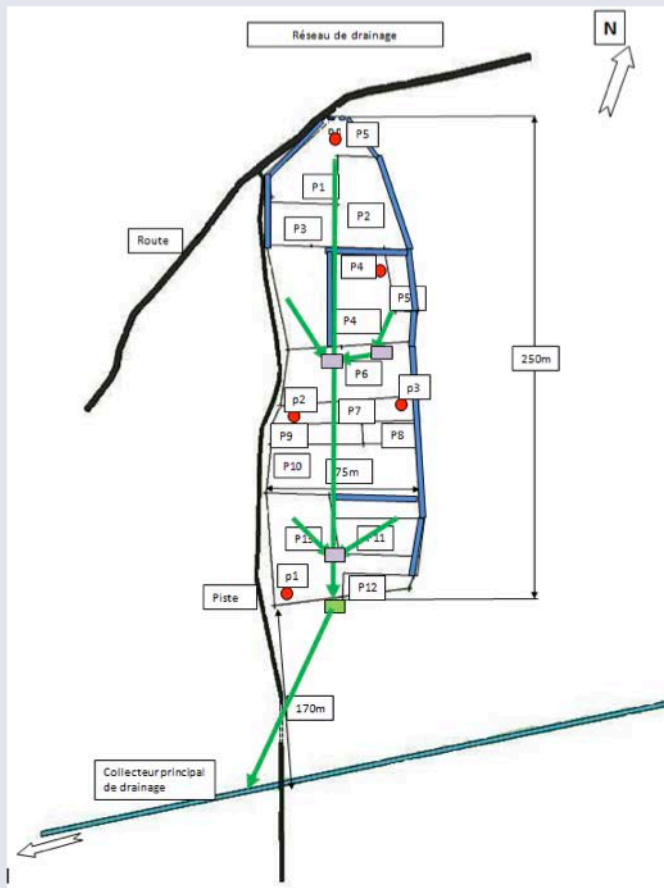


Figure 79. Location map of the piezometers.

Figure 80. Piezometer soil monitoring.



80

Figure 81. Discharge pipe of the drainage water through the solar pumping station to the external collector.



81

irrigation of the pilot, it is possible to project the replication of this pilot at a larger spatial scale, which is not to be considered randomly. Indeed, we have to remember that all the pilots implemented in this project focused on small size farms, without taking into account the structural constraints that are causing the regressive dynamics of culture systems. These constraints include in particular real estate elements of the farms and community management of water. In the specific case of this oasis pilot, the current land structure is not likely to facilitate the installation of an underground drainage system. It is important to provide a negotiation stage for the acceptance of the network path to install by the owners involved for any eventual project within this perspective. Indeed, the design and construction of the drainage system requires taking into consideration, initially, the general fragmentation of properties, a large majority of them are very small, then the prior approval of the farmers to extend the pipes in their plots, sometimes involving uprooting trees and other easily repairable damage.

This shows that the transition to another spatial scale that incorporates aspects of community management of water resources requires the establishment of a nature-scale pilot on a set of farms forming a [functional pedo-hydrodynamic unit](#). This concept of functional hydrodynamic unit may correspond to [one of the areas of the oasis \(10-20 ha\)](#) defined by one or (the) terminal (s) of irrigation water entry with a known flow rate, on the one hand, and a discharge gate for the drainage water, whose flow can also be determined. In this way, it would be possible to establish the water balance (volume and salinity of irrigation and drainage water) and salts, for one or more cropping seasons. This will be accompanied by the financial and economic operations balance sheets.

It is obvious that the identification of a particular sector requires a large contribution of technical services by CRDA Kebili and the GDA in charge of the management of irrigation of the oasis waters.

Dates	I	21-02-	24-02	28-02	03-03	L		08-03	12-03	16-03	I		22-03	28-03	05-04	10-04	18-04	25-04	30-04	
		2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
N° of piezometer																				
P1		113	120	145	172			133	120	123			0.86	103	110	130	143	153	145	
P2		143	155	148	156			141	120	116			0.58	0.94	117	152	153	143	150	
P3		143	153	154	156			153	128	124			0.66	104	116	146	160	170	151	
P4		106	146	150	155			136	119	0.96			0.88	110	126	141	154	164	122	
P5		135	150	154	130			105	80	0.30			0.30	0.93	122	138	152	159	120	

Table 14. Evolution of the depth of the sheet (in centimeters) before drainage ; I: after irrigation of the pilot and L: after irrigation of the neighboring plots.

Dates	Salinity in g/l Before drainage	Salinity in g/l after operation of the pumping																		
		08-02	14/02	20-02	24-02	28-02	08-03	10/03	12-03	16-03	22-03	28/03	05-04	10-04	18-04	25-04	30-04			
N° de regard	31-10 2011	08-02 2012	14/02 2012	20-02 2012	24-02 2012	28-02 2012	08-03 2012	10/03 2012	12-03 2012	16-03 2012	22-03 2012	28/03 2012	05-04 2012	10-04 2012	18-04 2012	25-04 2012	30-04 2012			
0		6.87	6.85	6.58	6.56	6.45	-	-	6.62	5.95	6.1	6.54	6.85	-	-	-	6.51			
1		6.79	6.51	6.51	6.37	6.40	6.64	6.56	6.58	5.91	6.1	6.4	6.84	6.56	6.42	6.77	6.51			
2	10.66	6.75	6.76	6.24	5.92	5.94	6.56	6.54	6.5	5.92	5.81	6.36	6.72	6.50	6.05	6.12	6.56			
3		6.82	6.81	7.66	8.16	8.18	6.75	6.45	6.48	5.79	5.4	6.29	6.94	7.25	7.94	8.06	6.48			
4		6.85	6	6.67	6.80	6.78	6.64	6.39	6.37	5.64	5.31	6.20	6.95	6.14	6.66	6.91	6.34			
5		6.18	6.78	6.78	-	-	6.24	6.32	6.11	5.66	5.20	6.16	6.18	6.4	6.645	6.76	6.69			

0: manhole of the main collector upstream 1: pumping manhole 2, 3, 4, 5: manholes respectively upstream and downstream

Table 15. Evolution of drainage water (g/l) in the manholes.

Depth (cm)	Electrical conductivity (mS/m)					
	After drainage					Before drainage
	P1	P2	P3	P4	P5	Global sample
20	2.91	2.48	3.82	2.6	1.44	13.7
40	2.78	2.37	3.72	3.29	1.64	10.1
60	2.76	2.44	3.73	2.78	2.42	11.4
80	2.73	2.4	2.92	2.16	2.35	9.5
100	2.49	2.12	2.72	2.03	2.61	9.2
120	2.22	1.86	2.55	1.86	2.31	-

Table 16. Results of the monitoring of the soil's salinity.

## PILOT OVERVIEW

**Geographical Location :** Governorate of Medenine, region of Smar, located 12 km north-east of Medenine in the South East of Tunisia.

**Local issue of irrigation:** The sedentarization of the local population, initially nomadic specialized in pastoralism, the concomitant development of rainfed olive cultivation under arid climate conditions, as well recourse to family irrigation inside the olive grove plantations using the little and poor quality underground water resources have not enabled until today to sustain the rural economy in this zone and the final stabilization of its peasant community on these lands. The pluri-activity of emigration remains for many young people the ultimate solution to improve family revenues and all the agricultural sectors reached their limit because of the lack of good quality water.

The production of new non-conventional water resources for irrigation may become the solution to the issue of developing the entire region. The population of all the Jeffara plain in Tunisia (governorates of Medenine, Tataouine, and Gabès) confronted and concerned with this perspective.

**Theme of the pilot:** The development of a sustainable irrigated family agriculture inside the olive groves, based on a hybrid system of olive farming and intensive off-season garden cropping with great efficiency of the water resources used and with high added value. This, through recourse to desalinization of the brackish waters available and performing irrigation techniques, outside the summer season.

**Agricultural production system:** It involves moving from a non-profitable rainfed olive production system threatened by episodes of draught and a hybrid system of intensive irrigated “olive cultivation-market gardening “, integrating family livestock breeding whose produce is intended for sale rather than family consumption.

**Water resources exploited:** A surface well tapping the surface water table.

**Availability of water for irrigation:** Availability is limited to around 40 m<sup>3</sup>/day.

**Water quality:** The well water has an average salinity of 4 g/l.

**Mode de gestion de la ressource eau :** The private well is managed privately, the water is pumped using electrical energy.



**Threats to the production system:** Rainfed olive cultivation is constantly facing water deficit, draught and recourse to irrigation with brackish waters that make land sterile.

**Evolution trends of the system:** The traditional production system is jeopardized.

## 1. General context of the pilot

The pilot is located in the Jeffara plain in Tunisia. This area is bounded to the west by the mountains of Matmata and to north-east by the Mediterranean. It is relayed to the east and southeast by the Libyan Jeffara. The region is part of the arid bioclimatic zone, lower under layer, with a negative annual climatic water balance ( $P_a - ETP_a$ ) largely negative ( $FTE > 1,600$  mm/year) and all the monthly water balance being in deficit, which makes rainfed cropping inappropriate and exposed to high risk of water shortage. It is therefore little or unproductive. It is also a poor region in natural resources. Most soils are either skeletal or gypsum or saline, with only wind-accumulated sand, accumulated especially in the valleys among the best soils with significant cultural aptitudes for some rainfed crops, including in particular the olive tree using the technical cultivation of dry-farming. As for groundwater resources, they are limited to surface water, structurally related to SASS, and in some locations to the deep CI layer. The landscape was typical steppe and agricultural activity was limited to nomadic pastoralism specializing in sheep and goat farming, with secondary camel breeding confined to low holomorphic areas (Sebkhat...). It was only in the last century that the best land had been highlighted through the cultivation of the rainfed olive.

Administratively, much of this plain is part of the governorate of Medenine. According to the technical services of the CRDA of this governorate, there are 5,469 shallow wells (of which 2,376 are operated by electrical energy) that can mobilize annual water volume of about 13 million  $m^3$  allocated mainly for agricultural use irrigation and family use. The quality of most of the water sheet is mediocre to bad (total salinity from 2 to 7 g/l, with an average of 4-5 g/l) for all uses, and it degrades over the years under the effect of over-exploitation. To this we add 157 deep wells reaching the deep Continental Intercalary aquifer, allocated largely to drinking water and irrigation of small public irrigated areas.

Currently, olive growing in this governorate covers about 200,000 ha (approximately 15% of the total area of the Tunisian olives) with over 4 million olive trees (approximately 6% of the total country's olive trees). But the olive growing in its most is not productive and faces multiple constraints (increasing aridity, drought, deteriorating terms of trade relative to production costs (chemical, labor) that threaten its sustainability and social stability throughout the region. It is in this context that the peasant genius has turned to irrigation family crops (vegetables, cereal and fodder ...) with brackish on very small areas between

the lines in the olive groves. This activity improves in the short term, even by little, household income. However, the negative impact of the brackish water, used increasingly during the summer, will inevitably cause land degradation.

Traditional irrigation is practiced during the hot and dry season with very little water consuming crops (watermelon, tomato, sorghum grain). This results in an allocation of a large volume of water and a supply of significant quantities of soluble salts that eventually accumulate in the surface layer of the soil.

The olive farming system and irrigation developing there are therefore increasingly threatened by neglect by the new generation of croppers, because of the lack of profitability, hence, the search for an alternative to the situation confronting the entire population of this region. This is why the water authority in Tunisia proposed to consider this Water--Agriculture issue within the SASS III project «agricultural demonstration pilots» with the aim of opening prospects for sustainable solution to water deficit.

