Tunisia

Cost assessment of water resources DEGRADATION

OF THE MEDJERDA BASIN

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.....Water is too precious to Waste

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Exchange rate:
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$EU 1 = Tunisian Dinar (DT) 1.573 (September 2012)
Source: <www.oanda.com>

ACRONYMS

B/C............................ Benefit/Cost Ratio
ANGed..........................National Agency for Waste Management
ANPE............................National Agency for Environmental Protection
BA .... Benefit Assessment
C/P............................ Costs/profits
CE .... European Community
CH_4 .... Methane
CO_2 .... Carbon dioxide
COPEAU.......................Water Pollution Control Network
CRDA............................Regional Committees for Agricultural Development
DBO_5 .... Biological Oxygen Demand
DCO .... Chemical Oxygen Demand
DGACTA.......................Directorate General for Development and Conservation of Agricultural Land
DGBGTH.......................Directorate General for Dams and Hydraulic Works
DGF..............................Directorate General for Forests
DGGREE....................... Directorate General for Rural Engineering and Water Exploitation
DGPA............................Directorate General for Agricultural Pesticides
DGQEV.........................Directorate General for the Environment and Quality of Life
DGRE............................Directorate General for Water Resources
dS/m .... deciSiemens per metre
EPA .... USA Environmental Protection Agency
EUT .... Treated wastewater
FAO .... Food and Agriculture Organisation
g................................ gram
GEG .... Ghdir El Golla complex
GES .... Greenhouse gas emissions
GIZ .... Gesellschaft für Internationale Zusammenarbeit (previously GTZ)
ha .... Hectare
INAT.............................National Agronomic Institute of Tunisia
KfW........................... Kreditanstalt für Wiederaufbau
kg.............................. Kilogram
km .... Kilometre
km^2 .... Square kilometre
m .... Metre
m^2 .... Square metre
m^3 .... Cubic metre
MdA.......................... Ministry for Agriculture
MdE .... Ministry for the Environment
MdSP .... Ministry for Public Health
ODESYPANO...............Office for Sylvo-Pastoral Development of the North-West
ONAS...........................National Office of Sanitation
OMS.......................... World Health Organisation (WHO)
GDP .... Gross Domestic Product
PISEAU.........................Investment project in the Water Sector
SIG .... Geographic Information System
SECADENORD..............Association for the Exploitation of Canal and Water Supply Systems of the North
SONEDE .... National Association for Water Exploitation and Distribution
STEP **........................** Wastewater Treatment Plant
TEEB **........................** The Economics of Ecosystems and Biodiversity
IRR .... Internal Rate of Return

UE............................ European Union
NPV .... Net Present Value
VET.......................... Total Economic Value
VVL.......................... Value of a statistical life
WFD .... EC Water Framework Directive

Executive SUMMARY

With a population of 10.6 million (2011) and a Gross Domestic Product (GDP) of 63.4 billion DT in 2010, Tunisia's water allocation is estimated at 472 m^3/inhabitant, which will drop to 315 m^3/inhabitant in 20 years' time, thus being among the 17 countries most stressed for water. The Tunisian natural resources are limited inquantity and, partly, in quality and in actual potential for exploitation. However, since the late 80s, Tunisia has accomplished important results in the area of water resource mobilisation, water and soil conservation, the fight against erosion, and full access to drinking water reaching almost 100% in urban regions and 94% in rural regions, while access to urban sanitation is 99% with rural areas, showing a mere 5% of effective access to sanitation.

Since 1999, Tunisia has adopted a water resource strategy primarily addressing the mobilization of supply and demand management. The State has implemented this strategy through a ten-year programme (2001-2011), built around three specific pillars: (i) integrated management and conservation of water resources; (ii) economic efficiency of water use in agriculture; and (iii) institutional restructuring and capacity building in the water sector. Since the Revolution in January 2011, through the Ministry for Agriculture, the new Government has focused on issues of employment, development and directing its interventions to the less privileged and disadvantaged regions, and on the other hand participatory management of the natural resources of the watersheds in these areas. In the latter, more specific prioritisation may be identified based on the cost and profit of interventions whereby sustainable water management is a critical component in reducing poverty, especially in rural areas.

As part of this general context, this regional study refers to the degradation cost of water resources at the watershed level, being supported by the SWIM-SM regional program, funded by a European Union financing totalling 7.0 million Euros.One of five components of this project is the improvement of water governance and integration of water issues in sectoral policies such as policies in agriculture, industry, tourism, etc. This aims at making water an important element in policies and national development strategies. While water problems and their economic effects have been assessed at the national level, much less is known at a more detailed watershed level as no accurate identification of problems and valuation of the associated costs of degradation have been undertaken so far. However, it is at the basin level that decisions have to be taken as to water resource management and protection. This would enable local institutions to have the required tools and being able to discuss on national and regional level based on costed policies required to reduce such costs.

Though its national focal point, Tunisia has asked for the SWIM-SM assistance in estimating the cost of water resource degradation in the Medjerda watershed. This basin was selected as a result of the following: (a) Medjerda is the longest river in Tunisia, considered to be the country's water tower, providing drinking water to more than 2.5 million inhabitants of the Greater Tunis and its Surrounds; (b) Medjerda crosses the six governorates of Beja, Jandouba, Le Kef, Siliana (all 4 are part of the North-West District) and Manouba as well as Ariana (these last 2 being part of the district of Tunis) whose character is rural and agricultural. These governorates are rich in natural resources, hold 75% of water reserves and include more than half of the country's forest areas; (c) The basin is facing a number of natural resource problems related to erosion, salinity, droughts, floods and siltation of dams as well as problems of agricultural, municipal and industrial pollution. It is thought to be a representative basin for a thorough analysis of costs and benefits related to the degradation and restoration of water resources in Tunisia.

The main objective of this study is to assess the cost of water resource degradation in the watershed of Medjerda. The expected results are: (a) an overview of the economic aspects of the Medjerda watershed management problems; (b) a cost assessment of water resources degradation; (c) an economic analysis of certain alternatives; and (d) specific recommendations in order to integrate the benefits for the environment and improve the management of this basin.

The results of the Medjerda degradation cost are shown in Table 1 and Figure 1. Note that the total cost for Medjerda and Grand Tunis is compared to the Tunisian GDP (63.4 billion DT in 2010) while the Medjerda Basin cost (intra-muros) is compared to the Medjerda GDP (5.8 billion DT in 2010) extrapolated using the GDP per inhabitant of the Medjerda basin (4,058 DT/inhabitant in 2010) and then multiplying with the number of inhabitants. The disaggregated results are available in Annex VI.

For Medjerda and The Greater Tunis, this cost reaches 214 million DT in 2010 ranging from 149 to 324 million DT on average equivalent to around 0.34% of the current GDP but 0.85% of the constant GDP (as compared to 2000) of Tunisia in 2010. As concerns Medjerda, the degradation costs are 192 million dinars in 2010 ranging from 132 to 296 million DT on average, equivalent to around 3.3% of the Basin region GDP. The cost attributable to human health is 81 million DT in 2010 or 42.5% of the degradation cost of Medjerda and 63% for the water category (Table 1 and Figure 1).

Table 1: Degradation cost for Medjerda and Greater Tunis, 2010 in million DT

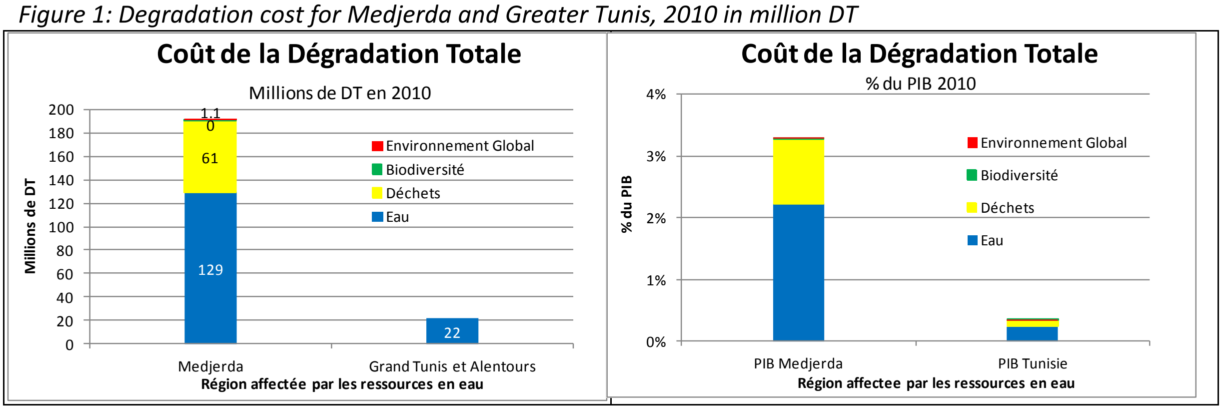
Categories	Medjerda	%	Minimum	Maximum	Greater Tunis	Minimum	Maximum	Total Medjerda and Greater Tunis	%	Minimum	Maximum
Water	129.5	68%	99.1	164.5	22.3	17.5	28.1	151.8	71%	116.6	192.6
Waste	60.5	32%	32.1	131.3	-	-	-	60.5	28%	33.7	130.9
Biodiversity	0.5	0%	0.4	-	-	-	-	0.5	0%	0.4	-
Natural disasters and General environment	1.1	1%	-	-	-	-	-	1.1	1%	-	-
Total	191.5	100%	131.6	295.8	22.3	17.5	28.1	213.9	100%	149.1	323.9
% GDP Medjerda	3.3%		2.3%	5.1%							
% GDP Tunisia								0.34%		0.24%	0.51%