## 2. Issue of the pilot

In the Jeffara plain, all the agricultural sectors are in crisis:

- sheep and goat farming has reached its limits and is faced with a growing deficit in fodder units of pastoral origin. The areas are decreasing because of cropping that is taking vast areas and productivity of remaining areas that continues to decline as a result of overexploitation.
- Rainfed olive cultivation is no longer profitable because of the large inter-annual rainfall variability and drought threats, on the one hand and the continuous increase in production costs, on the other.
- irrigation using brackish water of the shallow wells has shown its limits and cannot in any way constitute the suitable and sustainable solution to the social demand for good quality irrigation water.
- Irrigation in public irrigation areas from deep drilling will no longer be extended because of the lack of groundwater resources in large quantities and of good quality.

Agricultural development in this plain, a support to rural development requires specific solutions for each of these areas, as part of a comprehensive, integrated and coherent master plan. Fundamentally linked to the problem of water scarcity regarding family irrigation inside olive groves, the ultimate solution is conditioned by overcoming the first limiting factor, namely the good quality of irrigation water. Given the impossibility of increasing the supply using conventional resources, while mobilizing the last non confirmed underground resources, the only solution left is producing water through desalination of poor quality waters. In the first phase, it is important to focus attention and effort on brackish water resources of the shallow wells.

### 3. Theme of the pilot

Dans ce pilote, la démonstration portera donc sur le dessalement de l'eau saumâtre pour l'irrigation du système de culture familial réadapté à l'exigence des performances techniques et économiques. Les améliorations susceptibles de garantir à la fois la rentabilité économique, l'acceptation sociale et la conservation de la nappe exploitée seront introduites.

### 4. Objective of the pilot

Show that it is possible to improve the performance of this irrigated agriculture, make profitable the required investment, control adverse environmental impacts that could arise and improve the cropper's household income.

### 5. Location and characteristics of the pilot

The farm of the pilot is an agricultural plot of 1.2 ha, located 12 km northeast of Medenine on a terrace of the right bank of the Oued Smar, belonging to the family Lassoued and managed by Mabrouk Lassoued and brothers.

The geographic coordinates of this plot are: X= 10° 25 23 28 E; Y= 33° 25 23 28 N; Z= 34 m

The pilot's plot includes twenty non-irrigated olive trees, poorly maintained, and with poor productivity, with many missing trees. It is located adjacent to a surface well equipped with an electric pump and capable of delivering around forty m<sup>3</sup> per day. The total salinity of the water is 4.14 g/l and its detailed chemical analysis is reported in Table 17.

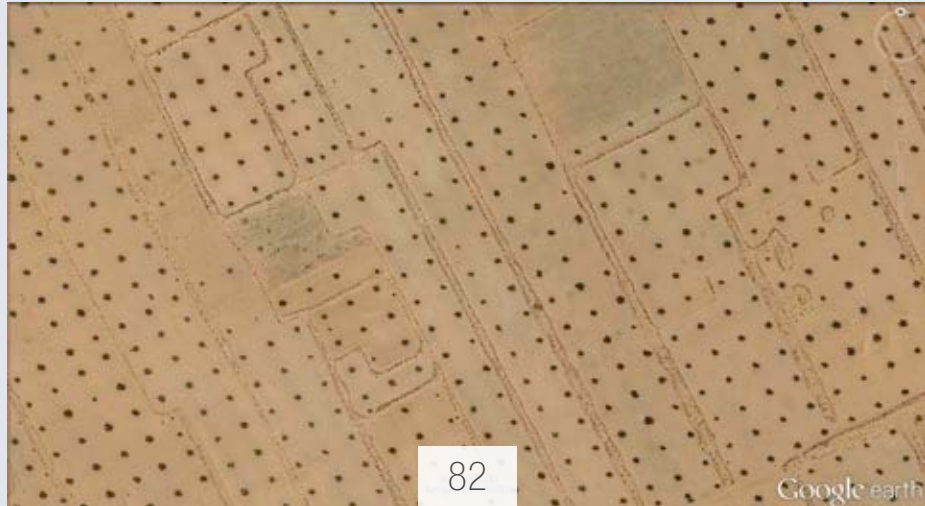
The average initial production of this plot was variable and reduced to an average of 50-200 kg of olives/year and dozens of fodder units from weeds (the equivalent of 100 kg of barley) grazed by small family sheep population.

### 6. Action plan of the pilot

It has four axes planned for all the pilots, namely institutional, technical, monitoring-evaluation and dissemination of results.

The main activities planned and implemented are as follows:

- mobilization of partners at local level;
- the development of a detailed plot plan with an appropriate rotation of crops planned;
- plot management work;



82



83



84



Figure 82. Groves of Zarzis region developed on sandy soils.

Figure 83. Olives dried during droughts (September 2010 just before the first autumn rains).

Figure 84. One of the many shallow wells and a small pool that mark the landscape of the region.



85



86



87

Figure 85. A plot of food crops irrigated in summer Irrigated using brackish water.

Figure 86. Illustration of summer fashion flood irrigation. (Note that the olive trees are irrigated directly but indirectly benefit from irrigation of vegetables with their powerful lateral root system).

Figure 87. A culture of watermelon with brackish water mid-summer. (Note the difference in the development of the olive tree irrigated land with olive groves in the non-irrigated land in the 2<sup>nd</sup> plan).



88

Figure 88. An olive tree benefiting from irrigation of intercropping, highly productive and saved from the impact of draught. It provides a yield of more than 200 kg of olives that is 10 times the average production/ tree in this region. However, irrigation using brackish water affected the soil through the salinization process.



Figure 89. Location of the pilot site in relation to the city of Medenine (yellow arrow).

Figure 90. Location of the pilot site on the right fringe of Oued Smar (yellow arrow).

Figure 91. Borders of the pilot's plot.



CE at 25° C in $\mu\text{S}/\text{cm}$	5 570
TDS (total of soluble salts) mg/l	4 526,4
Calculated dry residue in mg of soluble salts/liter	4 146
Na	577
K	18,5
Ca	545
Mg	205
Fe	< 0,050
Cl	1 040
SO <sub>4</sub>	1 970
HCO <sub>3</sub>	121
CO <sub>3</sub>	0,0
NO <sub>3</sub>	49,9

Table 17. Analysis sheet of the pilot's well (Analysis conducted by CITET).

- the acquisition of two greenhouses, small tunnels for protected vegetable crops and drip irrigation system;
- the acquisition, installation and commissioning of the desalination plant for the water of the well;
- installation of greenhouses, tunnels and the irrigation network;
- the construction of a storage basin for desalinated water and a basin to mix the irrigation water;
- the acquisition and installation of an electric pump to deliver and pressurize irrigation water;
- the acquisition of selected seeds and seedlings and farm inputs;
- establishment of cultivations;
- the technical monitoring of agricultural practices by the local monitoring committee composed of CN, the head of the project monitoring unit at CRDA Médenine, agricultural extension agent in the community of Smar; all this under the close supervision of successive chief managers of the CRDA, with support of the OSS team;
- dissemination of the results of the pilot through visits, workshops, a leaflet and a video extract.

This Action Plan and the terms of its implementation have been the subject of lengthy consultations with all project partners. These consultations have identified the guiding principles that have guided the realization of expected demonstrations.

These principles include, in particular:

- banning the irrigation of annual crops during the four hottest months, namely the months of June, July, August and September, to minimize water consumption and avoid low-value crops. Therefore, the suppression of traditional vegetables allowed the allocation of available water during this hot season, to satisfy the water needs of the olive trees and alfalfa plot.
- The period of herbaceous crops now lasts over the eight remaining months, corresponding to the cool season, under greenhouse, under tunnels and in open fields.
- The varieties and areas of these herbaceous crops are determined on the basis of their water needs, their growth cycle, the overall water balance of the pilot and their respective abilities to make the best of water used (at the quantitative and economic levels).
- Desalinated water is used after mixing with brackish well water to obtain two water qualities for the irrigation of crops according to their tolerance to salinity (1g/l for vegetables and 1.5 g/l for olives and alfalfa).
- Among the selected herbaceous crops, it was considered essential to include a small plot of forage (alfalfa, green barley) to help provide, in part, the feed needs of the family's cattle, two sheep and suites in average.
- Keeping/maintaining exhaustive financial accounts of the expenses and revenues , as well as self-consumed products by the head of the household.

## 7. Evaluation of activities carried out

This evaluation is summarized in Table 18.



Planned activities	Degree of completion	Results	Means of verification
Institutional activities			
Mobilization of water actors at local level	Entirely	Voluntary commitment of agricultural croppers and other actors to participate in the development of the plot	Report of the first mission of the RC in this region
Recruitment of a national Consultant	Completed	Contract signed and kick off of the NC's activities	Document of the contract Quarterly report of the NC
Holding an awareness-raising workshop	Completed	Committing partners of the project achieved	Quarterly report of the NC
Setting up the local monitoring and evaluation Committee	Completed	Structure of the committee finalized	Minutes of the meeting for the setting of the Committee Quarterly report of the NC
Partnership Conventions	Multiparty partnership conv. with IRA, CRDA of Kébili and the cropper	effective participation of partners in the development and monitoring of the pilot	Convention signed by partners Quarterly report of the NC
Technical activities			
Prospection of the field with the NC and the water authority, agricultural service and cropper for choice of the pilot's site	Entirely	Site and operation of the selected pilot	Mission report of the RC Quarterly report of the NC
Technical study and design of the pilot's components	Entirely	Pilot's action plan developed and adopted	Quarterly report of the NC
Identification of necessary works and equipment	Entirely	List of equipment and estimates of the cost of the pilot	Quarterly report of the NC Quotes of equipment

Implementing the action plan that includes mainly the construction of a storage basin, setting up the greenhouses and tunnels, laying the irrigation network, the acquisition and installation of a desalination plant, carried out as from the first and second agricultural season with technical innovation	Entirely completed	All the equipment set up and operational, desalination station installed and operational, the cropping system set up	Quarterly report of the NC Quarterly report of the RC
Agricultural performance	Entirely completed	Good valorization of water, high yields for the crops set up	Report of the first regional workshop for the dissemination of the results of the pilot (June 2012)
Economic performance	Accomplished	Excellent results of the first agricultural session	Report of the first phase
Environmental performance	Evaluated	No soil salinization	
Extension activities and dissemination of results			
Information workshop	1 <sup>st</sup> education workshop held	Committing croppers to have the pilot on their farms	1 <sup>st</sup> quarterly report of the NC
Dissemination of results	Presentation of the synthesis of national water strategies of the three countries to the Project Steering Committee in Algiers in May 2011	P o w e r P o i n t Presentation of the synthesis	Synthesis document Mission report of the RC in Algiers for the project steering Committee
Visit to the pilot	By the director general of CRDA Medenine with his collaborators, by the Executive Secretary of OSS, experts from various funders and the ministry of agriculture (June 2014)	Satisfaction of the visitors	Biannual Report of the NC Mission report of the RC

First regional workshop for submission of the pilot results Medenine in June 2012	More than 80 participants from the three countries including croppers and water decision makers	Presentation of results and visit to the pilot ; discussion of results and perspectives of the replication of the pilot at larger scale	Mission report of the RC on the first regional workshop on the pilots in Medenine.
National workshop for presentation of evaluation of the pilots in Tunisia (Jerba September 2013)	Thirty officials decision makers at national, regional and local levels participated in this meeting	Presentation, Discussion and validation of results, formulation of recommendations for the replication of pilots	PowerPoint presentation of results Report on the results of this workshop
Regional workshop, Algiers May 2014	Participation of the three countries	Validation of the results	
Monitoring and evaluation activities and reporting			
Quarterly reports of the national consultant	Rapport du CN en charge de ce pilote réceptionné et validé	Report of the NC in charge of this pilot received and validated	Document report of the NC
Quarterly reports of the NC	Soumis et validés	Submitted and validated	Regular reports of the RC
Biannual reports of the RC	Rapport du premier semestre (juil. à déc. 2011) soumis à l'OSS et validé	Report of the first semester (July to Dec. 2011) submitted to OSS and validated	Biannual report document
Annual report of the RC	Rapport soumis à l'OSS et validé	Report submitted to OSS and validated	Report document
Mid-term project report	Soumis à l'OSS et validé	submitted to OSS and validated	Report document
Report of the 1st phase June 2012	Soumis à l'OSS et validé	submitted to OSS and validated	Report document
Semestral report December 2012	Soumis à l'OSS et validé	submitted to OSS and validated	Report document
Report on the results of the pilots, Tunisia (March 2013)	Soumis à l'OSS et aux partenaires tunisiens	Submitted to OSS and the Tunisian partners	The mission report of the workshop
Draft final report of the pilots component (Dec. 2013)	Soumis à l'OSS et validé	submitted to OSS and validated	The relevant report
Final report on the pilots component	Soumis à l'OSS et aux partenaires du projet	submitted to OSS and project partners	This report

Table 18. Evaluation of activities completed.