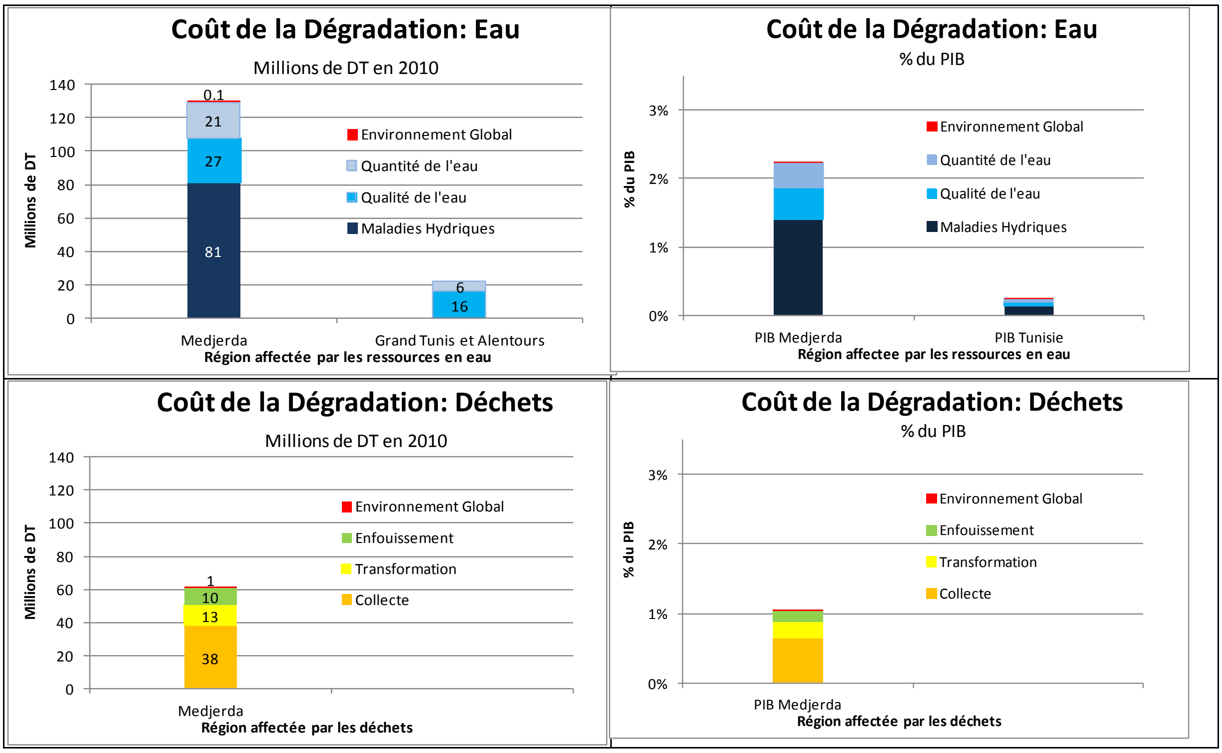
Source: Authors.

Broken down by category, water degradation is the highest in Greater Tunis and Medjerda in relative values, with 68% of the total in 2010. Waste, which is simply covered in Medjerda, come in second place with 32% relatively, biodiversity with 0.01% and overall environment with 1%. There were no natural disasters in the Medjerda basin in 2010 and therefore they have not been taken into account in this assessment.
Broken down by the water subcategory (130 million DT in 2010), waterborne diseases account for the majority of costs in the Medjerda Basin (81 million DT) followed by water quality (27 million DT), the water quantity (21 million DT, relatively low because 2010 was a favourable season) and finally the overall environment (1 million DT).

Broken down by the waste sub-category (61 million DT in 2010), collection represents the majority of costs in the Medjerda Basin (38 million DT), followed by waste processing (13 million DT), landfills (10 million DT) and finally the overall environment (1 million DT).

Figure 1: Degradation cost for Medjerda and Greater Tunis, 2010 in million DT





Source: Authors.

The cost estimate of water resource degradation has resulted in the following conclusions:

a) The cost of water salinity (11 million DT) within and beyond the Medjerda basin is almost equal to the salinity cost in agricultural production (12.3 million DT) within the same basin.

b) Damage due to lack of access to drinking water and rural sanitation (81 million DT) in the Medjerda basin is significantly higher than damage due to drinking water salinity.

c) Poor collection and lack of solidwaste treatment result in less important damages (61 million DT) than those due to lack of access to safe drinking water and sanitation in rural areas (81 million DT).

d) Damages affecting the River Medjerda water quality are less pronounced (17 million DT), which suggests that land-based pollution is not fully discharged into the river.

e) Damage created by erosion in dam siltation of dams are around 7.1 million DT, which may mean that dam silting may be the result of sediments in watersheds and not necessarily erosion of land sediments which do not always reach dam reservoirs. These damages are almost equivalent to soil nutrient losses due to erosion (7.4 million DT).

Based on these findings, four priorities emerge for the short- and the medium-term:

a) Treatment of drinking water salinity;

b) Sanitation in rural areas;

c) Solid Waste collection and treatment; and

d) Effectiveness of planning for dam siltation reduction.

Based on the priorities identified in the previous section, four intervention scenarios were considered but only three were implemented. Only drinking water salinity, water and sanitation in rural areas and waste management have been evaluated as categories. Interventions related to land use for erosion reduction and, thus, dam siltation have not been considered due to lack of studies establishing a causal link between land use and siltation reduction in order to perform economic assessment.

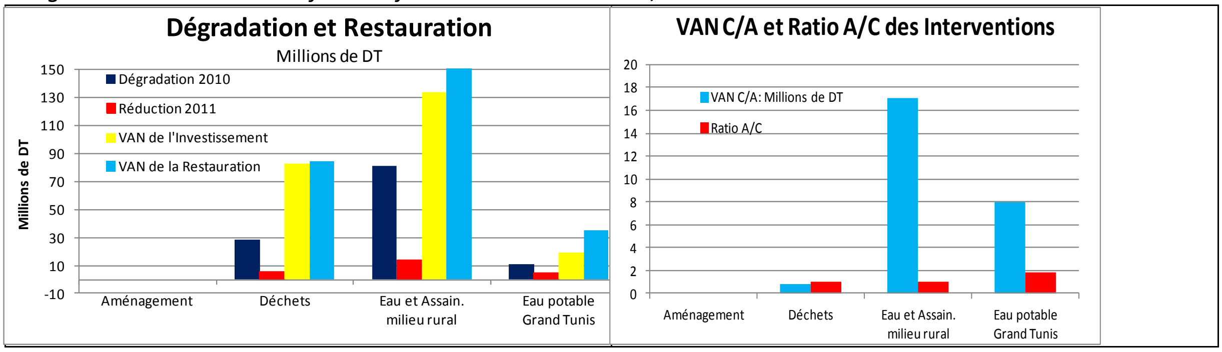
The most efficient scenarios were selected and shown in Table 2 and Figure 2. Concerning water and sanitation in rural areas, the combination of the *sanitation* scenario and the *drinking water and sanitation* scenario allows making the latter profitable. Concerning drinking water in Greater Tunis, desalination of part of the water resources in order to dilute the drinking water salinity is profitable. However, this alternative has not been compared to the cost of transporting water from the Barbara Basin dams, and it would become unprofitable if the threshold of 30,000 m^3/day over three months of desalination three months is exceeded. The strategic reserve of the Barbara Basin can ensure not only the safety of the resource, but also achieve water dilution when the salt content is high in summer, especially during dry seasons. For waste alone, any alternative to landfill with electricity generation in cells is profitable. The segregation and recycling alternatives are not profitable because they are too costly. Thus, to overcome this shortcoming, a multicriteria analysis could be considered for decision making with the focus not only on the C/A analysis but also on employment creation, poverty reduction, etc.

Table 2: Restoration cost for Medjerda and Greater Tunis, 2010 in million DT

Medjerda and Greater Tunis	Degradation 2010	Reduction 2011	Investment NPV	Restoration NPV	C/P analysis NPV
	Million DT	Million DT	Million DT	Million DT	Million DT
Planning	0	0	0	0	940-5,050 DT/ha 1,100-5,400 DT/ha
Waste	28.6	5.7	83	84	0.9
Water and Sanitation in rural areas	81.3	13.7	133.7	150.7	17.1
Drinking water in Greater Tunis	10.6	4.4	19	35	8.0

Source: Authors.

Figure 2: Restoration cost for Medjerda and Greater Tunis, 2010 in million DT



Source: Authors.

The mitigation cost analysis of three categories analyzed based on the net present value (NPV) of the investment over 20 years (24 years for waste) with a rate of 10% discount and internal rate of return (IRR), has identified the most efficient investments as follows:

a) For drinking water, desalination of 20,000 m^3/day over three months will have an NPV of DT 8 million and an IRR of 32% with an B/C ratio greater than 1.

b) Sanitation is profitable with or without drinking water and will create an NPV of 32 million DT with IRR 22%.**However, the water and sanitation combined matching investments are more profitable with an NPV of 17 million DT, an** IRR **of over 10% and a B/C ratio greater than 1.**

c) Transfer and disposal of municipal waste are only profitable if a transfer station and a landfill are established with power production from methane emissions in each governorate.These investments will have an NPV of 0.9 million DT, an IRR of 10% and a B/C ratio greater than 1.

Five intervention areas are proposed for the integrated and sustainable management of the Medjerda water resources underlying the recommendations of this study:

a) ***The gradual shift in the policy of intensifying natural resources exploitation*****,** especially through mobilization of water resources. This shift can be achieved based on criteria that explicitly include economic performance and degradation as well as the scarcity of the Medjerda Basin resources.

b) ***Focusing primarily on efficient investment for domestic pollution control in rural and peri-urban areas***that have been neglected in the past. The first priority would be for the State to invest in the expansion of drinking water and sanitation in rural areas of the basin where poverty is predominant, and for waste management to include not only a waste collection centre for each governorate, but also closure of illegal dumps.

c) ***Planning of upstream interventions that reduce dam siltation*** in order to conclude upon the determinants of siltation and assess with precision the impact of anti-erosion measures in relation to control and mobilization of surface water as well as adapt erosion control methods based on their effective use by farmers.

d) ***In partnership with water and environmental institutions, reorientation of a decentralized information network for continuous observation, tracking, monitoring of the environment and natural resources in the Medjerda basin*** aiming at understanding and assessment of the environment and its impact on health and degradation of the natural capital to contribute to decision-making based on accurate, regular data and information.

e) ***The establishment of horizontal action for overall, integrated water management in the Medjerda watershed.*** This group will aim firstly to develop expertise in the assessment of benefits and damages and water conservation, and secondly to provide advice regarding ways and means of integrating this aspect into sectoral development programs and strategies, and finally to implement a system of monitoring and evaluation for investments and activities in the Medjerda basin.