## 8. Main results

The activities carried out are illustrated by the photos.

Figure 92. Some members of the local team of actors.



Figure 94. A water tower for the storage of desalinated water.

Figure 95. The desalination plant with a processing capacity of 40 m<sup>3</sup>/day of water at 4 g/l with a yield of 50 %, that is 20 m<sup>3</sup>/day of water at less than 0,2 g/l of total soluble salts.

Figure 96. The mixing basin of brackish water and desalinated water to obtain different water qualities.



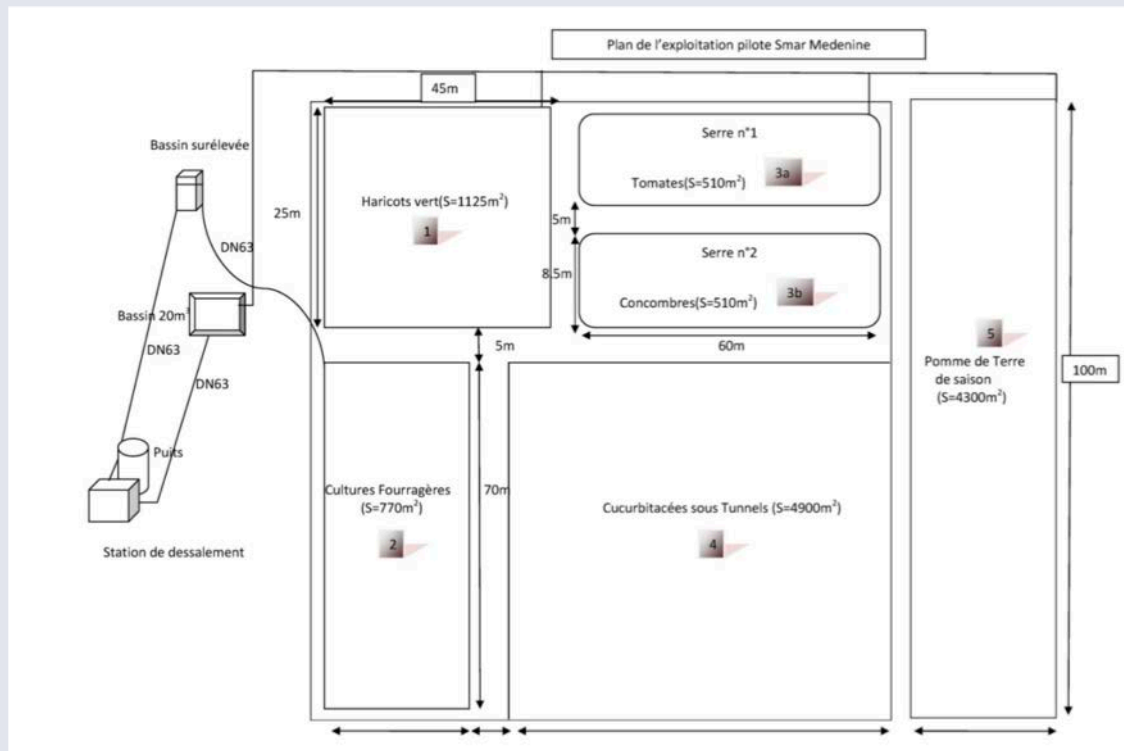


Figure 97. Site plan of the farm for the first agricultural season (2011-2012).

This plan is designed to develop both conventional greenhouses for tomato crops and early cucumber, early cucumber cropping under tunnels, potato crops and winter salad. This plot has an alfalfa plot to meet the feed needs of the family's sheep, as expected. All crops are irrigated and fertilized in the drip mode. Fertilization is mixed, organic and inorganic, and phytosanitary treatments are mostly preventive.

During the second growing season and following the recorded economic success during the first season, the cropper has taken the initiative after consultation with the Consultants and technical services of the CRDA, to acquire, self-funded, new greenhouses to extend the early vegetable crops. The approval of the technicians was granted only after checking the water balance and meeting the water needs of all cultivations, including those of the olive.

The initial state of the pilot's plot is shown in the next photo that was taken just after a big clearing plowing.

Figure 98. The plot of the pilot **before** and **after** the start of the first crops in March 2012.



99



100

Figure 99. The pilot's plot after establishing the crops (March 2012)).

Figure 100. Launch of a tomato crop under one of the greenhouses.



101

Figure 101. One of two greenhouses installed in the intercropping area of the olive tree lines.



102

Figure 102. The tomato crop in greenhouses in full production on 5 June 2012.

Figure 103. (a & b) The cucumber crop on the day of the visit to the pilot by participants from the three countries to the workshop for the dissemination of pilots results (5 June 2012).



103



104



105

Figure 104. Season potato crop in June 2012 at the harvest.

Figure 105. Croppers from the Smar community participate in the workshop for the dissemination of results of the « Pilots » component of the three countries accompanied by the SASS II project coordinator.



The first results related to technical, economic and environmental performance are considered very good, and even unexpected by all project partners as well as visitors of the three countries in the workshops during the first regional workshop on the pilots (Medenine June 2012). These results were supported and even improved during the 2<sup>nd</sup> agriculture season.

Crops	Area (m <sup>2</sup> )	Date of establishment	Date of the first crop	Total production in kg	Yield tons/ha	Productivity/ m <sup>2</sup> Kg/m <sup>2</sup>	Average sale price Dinar/g	Receipts Tunisian Dinar
Early tomato u/greenho	510	6/12/11	6/4/12	5 500	108	10,8	0,910	4 122
Salad	1 125	4/3/12	25/4/12	4 082	36	3,6	0,630	2 500
Early cucumber u/ greenh	510	7/12/11	20/4/12	5 070	99,4	9,94	0,770	1 862
Cucumber u/tunnel	4 980	26/1/12	5/5/12	12 536	25	2,5	0,491	5 796
Season potato	4 900	11/2/12	4/6/12	15 060	30,7	3,07	0,478	7 505
Alfalfa	840	15/4/12	End of July	770*	0,9*	0,9*	0,125	96
Olives			Nov.12	1 300 kg	1 000 Kg			1 000
Total	12 865			4 3018				2 2881

Table 19. Agricultural performance and income of the first agricultural season 2011-2012.

According to the first analysis, the total revenues for the first growing season are very encouraging. However, what matters in the end is the gross margin that this culture system gives and its impact on the income of the cropper.

The gross margin thus reached 7,761 dinars for the whole area of the pilot, which is 6,467 TD/ha or US \$ 4,042/ha. Compared with those generated by rainfed olive growing (150/ha on average) and family gardening-based irrigated farming system and summer sorghum (800 DT/ha), it indicates a very strong improvement in the economic valorization of irrigation water. This performance over time is to be confirmed.

For the cropper, this result is very positive; he is deeply convinced, and as evidence, he invested his profits earned in the first year in the acquisition of two greenhouses and their immediate operation during the second growing season, while respecting the balance of the water of his own farm and other principles that were the subject of mutual agreement.

Item	Labor	Mecha- nization	Manure	Seeds	Fertilizers	Station maintenance	Commercia- lization	Amortiation		Total
								Station	Greenhouse and network	
Total Charges	3,076	570	990	2,028	1,406	1,993	1,300	1,970	1,786	15,119 DT 9,450 US\$
Total Receipts	22,881 DT ou 14,300 US\$									
Gross margin	<b>+ 7,761 DT or 4,852 US\$</b> <b>6,467 DT/ha or 4,042 US\$/ha</b>									

Table 20. Economic balance of the pilot's first year.

It is noteworthy that the total amount of investments (fixed costs and variable costs in the first year) reached 44,537 DT with the farmer's own contribution being a total of 11,655 DT as follows: 5000 DT fixed costs and 6655 DT into variable costs; this represents approximately 25% of total investments. The involvement of the cropper in this financing is one of the criteria for which the farm was selected as it is also a guarantee of success of the new cultivation system proposed.

Socially, this cultivation system has created new jobs: permanent jobs and 300 temporary working days over a growing season of eight months. This opens up promising prospects in the fight against unemployment in rural areas in this area.

Environmentally, this system has halted the risk of soil salinization, since the salt content of irrigation water (mixture of desalinated water with brackish water) is greatly reduced. The results of soil analysis at the end of the growing season have shown that the soil salinization process was well controlled.

Date of salinity measurement	Evolution of the surface well water salinity g/l	Evolution of the salinity of desalinated water g/l	Evolution of soil salinity
			Average /maximum of the salinity of the five first surface layers of the soil (0- 20/ 21-40/41-60/ 61-80/ 81-100 cm) ms/cm in extract 1/5
2 January 2012	4.1	0.03- 0.1	3.4
25 June 2012	4	0.03- 0.1	4.5

Table 21. Evolution of the water and soil salinity.

These results clearly demonstrate the correct operation of the desalination station, as its maintenance is provided correctly, and the total absence of any negative impact of the irrigation method used on soil quality, which perfectly meets one of the objectives of the pilot. Although desalination brines are released into the adjacent Oued Smar, the amount of salt that reaches the water table is equivalent to that which pervades the land during a growing season with the traditional irrigation mode using brackish water.

## 9. Results of the second agricultural year

The action plan agreed for this second season takes into account the acquisition of two new greenhouses with an extension of the cultivated area to 1.38 ha, while respecting the general principles agreed with all partners. The rate of intensification was then increased to reach 131.6%.

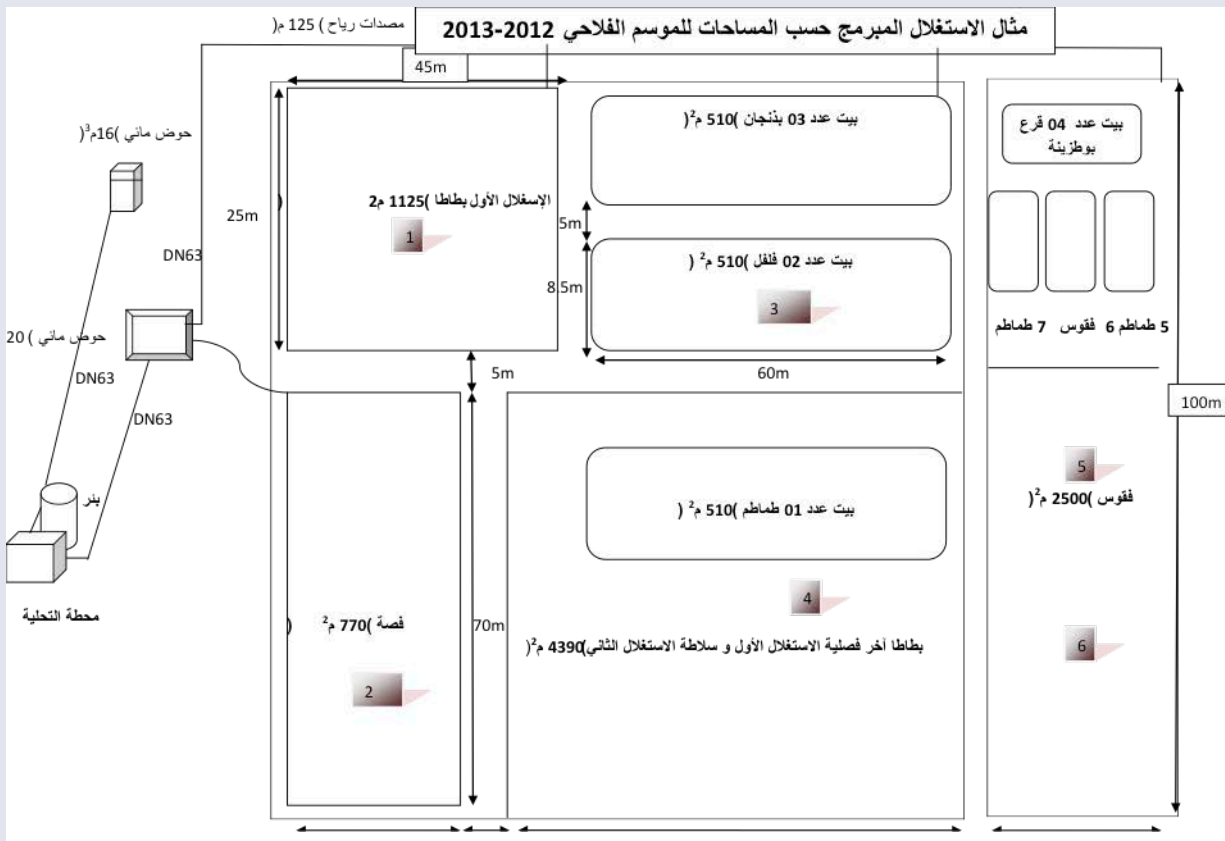


Figure 106. Plot plan of the farm of the pilot during the second agricultural season.



106



107

Figure 107. Land cover of the pilot by the end of March 2013 (after the harvest of intercropping crops in the open field).

Figure 108. Excellent development of an early pepper crop under greenhouse.

The following plot plan shows the location of the greenhouses and plots of other crops.

These crops are divided into:

- late season crops (or catch crops) in autumn (September to December 2012) such as potatoes;
- Winter early crops (October 2012-May 2013 cultivated under greenhouses, tunnels or in the open).

Technically, the yields of most crops harvested in 2013 were high, with the exception of salad crops that were damaged by birds and mice that benefited from the absence of green foliage in a context severe drought that hit the region. As for the economic assessment of this second season, it is synthesized in Table 22.

Item	Labor	Mecha- nization	Manure	Seeds	Fertilizers	Maintenance & energy	Commercia- lization	Amortization		Total
								Station	Irr. network	
Total expenses	5,549	930	1,500	2,893	2,598	1,060	3,119	1,970	3,642	22 332 DT 3,958 US\$
Total Receipts	35,799 DT ou 22,374 US\$									
Gross margin	<b>13,466 DT ou 8,416 US\$</b> <b>soit 9,757 DT/ha ou 6,098 US\$/ha</b>									

Table 22. Economic balance of the pilot's 2nd year.

These results confirm the high performance achieved during the 1<sup>st</sup> cropping season that clearly improved with two new greenhouses and a slight extension of the cultivated area (1.38 ha instead of 1.2 ha). Comparison of these economic performances as reported in Table 23 shows improvement in the economic efficiency of water thanks to a reasoned intensification of the family cropping system compared to the traditional systems practiced. The gross margin per hectare during the second year of the pilot is forty times that of olive rainfed system and more than seven times that obtained with the traditional irrigation system, with a clear potential to improve their performance. Indeed, the loss of the salad crops because of various predators (birds and mice) in a context of drought has undoubtedly reduced the gross margin.

Furthermore, this intensive system highlights the existence of a pool of physical and economic productivity, employability and profitability through the desalination of brackish water and irrigation use, despite its relatively high cost.

Furthermore, the increased cost of desalination in the second year of the pilot implementation (Table 24) did not prevent the cropper from obtaining a good gross margin at the end of

the cropping season. This demonstrates the flexible capacity of the cropper to pay irrigation water at a high price, as long as the cropping system can ensure return on the investment required. This result confirms one of the results of the socioeconomic and environmental survey (second component of the SASS III Project), namely that in the different situations of irrigation in the SASS area, the more intensive culture system is, the more the cropper values the water, even at real water costs that are significantly higher than those in conventional systems (free or paid water solely on the basis of maintenance cost of the water distribution structures).

At the environmental level, the results of the 2<sup>nd</sup> year confirm those obtained at the end of Year 1, namely the total control of the risk of soil salinization.

Item	Expenses (DT)
Amortization of the station	1,970 (19,700 amortized over 10 years)
Maintenance of the station (changing filters & membranes)	1,369
Electrical energy for desalination	1,200
Volume of desalinated water m <sup>3</sup>	3,485
Cost of one m <sup>3</sup> of desalinated water taking into consideration amortization of the station	1.302
Cost of one m <sup>3</sup> desalinated water excluding the amortization of the station	0.732
Energy cost for the desalination of 1 m <sup>3</sup>	0.344

Table 23. Components of the well water desalination costs.

## 10. Conclusion

All components of the pilot have been implemented to the best possible practice. The cropping plan was implemented over two consecutive seasons and the cropper has fulfilled all his obligations (participation in the financing, management of labor costs, manure and electrical energy, continuing the adoption of the cultivation system after the duration of the project ...). Similarly, all other project partners (IRA, and DGRE DGGREE ...) played fully their respective roles. We note in this regard the ongoing and effective contribution of the CRDA Medenine staff.

The technical, economic and environmental results of this pilot for two consecutive years, evaluated both internally by the PRSP, other technical bodies as well as external evaluations are considered very positive. The results were presented to the participants of various national and regional workshops (Medenine June 2012; Jerba, September 2013; Algiers, May 2014) and the different meetings of the Project Steering Committee, they

Item	Before project; rainfed olive tree cultivation	Before project; Hybrid system olive/irrigated summer crops	1 <sup>st</sup> year pilot Hybrid system olive/ Off-season irrigated crops	2 <sup>nd</sup> year pilot Hybrid system Olive/irrig. Crops off- season
Area	1.2	1.2	1.2	1.38
(%) Intensification rate	25	40	125	131
Gross margin DT or US \$	150	800	6,467 or 4,042 US \$	9,757 ou 6,098 US \$
Nbr jobs	18 days labor	200 days	1 permanent job and 300 days temporary labor	1 permanent job and 350 days temporary labor
Cost of desalination for 1 m <sup>3</sup> of brackish water	000	000	1.1 DT with amortization station and 0.6 DT without amortization station	1.3 DT with amortization station and 0.7 DT without amortization station

Table 24. Comparaison des performances économiques du pilote avec les systèmes de culture traditionnels.

were considered very promising and are likely to open new perspectives for the future of irrigation in this region in particular, and even for similar areas in Libya and Algeria.

Visited by many croppers and technicians from the Ministry of Agriculture and donor agencies, the pilot has attracted great interest for its replication in other farmers, even in other regions. It is clear that the profitability of the system exceeds the expected objectives, given the high cost of desalination. Certainly, the results are likely to encourage the replication initiatives of this model. The truth, however, is that these performances are obtained by a single cropper on a small farm of 1.2 hectares, with a monitoring of the project. This means that it is important to validate this model in several farms of the same land as part of a production system integrating all the technical, economic, trade and environmental problems of local irrigation development before proceeding with a widespread replication of this pilot in contexts that may be unsuitable.

Moreover, the impact of irrigation on intercropping in the olive groves on the development and productivity of olive trees, previously grown as rainfed, has been very positive and has helped to improve the profitability of investment in desalination. The initial yield was multiplied by 4 to 5 times, olive trees survived the drought and the gross margin generated by the olive tree has definitely improved. This is another perspective that opens planners to control decay threats to olive groves in arid regions as a result of drought, which are becoming

more frequent and long in these regions. The future agricultural demonstration pilot on a production system pilot should provide more precise answers to the many questions about the future brackish water desalination for irrigation.



## PILOT OVERVIEW

**Geographical location:** Governorate of Gabès, delegation of El Hamma, region of Magcem, located 5 km east of El Hamma on the Gabes-Kebili road.

**Local issue of irrigation:** Important geothermal water resources available in Libya that are not valorized in irrigation of intensive cropping as is the case in Tunisia.

**Theme of the pilot:** Use geothermal water resources in the irrigation of off-season high added value garden cropping.

**Agricultural production system:** It involves the transfer of know-how in terms of using geothermal waters for irrigation of intensive early high added value crops, with high employability and profit.

**Cropping system:** Winter intensive market gardening under greenhouses in controlled environment.

**Water resources exploited:** Geothermal waters supplied by a borehole in the Continental intercalary.

**Availability of water for irrigation:** The flow of the borehole is 50 l/s, it widely covers the needs of the cropper.

**Water quality:** The water of the borehole has an average salinity of 3 to 3,5 g/l and an initial temperature of over 40 °C.

**Water resources management mode:** The well is managed privately, the water is pumped using electricity.

**Evolution trends of the system:** This system is sustainable subject to the evacuation of residual waters of the desalination station into a saline recipient, such as the Chotts. Besides, the temperature of the water decreases over the years, which will require an additional energy to heat the greenhouses.

# Pilot

# 7

*NB. This pilot replaces pilot 4 planned in Libya on the same issue.*

## 1. General context of the pilot

This context is marked by the availability of significant geothermal water resources in the area, and by an important reserve of achievements, local knowledge and research results in the valorization of such resources in the irrigation of high added value crops.

## 2. Local water issue

Some areas of the SASS zone, especially in Tunisia and even Libya have significant geothermal water resources from the Continental Intercalary aquifer. In many cases, these water resources were in the past artesian (springs or wells), but due to overexploitation of the aquifer, many sources have dried up and the piezometric levels of many drillings have decreased more or less rapidly. However, these water resources that have the advantage of being tapped at temperatures above 55 ° C are not valued in the best possible way agriculturally. They are usually artificially cooled and allocated to irrigation of the oases without making use of the free heat.