DEGRADATION AND MITIGATION COSTS FOR WATER RESOURCES IN TUNISIA: MEDJERDA BASIN

1. INTRODUCTION

1. With a population of 10.6 million (2011) and a Gross Domestic Product (GDP) of 63.4 billion dinars in 2010,[1] Tunisia still faces awatr allocation of estimated at 472 m^3/habitant which will decrease to 315 m^3/habitant in 20 years[2] ranking among the 17 countries most hydraulically stressed compared to a regional average of 1,100 m^3 in 2011 and a global average of 6,600 m^3.In addition, 4.5 million m^3 represent the Tunisian annual use of water resources, of which 2.7 million are surface water and 1.8[3]are groundwater resources.In addition, 75.63%[4] of water resources are allocated to agriculture and irrigation, to 12.81% water and 3.86% for the industry.The agricultural sector contributes about 10% of GDP and provides employment for 16% of the workforce and 27% of the rural labour. It is expected that demand will exceed supply in the coming decades while a reduction of about 6% of the rainfall nationally is forecasted during the same period due to climate change. These changes are already affecting the agricultural sector with consequences related to drought, necessitating rationing of water, flood or flash floods that have ravaged several villages.

2. The Tunisian natural resources are limited in quantity and, partly, in quality and in actual potential for exploitation. However, since the late 80s, Tunisia has achieved significant results in the mobilization of water resources, the conservation of water and soil, the fight against erosion, a full access of drinking water reaching almost 100% in urban areas and 94% in rural while urban access to sanitation is 99% albeit only 5% in rural areas.

3. The surface area of arable land per capita (less than 0.3 hectare) is among the lowest in the Mediterranean region - an estimated 4.2 million hectares of land are more or less affected by wind and water erosion, out of which 2.5 million ha have already been managed by water and soil conservation works, while between 0.12 and 0.14 million ha of irrigable land have been affected by more or less high salinization. Land at risk of erosion (3.54 million hectares) are mainly concentrated in the centre of the country (48%) and in the South (36%). Soil management is also connected to water resources and largely influenced by policies related to rural employment and food security. Over 4.7 million hectares of arable land - including from 0.38 to 0.40 million irrigable areas.Tunisia is subject to high land erosion and degradation, which is among the main causes of dam sedimentation estimated at 16-19 million m^3 annually[5] reducing their capacity by 0.8% annually.Mineral resources are also limited to only phosphates with a stagnant production volume around 6 million tons.

4. Since 1999, Tunisia has adopted a water resource strategy primarily addressing the mobilization of supply and demand management. The State has implemented this strategy through a ten year programme (2001-2011), built around three specific pillars: (i) integrated management and conservation of water resources; (ii) economic efficiency of water use in agriculture; and (iii) institutional restructuring and capacity building in the water sector**.**The Ministry of Agriculture (MoA) has initiated the preparation of the water strategy until 2050.

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[1] World Bank website: <www.worldbank.org/en/country/tunisia>.
[2]World Bank. 2007. Making the most of scarcity. Accountability for better water management results in the Middle East and North Africa. MENA Development report.World Bank, Washington D.C.
[3] ANPE Report on the Network of Pollution Control in Tunisia 2010.
[4] World Bank website: <http://databank.worldbank.org/>.
[5]DGBTH. 2003. Management of siltationin the reservoirs of the large Tunisian dams, prepared by Ms M. Abid, 22p, and personal communication withDGACTA, July 2012.

Moreover, public investment for the 11th Plan (2006-2011) has been estimated at 2.2 billion DT, most of which are devoted to the management of natural resources, with 56% of the value allocated to activities related to water, 15% to forestry activities, and 10% at CES.[6] These investments were mainly based on technical solutions implemented by the services of the MoA.However, environmental and general benefits have not been estimated to reach optimal policies for sustainable management of natural resources, mainly water resources.

5. Since the Revolution in January 2011, Tunisia has experienced a total upheaval in its socio-economic fabric.The new Government has focused on issues of employment, rural development and poverty reduction, especially in the Central West region where poverty has reached 29% compared to the Greater Tunis where poverty is 5-7%.[7] Therefore, the MoA has highlighted the need to focus interventions, on the one hand, on the less privileged and disadvantaged, and, on the other, to manage natural resources in a participatory manner at the watershed level of these regions. In the latter, more specific prioritisation may be identified based on the cost and profit of interventions whereby sustainable water management is a critical component in reducing poverty, especially in rural areas.

[6] MARH. 2007. The 11th plan of economic and social development. Agriculture and Fishing Sector, 67p.ONAGRI website.
[7] World Bank website: <www.banquemondiale.org/fr/country/tunisia/overview>.

2. SUSTAINABLE WATER INTEGRATED MANAGEMENT – SUPPORT MECHANISM (SWIM-SM)

2.1 General overview

6. Within this context, this regional study refers to the degradation cost of water resources at the watershed level, being supported by the SWIM-SM regional program.[8] This is a regional programme for technical support whose objective is to promote actively the extensive dissemination of sustainable water management policies and practices in the region given the context of increasing water scarcity, combined pressure on water resources from a wide range of users and desertification processes, in connection with climate change. Regional in scope and in order to add value and complement other regional processes through regional and national reproducible, the SWIM-SM program aims to:

- Provide strategic support to nine[9]southern Mediterranean countries partners of the European Union for the development and implementation of policies and plans for sustainable management of water, involving a cross-sectoral dialogue and consultation of the institutions concerned.
- Contribute to the strengthening of institutions and the development of management and planning skills necessary as well as facilitating the transfer of expertise.

7. One of five components of this project is the improvement of water governance and integration of water issues in sectoral policies such as policies in agriculture, industry, tourism, etc. This aims at making water an important element in policies and national development strategies.