However, Tunisia (governorates of Gabes kebili and Tozeur) displays a successful experience in the valorization of such waters for irrigation of off-season and hyper intensive vegetable crops. This experience started in the 1980s and still continues with the improvement of a developed technology package. There is even a specialized technical center in geothermal cropping system. The cultivated area in these three governorates is about 150 ha, the production of which is intended largely for export. The most cultivated varieties are tomatoes, pepper, cucumber, watermelon, melon and eggplant. However, although this system is very profitable, and because of the high salinity of these waters (2-5 g / l of soluble salts), the irrigation has a negative impact on soils, because it ends in a few years by salinization and in the degradation of the functional properties of irrigated land. Faced with this problem, the pioneer croppers in this field have taken the initiative to adopt an original solution, relevant and rewarding, to increase productivity while avoiding losing their land. The solution consists in valorizing the heat of the water in heating greenhouses where early crops are produced, then desalinate the water for the irrigation of these crops.

The advanced technology developed for this cropping system showed its economic, social and environmental value. Taking advantage of this success and after noting that it was not possible to carry out the pilot 4 planned in Libya, project managers had deemed it fit to capitalize on these results and vulgarize them in all the SASS areas for the benefit of three countries, including Libya that is very interested in the issue.

## 3. Theme of the pilot

This theme focuses on two axes. The first, that is relatively old, is the use of hot water in the heating of greenhouses to produce very early crops, therefore with high value, largely for export. The second, which consolidates the first, concerns the desalination of geothermal waters prior to their use in irrigation, which increases their physical efficiency (productivity of one cubic meter of water) and economic valorization.

## 4. Objective of the pilot

Disseminate in the three countries the results of a cropping system that is very efficient in social, economic and environmental terms on one hand, and prepare for the transfer of technology of this system into the Central Zone of wadis where pilot 4 was initially planned.

## 5. Location and characteristics of the pilot

The pilot is a farm with an area of 12 hectares, created there over 25 years and specializes in off-season vegetable crops, irrigated and heated with geothermal water. It is located in the governorate of Gabes Delegation of El Hamma, Magcem area, located 5 km east of El Hamma on the road between Gabes and El Hamma.

Its geographical coordinates are:  $X= 33^{\circ} 52'19 23 \text{ N}$  et  $Y= 9^{\circ}52' 34 88 \text{ E}$

Initially, the farm was structured in a little personal private property, it then evolved into a company including other partners.

The team of the company consisted of:

- a general manager;
- a technical team of 3 engineers;
- an administration that includes 5 managers;
- three chief technicians; and
- 120 permanent workers.

The main information that describes the potential and performance of this farm are:

### 5.1. The area of the farm

The farm globally covers 40 hectares, but the indoor cultivated irrigated area is about 12 hectares.

### 5.2. The varieties of the crops

The various species of plants used are all grafted plants on resistant rootstock which is the "Maxifort".

Using the "TYTY" for cocktail tomatoes, "Climberly" for cherry tomatoes and Cristal variety "for the eggplant.



Figure 109. Satellite image of the Pilot 7 farm in Tunisia (Chenchou, Mgacem, El Hamma de Gabes).

### 5.3. Water resources used

The company has a private borehole located on the farm.

The level of the static water table is about 34 m below the natural ground. A submerged pump is used to pump water at a depth of 46 m below the natural ground using a 65 HP power engine at a rate of about 50 l/s.

The water of this table has a sodium sulfate-geochemical facies with a total salinity of the order of 3.5 g/l.

The temperature of drilled water decreased compared to previous years, since it was around 53 °C, to reach 40 °C now; that is why the company has been brought to the complementary greenhouse heating by thermal energy (olive pomace).

### 5.4. Desalination of drilled water for irrigation

Initially, irrigation was carried out directly using available brackish water and the cropping

was conducted in natural soil. Following multiple negative impacts of salinity on soil and crops, and many fungal diseases and nematodes on yield, the option to desalinate drilled water for irrigation and the use of artificial substrates as replacement of natural soil was adopted and fully applied, excluding the crops under tunnels.

The company has two reverse osmosis desalination stations with a daily production of 35 m<sup>3</sup>/h for both stations delivering water with salinity lower than 0.2 g/l.

## **5.5. Greenhouses Heating**

Greenhouses heating is active using the thermosyphons method. The water is heated by an olive pomace-fueled boiler that is heated to reach a temperature of 70 °C before the water is circulated in the steel pipes suspended in greenhouses.

The heating circuit is closed, which avoids the problem of disposal of surplus water after heating.

## **5.6. Fertilization**

On this farm, local fertilization is practiced using fertigation. In the beginning a concentrated stock solution is prepared, which is then mixed with osmosis water to give a diluted nutrient sub-solution with concentrations appropriate to each crop.

The stock solution is prepared in two separate containers to avoid precipitation of incompatible minerals.

In Tray 1, we put the potassium nitrate, NPK, and trace elements. Tray 2 contains magnesium nitrate and iron.

## **5.7. Fighting against diseases and pests**

Pest control has been integrated as biological and conventional chemical control are used jointly.

Biological control consists in the introduction of beneficial insects at the level of eggplant crops (Swirski: 400 pouches/tunnel), the use of SAS and insect-proof, electric traps, pheromone traps and yellow panels.

## **5.8. Marketing**

The choice of species and cultivars is imposed by the market receiving the produce. This market is Europe and the company is equipped with a packaging line to meet European standards.

## 6. Action plan of the pilot

This plan is prepared by the Company's technical staff in accordance with its strategy, established based on demand of the European market reported previously. Therefore, the SASS III project has not been involved in the design or management of the farm; these actors and partners have just visited and used these results to the benefit of decision makers and Libyan and Algerian croppers.

The cultivation plan is almost the same every year, knowing that crops are conducted on artificial substrates; and for this reason, it is not necessary to respect crop rotations. Substrata flanges are normally replaced every year.

The plan includes:

- 3 hectares multihood greenhouses (37 in total) of "cocktail" tomatoes;
- 4 hectares multihood greenhouses (40 in total) of "cluster" tomatoes;
- 4.4 acres of tunnels producing eggplant.

## 7. Evaluation of activities carried out during the first agricultural year (2011-2012)

Given the fact that this pilot and all its components were established and managed by the Company, the project activities in this case were limited to monitoring the deployment of technical activities and to collecting their results to evaluate the technical and economic efficiencies. One of the Company's horticultural engineers has been appointed by the CEO of the Company to provide all information and non-confidential useful data.

Besides the evaluation of the performance of this cropping system, the project started disseminating its results through the first regional workshop on the six pilots and organized a visit to the pilot at the time on June 6, 2012. The visit was beneficial to all national consultants in charge of the pilot in the three countries as well as many engineers and farmers of the Tunisian South.

Planned activities	Degree of completion	Results	Means of verification
Institutional activities			
Mobilization of the owner and obtaining approval for partnership to make of his pilot farm an agricultural demonstration pilot	Entirely	Voluntary commitment of the cropper to disseminate his experience and results	Partnership convention OSS/ cropper
Empowering horticulture engineers of the farm to provide data and information available and carry out visits to the pilot	Completed	Contract signed and kick off of the engineer's activities	Contract document
Planning a visit to the farm and a meeting at OSS between the Executive Secretary and the owner	Completed	Action plan developed	Mission report of the RC
Technical activities			
Launching the data collection on the farm	Completed	Operation of the pilot described	Mission report of the RC
Designed agricultural activities are running regularly by the staff of the cropper Harvest, packaging and export carried out regularly	Entirely completed	All the facilities are operational  Operation standards are rigorously observed	Quarterly report of the RC
Technical and economic performance	Duly evaluated	High performance providing for replication of the farm and best valorization of water resources	Report of the first regional workshop for dissemination of results of the pilot June 2012  This report
Extension activities and dissemination of results			
Extension and dissemination of results workshop	1 <sup>st</sup> regional workshop to report back the pilot's results to technicians and croppers of the three countries; June 2012	Manifestation of interest by participants to transfer the experience to Libya and Algeria	Mission report on the first regional workshop on the pilots held June 2012

Dissemination of results	Presentation of the performance of the pilots during the first regional workshop on the pilots	PowerPoint presentation	Mission report of the RC in Algiers to the Project Steering Committee
Visit to the pilot	Visit to the pilot by participants to the workshop on the pilots (50 participants)  Visit to the pilot by Mrs. Kerry, representative of the GEF in May 2013 on the occasion of the annual meeting of the Steering Committee	Visitors satisfied  Very positive evaluation	Biannual report of the NC  Presentation to the Steering Committee
First regional workshop on the results of the pilot in Medenine in June 2012	More than 50 participants from three countries including Algerian and Libyan croppers and water decision makers  National workshop for presentation and validation of results	Presentation of results and visit to the pilot ; discussion of results and recommendations on extension of the pilot concept at larger scale  Validation of results and collection of suggestions for the elaboration of recommendations	Mission report of the RC on the first regional workshop on the pilots in Medenine  Presentations
Monitoring and evaluation activities and reporting			
quarterly reports of the RC	Submitted and validated	Information shared on progress in implementing the pilot component	Regular reports of the RC
Biannual report of the RC	Report of the first semester (July to December 2011) submitted to OSS and validated	Same as precedent	Document of the semester report
Annual report of the RC	Report submitted to OSS and validated	Same as precedent	Document of the report
Mid-term report of the project	submitted to OSS and validated	Self-assessment presented	Document of the report
Semester report June 2012	submitted to OSS and validated	Self-assessment presented	Document of the report



Presentation of results 2012- 2013 to the SASS III Project Steering Committee	Presented	PowerPoint presentation	The presentation itself
Report on the results of the pilots in Tunisia (March 2013)	submitted to OSS and validated	Self-evaluation of the project results and operational recommendations	The relevant report
Draft final report on the pilots component (December 13)	submitted to OSS and validated	Evaluation of all the pilots	The relevant report
Final report on the results of the pilots of the three countries	submitted to OSS for validation	Evaluation underway	This report

Table 25. Évaluation des activités réalisées au pilote 7.

## 8. Results and their evaluation

### 8.1. Technical results of the agricultural year 2011-2012

The following photos illustrate the technical results obtained during the agricultural season 2011-2012.

### 8.2. Economic performance

Thanks to the croppers' long experience in this field and his mastery of all segments of this activity, the farm achieved excellent performance in terms of efficient use of irrigation water (25 kg tomato/m<sup>3</sup> of water) and profitability.

The control of the management of irrigation water is one of the factors of production that highly contributes to achieving these results. Indeed, this irrigation is managed according to the climatic conditions and vegetative stage of crops. It is automatic and controlled on the basis of solar radiation. The average daily consumption of irrigation water is about 100 m<sup>3</sup> for the entire cultivated area, which corresponds to an average of 12,000 m<sup>3</sup>/ha during the growing season, which represents the lowest consumption of the intensive systems described in this area in the SASS zone of the three countries. Moreover, for the production of eggplant in soil, in greenhouse or under tunnels, the average consumption is estimated at 5,000 m<sup>3</sup>/ha during the season. For cherry tomato produced in substrata and greenhouse chapel, consumption reached 15,000 m<sup>3</sup>/ha.

As for economic performance, they are still very high compared to crops grown on the ground. The numerical details of this performance are summarized in Table 26.



110

Figure 110. Basins for the preparation of the stock solution of liquid fertilizers.

Figure 111. One of the two osmoses for the desalination of brackish water.



111

Figure 112. General view of the cultivation using the heating network.



112



Figure 113. Side view of the tomato plants under greenhouses.

Figure 114. Details of crops on the flange of the artificial substrata.