8. Although water issues and their impact on the economy have been assessed nationally, the situation is different at the watershed level because no clear identification of problems and costing associated with degradation have been completed yet. However, decisions must be made at the basin level regarding the management and protection of water resources, in close collaboration with local authorities, and in particular concerning systems of water and soil conservation and wastewater treatment on the regional/local level. The cost of water resources degradation (Cost of Water Resources Degradation or CWRD) would allow local institutions to have the necessary tools to discuss based on cost figures with the central authorities, the national ministries, and in particular with the Ministries of Finance, other competent authorities and the public, everything about the different types of costs of degradation and the policies needed to reduce these costs.

9. Tunisia, through its national Focal Point, has requested assistance from SWIM-SM to estimate the degradation cost of water resources in the Medjerda watershed.This basin was selected based on the following reasons:

a) • The Medjerda is the longest river of Tunisia. Its source is from the north-eastern Algeria, it flows east towards Tunisia over a distance of 450 km, including 350 km in Tunisia and flows into the Mediterranean Sea.Medjerda is considered the country's water tower providing drinking water to more than 2.5 million people including the Greater Tunis area and its surroundings such as Cap Bon, Sahel and Sfax.

b) The Medjerda crosses the six governorates of Beja, Jandouba, Le Kef, Siliana, Ariana and Manouba, which are mostly of rural and agricultural character.These governorates are rich in

[8] Website: <SWIM-SM : <www.swim-sm.eu>.

[9] The nine countries are Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, the occupied Palestinian territory, Syria and Tunisia.

natural resources, contain 75% of water reserves and include more than half of the country's forest area (535,000 ha). However, socio-economic development of these governorates is limited due to low *agricultural productivityand lack of services and opportunity for job creation.*

c) The Medjerda basin is crossed or affected by 9 storage dams, out of which two dams, the Sidi Salem dam (capacity of 814 million m^3) and the Nebeur-Mellegue dam (182 million m^3), are built on the river and are subject to significant siltation.

d) The basin is experiencing a number of problems relating to natural resources and linked to erosion, salinity, drought and floods and dam siltation as well as problems linked to agricultural, municipal and industrial pollution.It is thought to be a representative basin for a thorough analysis of costs and benefits related to the degradation and restoration of water resources in Tunisia.

e) The Medjerda basin has been the object of numerous reports and scientific and technical information (which, when available, will be used in this study); however, none of these studies have addressed the economic dimension of the degradation of this basin and the cost for its rehabilitation.

2.2 Objective of the Study

10. The main objective is to evaluate the cost of water resource degradation in the Medjerda watershed to help decision-makers at national and local levels to identify and prioritize specific actions to improve the management of this basin through potential funding of projects related to environmental benefits and the reduction of externalities.

11. The expected results are:

a) an overview of the economic aspects of the Medjerda watershed management problems;

b) a cost assessment of water resources degradation in the Medjerda basin including ecological degradation and environmental health;

c) an economic analysis of priority alternatives;

d) specific recommendations in order to incorporate the advantages for the benefit of the environment and improve the management of this basin.

12. The cost of the degradation of water resources can be considered as a measure of well-being loss due to the degradation of water resources. A well-being loss includes, but is not limited to:

a) Loss of healthy life and well-being of the population (e.g., burden of disease);

b) economic losses (e.g., income which some economic agents had to give up on); and

c) loss of environmental and water opportunities (e.g., loss of tourism, fishing resources and biodiversity).

3. THE MEDJERDA BASIN

3.1. GENERAL DATA ON THE MEDJERDA BASIN

13. The Medjerda Basin covers an area of 23,700 km^2 divided into three distinct parts. The first, called Higher Medjerda, spans from Algeria to Ghardimaou (7,870 km^2). The second, Middle Medjerda, includes all tributaries and extends to Medjez el Bab. Finally, Lower Medjerda, ends at the mouth of KalaatLandalous. The Medjerda Tunisian section covers an area of 15,930 km^2, or 9.7% of the total area of the country, but reaches 20,243 km^2 when all the structures built to bring water to the Greater Tunis, including Tunis and Ben Arous (other neighboring regions benefit from water transfer but are not included in the analysis), are considered. The basin displays semi-arid Mediterranean climate with an average rainfall ranging from 400-600 mm. In 2010, the total population was estimated to be 2.2 million, or approximately 21.2% of the Tunisian population, with a population density of 110 inhabitants per km^2, which is higher than the national average of 68 inhabitants per km^2.10 In addition, 37% of the population is either urban or municipal and 63% of the population is rural.The most populous areas are located in the plains along the river and itstributaries. 6 governorates Jandouba, Beja, Kef, Siliana, Ariana and Manouba are mainly rural and hold one third of the forest area, a quarter of the best agricultural land and 2/3 water mobilized the country.[11] With a large agricultural area, the pillar industry of the basin is agriculture, which employs more than 87,500 people and contributes 50% of food production in the country. Moreover, it is also an important center of agricultural farming. Thus, a large part of the water resources of the basin is allocated to irrigation and livestock.