Figure 115. Side view of the eggplant crops on artificial substrata.

Figure 116. Cherry tomatoes, Cocktail variety at two levels of maturity.



114



115



116





Figure 117. Equipment for the manufacture and printing of the carton paper packages for produce to be exported.

Figure 118. Weighting and ticketing produce for exportation.



Figure 119. Tomato and eggplant boxes packaged and ready for export.



Culture	Rendement	Prix de vente moyen
Cocktail Tomato	15 Kg/m <sup>2</sup> or 150 tons /ha	2 Euros/kg
Cherry Tomato	32 Kg /m <sup>2</sup> or 320 tons/ha	1 Euro/kg
Eggplant	20 Kg/m <sup>2</sup> or 200 tons/ha	0,8 Euro/kg
Cost of production per m <sup>3</sup> of desalinated water	0,625 Tunisian Dinar or 0,325 Euro	
Water use efficiency ( productivity of one m <sup>3</sup> of water)		
	Water use efficiency	Benefit per Kg
Eggplant	40 Kg /m <sup>3</sup> water	Production cost per Kg = 1,145 Sale price per Kg = 1,6 DT Benefit/Kg= 0,455 DT
Cherry tomato	21,3 Kg /m <sup>3</sup> water	Production cost per Kg = 1,3 DT Sale price per Kg = 2 DT Benefit/ Kg = 0,7 DT
Cocktail tomato	15 Kg /m <sup>3</sup> water	Production cost/Kg= 1,75 DT Sale price Kg = 4 DT Benefit = 2,25 DT

Table 26. Performances techniques et économiques du pilote 7.

These exceptional technical and economic performances were presented to the participants of the First Regional Workshop on the pilots held on June 5, 2012 in Medenine and the pilot site. Obviously, most of the visitors were very satisfied with this demonstration. These results prove that it is indeed possible, after desalination of the water resources available, to value to the best possible this scarce resource by means of a reasoned intensification of the cropping system. Indeed, these performances are higher to those produced by small farmers in the region who practice a similar ground cropping irrigated directly with brackish non desalinated geothermal waters, in small greenhouses (with all the constraints linked to the negative impacts of salinity on soil and crops on the one hand, and yield losses caused by pests and diseases, on the other ...). However, despite the performance of this hyper-intensive :

- the conditions, structures and replication prospects of this production system by the community of farmers practicing this hyper-intensive system of geothermal greenhouses;
- the environmental impacts associated with the discharges brines resulting from water desalination in natural hosts;
- the sustainability of this culture system compared to possibility of loss of export

markets in case the local market is not able to absorb all the produce at high prices to ensure the profitability of these high added value crops.

### **8.3. Activities carried out during the second year 2012-2013**

The cultivation plan for this second year was the same as in the previous year. The only important difference is the introduction of new tomato varieties to test their behaviors and qualities. The picture 120A shows one of those varieties.

## **9. Conclusion**

The theme of this pilot is of unquestionable strategic importance at the technical, environmental, social and economic levels for the development of the populations living in the SASS zone, especially as the latter is extremely rich in terms of infinite potential in solar energy resources, which can be eventually put to use for the desalination of brackish geothermal waters. The results obtained at all levels for two consecutive years are edifying and draw attention. It is important to place them in their context and reflect on the possibilities of their replication in other Libyan and Algerian contexts.

Technical performance is remarkable; it could even improve with extended crop cycles. Current yields are on average 250 tons ha for tomatoes and 300 tons for eggplant.

The efficiency of the use of irrigation water (25 kg tomatoes/m<sup>3</sup> of water) is higher in Tunisia, it is comparable to that achieved on the north shore of the Mediterranean, with the added benefit of a lower cost of production. This is what allows the export of almost all the produce to Europe.

Through the desalination of brackish water, it was shown how profitable the heavy investments in all segments of this sector can be. The success is such that farms are being extended over 32 hectares within the context of a Tunisian-Dutch private partnership. Replication potential of this production system meets all the conditions for sustainable local development are real and deserve to be used in both Libya and Algeria. As for Tunisia, it has developed the sector for over thirty years. Initially, they were heated off-season crops then heated with geothermal water in simple mono-tunnel greenhouses by smallholders. Later, following commercial success and after identification of the direct working limits of the irrigation water on the same land, the recourse to desalination of such water resources and off-season cropping gave unmatched performance. The area used initially by this cropping system in 1983 was 3 hectares spread over several smaller farms. In 2013, the area was 139 hectares spread over 54 small farms (1-5 simple greenhouses, 500 to 2.500 m<sup>2</sup> per cropper) and 5 large companies that operate dozens of hectares.



A



B

Figure 120. State of crops during monitoring visit Evaluation by Mrs. Kelly West from the GEF to the pilot on 26 May 2013.

Currently, there is a national strategy for the development of this sector over 180 ha. This raises the question of meeting the needs of this area in geothermal water resources and its fair allocation of the resource among smallholders and large corporations.

## IV. SYNTHESIS OF THE RESULTS OF THE PILOTS OF THE THREE COUNTRIES

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The evaluation of the technical, economic and environmental performance was carried out at several levels:

Internal assessments (self-evaluation) :

- at the local level, it is the local monitoring & evaluation committees established with the beginning of each pilot, that conducted this assessment based on the pilots results and their comparison with those of neighboring conventional farms. This assessment is the most significant because all members of these committees experience daily effected changes and assess the visible impacts on the behavior and life of the farmer.
- At the central level, the analysis of numerical results and their evaluation was entrusted to OSS based on indicators selected in advance in the project document. This assessment allows placing the results in their specific contexts and comparing them to identify the causes enabling the successes and constraints at the origin of potential failures.
- At the regional level, these performances were submitted to the discussion of the project steering committees and regional workshops dedicated to the pilot project component. For national water authorities, this assessment is rated as a strategic reflection on the relevance of the lessons of the results obtained in relation to broad national development policies of the SASS regions of the three countries. It is in this sense that the lessons learned from this reflection are stated as operational recommendations.

External evaluations: several evaluations of the project's products were reported by external evaluators to OSS.

At all these levels of evaluation, the verdicts are all positive. They can be summarized as follows:

- Farmers are very satisfied with the technical innovations introduced by the project and their economic and environmental impacts;
- Local decision makers of the various administrations in charge of water management and local development are convinced of the project's approach and relevance of the intensified cropping system trends to create jobs and engage a new dynamic of sustainable local development;
- National authorities have all reacted positively to the results and asked OSS to take the initiative to renew the project into a second phase in order to validate the performance achieved in sustainable agricultural production systems;
- The external evaluators also appreciated the approach in the dissemination of



agricultural technology progress through “pilot” demonstrations and considered the results recorded at the level of completed pilots as evidence of successful demonstrations, insofar as farmers, the most affected by changes introduced, are very satisfied with the immediate impact on the economy of their households and the future of their children.

Achievements and constraints encountered in their implementation are summarized in Table 27.

Pilot	Location	Theme	Realizations and constraints encountered
1	Reggane, Algeria	Restoration of the flow of the Foggara through solar pumping and renovation of the oasis cultivation system	Management, agricultural equipment completed, intensification of the oasis system Pumping station not installed yet
2	Touggourt, Algeria	Restoration of the soil quality through underground drainage of the soil and intensification of the oasis cropping system	Management, underground drainage, localized irrigation network, introducing intercropping
3	Essouani, Tripoli, Libya	Rationalization of the use of brackish water in irrigation	Pilot entirely realized with a balance of two consecutive years Labor constraint
4	Oued Zemzem, Libya	Valorization of geothermal water in irrigation	Pilot not developed for security reasons, replaced by pilot 7 in Tunisia on the theme
5	Kebili, Tunisia	Restoration of the quality of the soil through underground drainage network using discharge solar pumping, intensification of subsistence crops	Development, hydro-agricultural equipment entirely carried out, but the borehole collapsed. A New borehole has been developed in order to restart the pilot
6	Smar, Médenine, Tunisia	Desalination of brackish water and intensification of crops	Pilot entirely developed and perfectly operational
7	Chenchou, Gabès Tunisia	Valorization of brackish geothermal waters in irrigation	Pilot entirely developed and perfectly operational

Table 27. Summary of achievements and constraints.

We deduce from this table that all the targeted issues were dealt with. One of the six planned pilot has not been implemented in its site in Libya (O. Zemzem) for security reasons and was replaced by another site in Tunisia (El Hamma, Gabes). Two other pilots, Reggane in Algeria and of Kebili have not been completed for reasons of force majeure. However, initial results are very positive and augur, very significant technical, economic and environmental performance. They will be finalized by the local authorities as from the fall of 2014. The

other three pilots achieved and even exceeded the expected results at all levels. Table 28 evaluates their performance.

Pilot	Expected performances	Indicators	Targeted objectives	Performances achieved
1	<ul style="list-style-type: none"> <li>- Improving the satisfaction of water needs,</li> <li>- Intensification of cropping,</li> <li>- Improving croppers' revenues</li> </ul>	<ul style="list-style-type: none"> <li>- m<sup>3</sup>/ha</li> <li>- Improving the efficiency of water use</li> <li>- Improving croppers' revenues</li> </ul>	<ul style="list-style-type: none"> <li>- Inc. by 30 to 40%</li> <li>- Inc. by 20%</li> <li>- Inc. by 20-30%</li> <li>- Inc. by 20%</li> </ul>	<ul style="list-style-type: none"> <li>- Not realized pending the setting up of the solar panel</li> <li>- Yes, thanks to localized irrigation</li> <li>- Positive but not measured</li> </ul>
2	<ul style="list-style-type: none"> <li>- Improving the drainage of lands</li> <li>- Desalination of the soil</li> <li>- Intensification of the cultivation system</li> </ul>	<ul style="list-style-type: none"> <li>- Dropping hydromorphic level</li> <li>- Dropping salinity of the soil</li> <li>- Increasing the croppers' revenue</li> </ul>	<ul style="list-style-type: none"> <li>- Drop by 20-40 cm</li> <li>- drop by 30-50%</li> <li>- Inc. by 20-30%</li> </ul>	<ul style="list-style-type: none"> <li>- Drop by 30 cm in 2 months</li> <li>- Drop by 40% over one year</li> <li>- Revenues more than doubled and remain improvable</li> </ul>
3	Technical innovation to improve the valorization of water	<ul style="list-style-type: none"> <li>-Improving the croppers' revenues</li> <li>- Dropping salinity of the land and restoration of their fertility</li> </ul>	<ul style="list-style-type: none"> <li>- Inc. by more than 30%/year</li> <li>- Stabilization of the salinity at a level compatible with crops</li> </ul>	<ul style="list-style-type: none"> <li>- Revenue tripled</li> <li>Objective achieved</li> </ul>
4	<ul style="list-style-type: none"> <li>- Development of hyper-intensive geothermal greenhouse cropping</li> <li>- Control of the land salinization</li> </ul>	<ul style="list-style-type: none"> <li>- Setting up the greenhouses and transfer of the irrigation technology using hot waters</li> </ul>	<ul style="list-style-type: none"> <li>- 2,000 m<sup>2</sup> of greenhouses</li> <li>- Reducing water salinity and that of the soil</li> </ul>	The pilot has not been develop, see performance of pilot 7 that replaces it
5	Control of the hydromorphy, desalination of lands, and intensification of crops	<ul style="list-style-type: none"> <li>- Dropping level of the water table</li> <li>- Dropping salinity of the soil</li> <li>-Inc. revenues</li> </ul>	<ul style="list-style-type: none"> <li>- 20-40 cm in the 3rd year</li> <li>- 25-30 %</li> <li>- 20-40%</li> </ul>	<ul style="list-style-type: none"> <li>Performance achieved since the first year</li> <li>Drop by 40 % in two months</li> <li>Not developed because of the water supply from the borehole</li> </ul>

.../...