14. The Available Gross National Income per capita was about 6,054 DT in Tunisia in 2010 with a lower per capita income, which could reach 50% in some areas of the Medjerda basin. The area of the Northwest is the most affected by illiteracy, especially among women, reaching 43% in 2004. The area of the Northwest also recorded a high level of unemployment at 19.6% in 2007.[12]

Box 3.1: Main Features of the Medjerda Basin

River length: 450 km in Algeria and Tunisia, 350 km of which in Tunisia.
Surface area of the watershed: 15,930 km^2 or 9.7% of the surface area of Tunisia.
Population: 2.2 million inhabitants (21.2% of the total population), of which 1.6 million people in rural areas.
Structures: 9 dams.
Agriculture: 25% of the agricultural sector and the most fertile region of Tunisia.
Drinking Water: Main source for more than 3.8 million inhabitants including the inhabitants of Medjerda and Greater Tunis (Tunis and Ben Arous) and other neighbouring regions. They depend more or less locally on the Medjerda water resources but are not included in the analysis.

15. The Medjerda Basin (Box 3.1 and Figure 3.1) is supplied by 4 tributaries or wadis on the left bank and five wadis on the right bank of the river. The river is perennial and has a mean annual flow of 29 m^3/s with large seasonal variations. However, the basin is subject to deep waterlogging and salinization due to stagnation of saline runoff water. Waterlogging and salinity are the cause of land degradation, which can reach up to 60% of the land in the region thus contributing to dam reservoir sedimentation and to their reduced capacity. Therefore, usually, runoff and drainage waters, enriched with soluble elements, flow towards the lower parts of watersheds and, in the case of Medjerda, the watershed becomes an outlet and salts migrate downstream to the basin to the particular detriment of drinking water quality and agricultural productivity.

[10]The study of the Integrated Management of the Basin.Final Report on the Regulation of Flooding in the Basin of Medjerda, Summary, (January 2009 Nippon Koei Co. Ltd.)
[11]Feasibility study: Management of municipal waste of the Valley of the MedjerdaANGed 2010.
[12] Ibid.

16. Similarly, the construction of nine dams on the river and its tributaries has changed its flow regime. These dams are primarily used for storing water during water rise, to regularize their disposal for the purposes of agriculture and irrigation and for water use during drought periods (Table 3.1). Due to severe erosion of the alluvia because of the river flow and a considerable loss of the forest regime, these dams have been subject to siltation, which has reduced their storage capacity, and it is expected that due to climate change, such storage capacity will decrease from 30% to 40% by 2030.

Table 3.1: Dam siltation in the Medjerda, 1950-2010

Dam	Watershed	Initial capacity	Commissioned	Installed HE power	Siltation since commission	Siltation in 2010	Percentage of siltation since commission
	km^2	Million m^3	Year	MW	Million m^3	Million m^3	%
Nebeur-Mellegue	10,300	182	1954	13.0	122	2.5	67
Ben Metir	103	62	1954	9.0			
Kasseb	101	82	1968	0.7	3	0.2	3
BouHertma	390	178	1976		6	0.2	5
Sidi Salem	7,950	814	1981	36.0	171	6.8	21
Siliana	1,040	70	1987		17	1.1	24
Lakhmess	127	8	1966		1	0.0	12
Rmel	232	4	2002				
Laaroussia			1950				
Total	**20,243**	**1,399**		**58.7**	**319**	**10.8**	**23%**

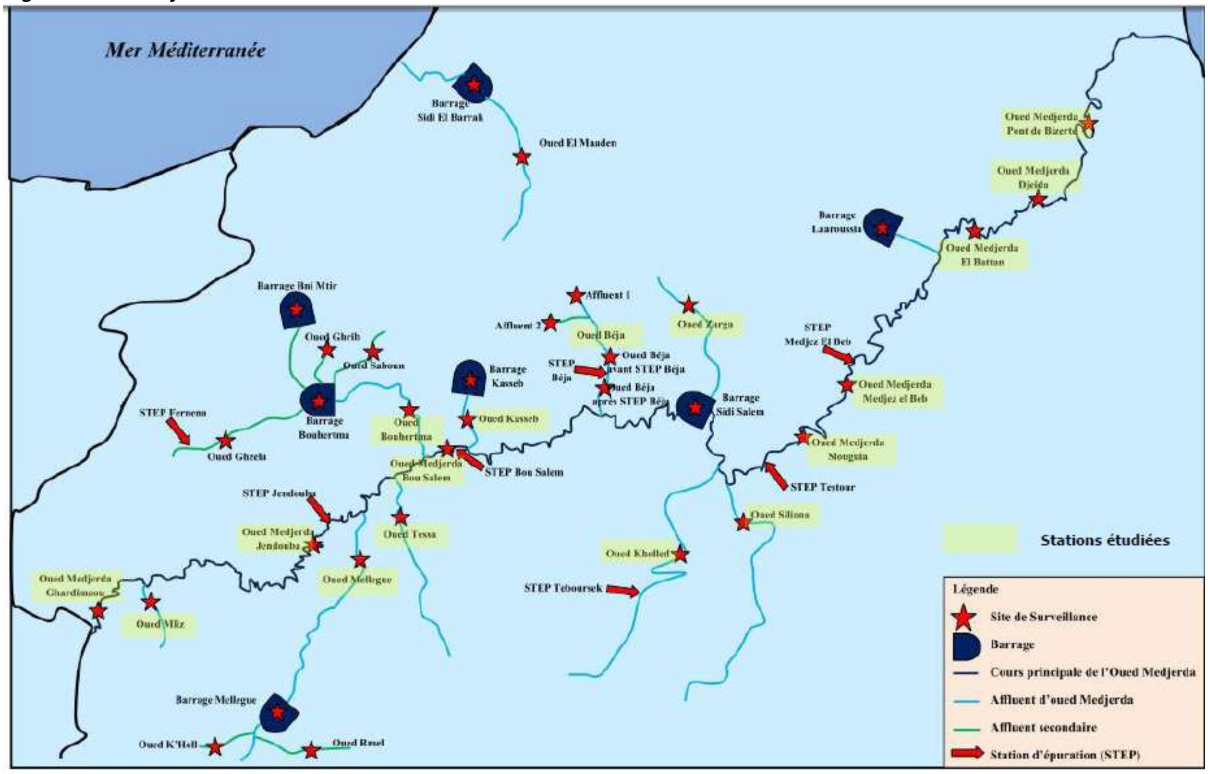
Source: Data provided by the MoA, Dams and Large Hydraulic Works, Directorate of Dam Operations and Hydraulic Structures Maintenance (2010).