6	- Control of water salinity in irrigation and intensification of crops	- Water desalination - Inc. yields of the crops - Improving revenues of the croppers	- Salinity less than 1 g/l - Inc. by 50 % - Inc. by 20-40 %	- Desalination successful and obtaining different water qualities (1 g/l and 1,5 g/l) - Yields more than doubled for all crops - Increase by more than 100%
7	Innovation of crop intensification irrigated with desalinated geothermal water	- Inc. in efficiency of water use in irrigation - Inc. croppers' revenues - Control of environmental impact	- 60-80% - Salinization process entirely stopped	- Excellent technical and economic performance exceeded set objectives - Demonstration provided with desalination of water and soil-less culture

Table 28. Evaluation of the performance of the pilots.

Pilot	Agricultural results	Economic results	Environmental results
1	Visible improvement of the subsistence crops using just limited water resources, pending the supply of additional pumped water using solar energy	No figures provided, but there is a great satisfaction and big hope of the croppers to do better with expected additional water resources provided by the solar pumping station	No new impact
2	Visible increase in the yields and the quality of dates in the pilot plot in comparison with the control plot, intensification and diversification of vegetable and animal produce	Receipts from sales of dates of the first crop doubled, increase in yields of annual crops and success in poultry production  Croppers' revenues improved	Visible efficiency of the underground draining and efficient desalination of superficial layers of the soil
3	Mitigated results of the 1 <sup>st</sup> year because of the damage to the crops  Excellent yields for all the crops during the second year	Economic results of the first year were null  Economic balance of the 2 <sup>nd</sup> year was highly positive with significant improvement of the croppers' revenues	Control of soil salinization

5	The water failure caused the total suspension of irrigations, therefore no yields, but the efficiency of draining and solar pumping was excellent	No economic balance	Excellent results with significant decrease of the level of the water table and significant decrease in the soil salinity
6	Important improvement of the desalinated water use, high yields	Economic profitability of the desalination guaranteed during the two consecutive years, even when taking into consideration the amortization of installed equipment, including the desalination plant	Total absence of negative impact on the soil
7	High efficiency of the geothermal desalinated water used in irrigation	High profitability of the heavy investments approved and important profit guaranteed. High employability of managers and labor	No salinization of the soil because of non-soil cropping

Table 29. Evaluation of the technical, economic and environmental results of the pilots.

## V. GENERAL CONCLUSION

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The specific objective of the «demonstration pilots» component was to demonstrate the feasibility of changing the behavior of primary water users, i.e. farmers, compared with the objective of improving the management of this resource at the level of their plots to improve efficiency, increase yields, and returns on new investments needed to improve the income, educate and train social actors and preserve the natural resources against all forms of degradation.

This component was implemented largely in accordance with the project document. Two cases of force majeure have hindered the completion of the action plans defined for two pilots, one in Algeria and one in Tunisia. Pilot 4 planned in Libya was replaced by the Pilot P7 on the same theme in Tunisia.

All treated themes were found to be representative of the main technical constraints to maximize SASS resources. Therefore, the results obtained in the various plots, after two consecutive years, could be relevant answers to the issues raised by the national water authorities (ANRH, GWA and DGRE).

The results obtained in the four completed pilots, at the technical, economic and environmental levels are edifying. They have captured the interest of all direct visitors to the pilots and all those who participated in the various dissemination events or evaluation of these results. They received positive assessment, both internally and externally, and have been deemed capable of opening up promising prospects to reverse degradation trends and the decline of irrigated agriculture in many parts of the SASS zone and for sustainable local development.

The two unfinished pilots, the efficiency of hydro-agricultural infrastructure in place and the first results of intensified cropping systems bear good signs as to the relevance and viability of the innovations introduced by the project. Local authorities are committed to continue the project as they restore the supply of irrigation water as provided by the project.

The project shows mainly that an efficient new irrigated agriculture is possible in this region, an agriculture that reconciles all sustainability attributes: a sufficiently productive intensive agriculture to ensure a better life for local people, and with the maintenance and consolidation of community social organizations, and in synergy with the natural, social and economic arid and desert environments that predominate in the SASS zone.

However, all performances should necessarily be validated in agricultural demonstration pilot production systems integrating all the structural constraints that can hamper replication of such intensive culture systems whose effectiveness and efficiency were highlighted by this project. The three countries unanimously agree to engage in a new project in this direction and asked OSS to design this project, to define the objectives, approach, resources and time and finalize it with the National water authorities.





# OPERATIONAL RECOMMENDATIONS

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for an efficient management of irrigation water in the SASS zone

## 167 INTRODUCTION

- 167 Objective of the operational recommendations
- 167 Recipients of the operational recommendations
- 168 The targeted areas of action
- 168 Capitalization of results
- 168 Lessons learned from the results

## 171 OPERATIONAL RECOMMENDATIONS

- 171 Recommendations at the institutional level
- 171 Recommendations in the technical field
- 173 Recommendations on the socioeconomic issues
- 176 Recommendations in the environmental field





## 1. INTRODUCTION

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This report provides recommendations based on the results and lessons learned from the pilots. Aspects related to the improvement of water management at the level of water supply and mobilization on the one hand, and the improvement of the efficiency of the transfer and distribution of resources from the water points to the farm (control of water losses) are not included in this report.

The approach to the design and formulation of these recommendations is based on the following:

- a clear definition of objectives;
- targeting recipients actors;
- the targeted area of intervention;
- capitalization of results;
- taking into account the strategic lessons of the results.

### 1. Objective of the operational recommendations

These OR target the operationalization of technological innovations tested in the pilot, proven effective and validated by the water stakeholders and external assessors. This is to initiate a process of change in the behavior of farmers for a better management of the resource at the farm and the establishment of a process of sustainable local development.

### 2. Recipients of the operational recommendations

Improving the management of irrigation water requires the contribution of the entire chain of actors involved who represent decision-making centers in the mobilization of water resources and their utilization. These include:

- the consultation mechanism established by the three countries and responsible for the sharing of knowledge and information on the SASS, its management and its evolution;
- the countries represented by their focal points, namely ANRH in Algeria, Libya and the GWA DGRE Tunisia. In each of these countries, other actors at central and local levels have key roles in the management of water and irrigation development. They are directly or indirectly affected by the recommendations.
- Farmers who are at the heart of the problem of irrigation in the SASS zone, part of the problem but at the same time at the heart of the solution to.
- OSS as an implementing entity of the project, as far as it is solicited to prepare a

new project for the validation of the results obtained in the pilots and to the extent that it hosts to the Coordination Unit of the Consultation Mechanism.

### 3. The targeted areas of action

Improving water management at the level of the farm can be achieved through the adoption of new measures/tools in:

- the institutional area;
- the area of agricultural and energy technologies;
- socio-economic area;
- the environmental field.

### 4. Capitalization of results

In the pilots, the ability to operate and manage water other than by traditional methods has been demonstrated, with technical efficiency and a clearly better economic value, with the conservation of the integrity and quality of both the water resources and the soil.

As these results were obtained without taking into account the structural constraints of the regions, it is strongly recommended that before adopting them, they must be tested and validated in agricultural demonstration pilot production systems that integrate all the components of the socio-economic environment (markets, agricultural services, access to bank loans, availability and cost of labor).

The three countries are already convinced of the need for the establishment of these pilots and their sites have already been identified by the local national technicians. It is within this perspective that the operational recommendations are proposed in this report.

### 5. Lessons learned from the results

We can classify the main lessons into three categories:

#### **5.1. Lessons on the “demonstration pilots” concept and the participatory approach for its implementation:**

The “demonstration pilots” concept proved very relevant in the search for proximity pedagogy to trigger a radical change in the behavior of the primary user of water. The demonstration of this change is made by croppers themselves at home and with their own financial contribution. It is a guarantee of credibility for the community of neighboring farmers and even planners who set policies, guidelines, incentives and strategies for farmers.

The choice of the farmer as a decision-making center to trigger initiatives and the desired change in the parameters of the productivity of irrigation, natural resource conservation and improvement of the cropper's living conditions also proved very productive. The success is such that social demand, local and even at national level, is continuously being expressed and taking momentum with local governments to extend the pilot action plans to the surrounding farms.

## **5.2. Lessons learned related to technical innovations to improve the water efficiency:**

- The farmers showed ability to learn new agricultural techniques in all the pilots, croppers have shown a remarkable ability to learn, adopt technical innovations and change behavior to produce more and better with less water or same quantity of water. The fact that they have financially contributed to the pilot during the first year is another factor that has strengthened their commitment to success. The first positive results at the end of the first growing season encouraged them to invest the profits earned in order to intensify their crops or expand acreage with the water available.
- The choice of a rational intensification of the cropping systems has led to rapid achievement of the objectives assigned to these pilots, namely: to increase water efficiency, improve the income of farmers and preserve water resources and protect the soil against degradation. The rational crop intensification has helped go beyond the traditional oasis systems of the vicious circle of land degradation, water shortages, farmers impoverishment and ultimately the divide between the oasis society and the oasis that has become incapable to support its population; the latter being compelled to adopt a new strategy and way of life ... More than that, this openness to rational intensification is achievable even at the level of small farms, where the family labor is often more available than in other contexts.
- Among the technologies introduced:
  - ▶ some were already known and practiced in the three countries but in other regions : the case of chemical fertilizers and preventive and curative phytosanitation; they were introduced and adapted to the context of the pilots and were rapidly adopted by the croppers after seeing their positive impacts;
  - ▶ others were unknown such as the desalination of brackish water for irrigation, the use of solar energy for pumping, underground drainage networks, composting vegetable waste...

Adapted to the needs of the cropping systems, these techniques have proven very efficient over the duration of the project. Their adoption at large scale, after validation at the level of the pilots' production system, seems inevitable. They open

up promising prospects for the development of irrigation in the SASS zone. Obviously, their systematic and blind generalization is excluded. It is important to consider the earlier natural and socio-economic contexts of each region and prepare the general solutions to their potential and constraints.

- The reputation of farmers who categorically refuse to pay water at its actual cost proved false, at least for intensive culture systems (P2, P3, P6, P7) capable of valorizing to the best possible this rare and expensive resource and make it profitable enough to generate attractive gross margins. This result confirms the findings of the second component “socio-economic and environmental surveys on SASS farms,” that there is a significant margin of elasticity of the ability of operators to pay more expensive water (2 to 3 times its current price) in intensive farms.

## 2. OPERATIONAL RECOMMENDATIONS

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### 1. Recommendations at the institutional level

#### 1.1. Recommendations to the Consultation Mechanism

This mechanism should assist countries in applying recommendations in order to ensure the convergence of governance of irrigation in the three countries.

##### a. Creation of a national coordinating, monitoring and evaluation body in each country

In all the three countries, there are many direct and indirect actors in the field of water and irrigation. These actors manage respectively segments of the sector, sometimes with little coordination. To succeed in implementing the desired change for an integrated management of the water resource in the three countries, it would be helpful if each country created a national authority to undertake the task of coordination, ensure consistency of the various roles, approaches and means, and ensure the monitoring and evaluation of the operation of SASS and its valorization in local development.

This body would not necessarily be a new administrative structure but rather an annual council consisting of representatives of the various administrations, national agencies and nongovernmental organizations in charge of various aspects of SASS water management and development to prepare annually the inventory and state-of-art in the mobilization, operation and efficiency of SASS water in irrigation, with socio-economic and environmental impact based on development and environmental indicators used in each country.

For its part, the consultation mechanism could help to standardize national indicators for SASS monitoring and evaluation and propose a list of common relevant indicators.

On this basis, the council will be entitled to propose the necessary recommendations to improve the effectiveness of the various actors to achieve the overall objectives of irrigation.

An annual report could be produced by each country's Council; the Consultation Mechanism, through its Coordination Unit, could generate an annual general summary on irrigated agriculture in the SASS region, its performance and impacts.

##### b. Capacity building of the water managers and agricultural extension

Countries should focus on training the various professions of the water stakeholders at national and local levels, in relation to:

- new technologies of water production or mobilization, including renewable energy;
- community management of water in the new intensive agricultural production systems.

### **c. Dissemination of the “agricultural demonstration pilot” concept**

This concept developed within this project should be the subject of formalization at the level of the Consultation Mechanism and wide dissemination at the country level in order to be developed as a popular tool of agricultural technical extension in the various SASS regions, knowing that because of remoteness, SASS irrigated areas often neglected by extension services.

### **d. Support of countries in the replication of their respective pilots in their respective SASS regions**

The three countries widely agreed on the need to replicate the pilot cropping system as described in this report. The Consultation Mechanism should support and monitor these countries to develop their pilots and strengthen the necessary synergies between countries for the benefit of their experiences and respective results in the field.

## **1.2. Recommendations to the focal points of the countries**

These recommendations are variations on those addressed to the Consultation Mechanism.

### **a. Adaptation and implementation of operational recommendations to the Mechanism**

Countries should be involved in the adoption, adaptation and implementation of operational recommendations validated by the Consultation Mechanism, particularly with regard to the implementation of cropping systems demonstration pilots.

They are called to participate in the development of the new project on the replication of the pilot with OSS. Their contributions to the design of this future project will guarantee its successful implementation.

### **b. Adoption and implementation of the program to improve national capacity**

The renovation of irrigated cropping systems requires training and updating technicians and policy makers at the technical, economic and environmental levels.

Concerning the program to improving the capacity of water managers, it is up to the countries to adopt the broad outline of the program, adapt it to their needs and resources and implement it. Special support should be devoted to community organizations at the local level.

**c. Design a new strategy to consolidate the social organizations** in charge of the management of the existing irrigation water in the SASS regions and support (legal, accompanying measures...) for the creation, as requested by the recipients, of new mutual agricultural services organizations. These cooperatives are expected to play a key role in the agricultural economy of the SASS zone.

### **1.3. Recommendations to the farmers' community**

In many cases, existing community organizations lost the effectiveness of their roles. The renovation of irrigation in the SASS area could not be sustained without the consolidation and the support of the administration. It is therefore important that farmers' communities seize the opportunity of the implementation of the national consolidation strategy of these organizations. Awareness workshops at the local level would allow the mobilization of farmers for their involvement in the process of renovation or creation of their community organizations.

## **2. Recommendations in the technical field**

These recommendations focus on the technical aspects of land development, hydro-agricultural equipment and techniques for crop intensification.

### **2.1. Recommendations to the Consultation Mechanism**

Given the speed with which are produced and applied new agricultural intensification technologies, it is recommended that the Coordination Unit of the consultation mechanism develop a technology watch on all areas of research related to farming systems in the arid and desert regions. This watch could be achieved with the support of a team of researchers from specialized national institutions that would be responsible for producing a report for countries every two years, with proposals on possible applications of the innovations developed.

### **2.2. Recommendations to countries**

#### **a. Consolidation of agricultural extension systems**

Agricultural extension systems in the three countries are sometimes inefficient in the SASS zone. It is of the utmost importance to boost existing systems or create them with substantial support given the remoteness of areas affected from the sphere of public or private extension action. A workshop dedicated to the renewal of extension systems in the SASS area for the benefit of the three countries could be the beginning of a reflection on this theme.

#### **b. Implementation of the agricultural demonstration pilots in production systems**

After validating the results obtained during the last workshop of the Steering Committee, Countries should consider the development of a program for the implementation of agricultural demonstration pilots that concern them, in consultation with the Consultation Mechanism.

It is understood that these pilots will have area scales that vary according to the topics addressed. These scales should correspond to operational hydro-pedo-agricultural units (water, drainage ...). On this basis, the main features of the pilot design are:

- For the theme of pilot 1 on safeguarding the irrigated oasis system of the foggaras (Tuat region, Gourara, Tidikelt), the area unit capable of integrating the operation of the oasis production system is a whole oasis with all the exploited water resources. This oasis could be that of Ksar Ait Messaoud near Reggane. In this case, the oasis will be considered with all the foggaras that supply it with water, the community management mode as well as the community's rules for the sharing and management of this resource. Indeed, the current situation of this oasis is very complex and the pilot of this project consists only of five cultivated plots. The pilot implementation does not incorporate this complexity and it is essential to ensure the reliability of the technical solutions taking into account other structural dimensions in the management of irrigation water. For example, improved yields of some crops have resulted in the emergence of marketing problems at the local level. If we consider this issue at the scale of an oasis, it would be possible to solve it through the pooling of the transport service and marketing of the produce outside the Reggane region. The same would be applicable to the difficulties in the supply of essential agricultural inputs (fertilizers, pesticides...).
- For pilot 2 (Touggourt, Valley of Oued Righ) whose theme is the restoration of land quality and renovation of the cultivation system, the suitable area scale for the reliability of efficiency of the underground drainage within the plots can only be a an operational hydro-soil spatial unit with several irrigated farms connected to an external efficient open drainage network, supplemented by an underground drainage system across all the farms. This unit should be at least one area of the oasis of Sidi Mahdi, or the equivalent in terms of area with the same problem of poor drainage and soil salinization.

In addition, this sector should be located in the upstream part of the Oued Righ valley, where farms drainage water could flow by gravity to the water collecting channels of the external community network. We must keep in mind that in the downstream section of Oued Righ valley, the evacuation of farm drainage requires pumping and discharge of this water, given the very low slope.

Furthermore, to integrate this pilot in the context of the entire hydrology of Oued Righ, it is strongly recommended to capitalize on the results of the pilot 6 realized in Tunisia on desalination of brackish water for irrigation, and adding to the future pilot a desalination station of the oasis drainage water. The desalinated water could be used for irrigation of a new neighboring culture system outside oasis with high-value crops. Another option for the reclamation of the good quality water would be mixing it with brackish water used to further improve yields and quality of productions.



- For pilot 5 (located in Kebili in Tunisia), facing the same problem of poor drainage and soil salinization, the operational unit should also be a water-soil system, an oasis or a sector of the oasis area located in a low zone (edge of Chott), suffering from waterlogging. This pilot is already benefiting from a public drainage system outside the farms (similar to that developed within the APIOS project) but requiring the installation of a buried drainage network inside the farms and pumping /discharge of inner drainage water to the outside network. The pump should be solar.
- As for the replication of pilot 6, whose theme is the desalination of brackish water for irrigation; two options of cultivation systems are available with different spatial scales:
  - ▶ option1: irrigated olive monoculture system: in this case, the operational unit of the production system should be one or more adult contiguous groves, with an area of several dozen hectares (50 to 300 hectares), depending on the flow of brackish water available;
  - ▶ option 2: mixed Intensive cropping system (olive trees and vegetable intercropping) with several small farms benefiting from the same water resource within a community framework or individual private water points. The total area should be a few dozen hectares.

In either option, it is important to integrate the issue of disposal of waste water from desalination plants, their transfer in impermeable pipes over long distances and their discharge into a natural saltwater host, after authorization by the relevant authorities. This issue should be addressed in all its technical, financial, environmental, institutional and economic dimensions. Its cost, its financing and its implementation should be analyzed to achieve operational solutions.

- As for pilot7, whose theme is the development of geothermal water for irrigation of a hyper-intensive cropping system, it been confirmed as a production system. It must be operated as such in its technical, economic, social and environmental dimensions and assessed in case of possible replication in other Algerian and Libyan contexts.
- Compared to pilot 3 in the Libyan Jeffara, whose theme is the development of an intensive cropping system using brackish waters, its area remains dependent on the flow and quality of the water that will be mobilized. If the water has a salinity exceeding the level tolerated by the proposed crops, it is appropriate to draw lessons from the success achieved in pilot 6 in water desalination in Tunisia and test it in the Libyan Jeffara, targeting an Intensive cropping system to meet the high demand of the Libyan market for garden produce.

### 3. Recommendations on socioeconomic issues

In order to ensure economic sustainability, it is important to ensure the profitability of investment for the adoption of technical innovations and generation of sufficiently high gross margins. This will motivate local people, especially young people to stay on their land and invest in it. All stakeholders will have complementary roles to play.

#### 3.1. Recommendations to the Consultation Mechanism

The Mechanism should assist countries in developing policies and strategies to encourage intensified cropping and the use of new agricultural techniques benefiting croppers and their convergent implementation. This support can take various forms such as the identification of actions to be undertaken, training policy makers in controlling commercialization by community organizations.

#### 3.2. Recommendations to countries

To protect farmers economically, countries should, within their respective strategies, adopt measures of various kinds (legal, social and financial) to encourage croppers to adopt technical innovations that are likely to increase yields and enable the optimum valorization of water and ensure therefore higher gross margins of their cropping systems.

### 4. Recommendations in the environmental field

These recommendations are related to the monitoring and evaluation of the environmental impacts of the SASS operation, irrigation and crop intensification on all components of the oasis, arid and desert ecosystems.

#### 4.1. Recommendations to the Consultation Mechanism

The Mechanism should establish a grid of relevant state-pressure-action indicators to be proposed to countries. A workshop could be held with country specialists to capitalize on achievements and develop a draft grid and a dashboard on the state and development trends of the SASS and its impact on the farm.

#### 4.2. Recommendations to countries

Countries are encouraged to support the mechanism in the construction of this grid of indicators and to develop their dashboards that are adapted to their context. They should also involve farmers in the collection of information and data relating to negative impacts on water and soil resources.





## SASS III

## AGRICULTURAL DEMONSTRATION PILOTS IN THE SASS BASIN

The North-Western Sahara Aquifer System (SASS) is a basin of over 1,000,000 km<sup>2</sup> shared by three countries (Algeria, Tunisia, Libya) whose water reserves are substantial with an almost fossilized aspect.

The implementation of “Agricultural Demonstration Pilots” within the framework of the SASS III project was intended to demonstrate within a participatory approach, the feasibility, effectiveness and efficiency of technical solutions to local problems of unsustainability management and operation of the SASS resource in irrigation in the three countries sharing the resource.

Six agricultural demonstration pilots at farm scale level, with different themes, were implemented by farmers themselves in the three countries. The technical innovations introduced aimed at the intensification of cropping systems, water saving and the improvement of the resource’s valorization through the selection of high added value crops.

The results obtained after two crops in the three countries help confirm the availability of efficient technical solutions for the renovation of cropping systems and making them viable at farm level. What remains to be done, however, is validating these results and making them reliable on a larger spatial scale in pilot “production systems” integrating the various local structural constraints to the development of irrigation in the SASS area.



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