17. The largest dam in Tunisia is the one of Sidi Salem on Medjerda, which covers more than 7,950 km^2.At a height of 54 meters and a capacity of up to 750 million m^3 reservoir with a surface of 4,300 hectares, it has a 20 MW hydroelectric plant and spillway.[13] Several other dams reservoirs help control the waters of the basin including the two commissioned in 1954 Nebeur on the Melleguewadi, which covers 10,300 km^2 and is currently silted now with 122 million m^3 of capacity lost since 1954 as compared to 182 million m^3 at baseline (but 188 against 306 of small scale hydroelectric plants) and Ben Mandir, controlling 103 km^2 of the watershed in an area of high rainfall with water of very good quality. The Sidi Salem, Nebeur, BouHertma and Siliana dams have an important role in water rise management and the fight against floods and provide regular water to downstream users. The Kasseb, Lakhmess and Rmel dams produce some electricity and are mainly intended for irrigation. However, small-scale hydroelectric works increase sedimentation of riverbeds downstream and affect biodiversity. Finally, the Laaroussia Dam is used for irrigation and drinking water through: the Canal of Taulierville (or Great Canal) built in 1956 with a length of 56 km, a capacity of 13 m^3/s, which is used for the irrigation across the old areas of the Medjerda Lower Valley of 31,000 ha; the subnet of the Medjerda Lower Valley is used to irrigate 6,000 ha of new areas; and the Medjerda - Cap Bon Canal subnet, which has operated since 1984 with a length of 120 km, flow starting at 16 m^3/s and ending at 8.8 m^3/s, while finishing at the Belli treatment plant (see SONEDE below).

18. Hydroelectric (HE) production, which is concentrated in the north of Tunisia, strongly correlated with rainfall in the north-east and north-west of Tunisia between 2000 and 2010 (correlation coefficient 0.85). The annual average over the period was 89 million kW/h with an average of 0.7% of the total electricity production.

[13] Wikipedia website: <http://fr.wikipedia.org/wiki/Barrage_de_Sidi_Salem>.

Figure 3.1: Medjerda Basin



Note: 6 of 9 dams are simply indicated.
Source: ANPE Cooperation Committee Marseille Provence Mediterranean September 2011.

19. Since 1973, the Medjerdawadi[14] has been subject to intensive flood periods that have been devastating on both sides of the river, submerging villages including Boussalem area in the governorate of Jendouba and many other areas surrounding the Medjerdawadi such as Jdaida and El Battan in the governorate of Manouba. Given the high, acute rates, dams such as the Sidi Salem and Mellegue have required releases of flood volumes up to 750 m^3 per second causing an overflow of the river bed which was accompanied by the transport of large volumes of sediment along the riverbed, thus contributing to increased flooding, increased the "delta-ization" of the river mouth[15] (an increase equivalent to 6.2 km^2 in the 20th century) and thus affecting biodiversity.

3.2. POLLUTION OF THE MEDJERDA BASIN

20. Pollution at the Medjerda is characterised by agricultural, industrial and urban pollution.16 Agricultural pollution is due to concentrations of phosphates, nitrates and fertilizers because of the production of vegetables, fruits and grains and cattle raising. Similarly, land irrigation generates salinity that exceeds the threshold of 0.2 g/liter stipulated by European regulations for drinking water as compared to 1% to 1.5% for the Tunisian regulations. This salinity is due to the groundwater salinity, which ranges from 1.5 to 2 g/liter and can reach up to 5-7 g/liter, and also to the intrusion of seawater. In view of salinization in some areas of the

[14]The study of the Integrated Management of the Basin.Final Report on the Regulation of Flooding in the Basin of Medjerda, Summary, (January 2009 Nippon Koei Co. Ltd.)
[15]Jebari et al. (2012).
16Characterisation of types of pollution in the Medjerda wadi in Tunisia, Cooperation Committee Provence Mediterranean, Water Agency, COPEAU, ANPE, September 2011.

Cap Bon region, farmers are forced to mix groundwater with water from the public network, to improve quality, but at a higher cost. Drainage containing nitrates and pesticides used for agricultural activities was estimated at 2.213m^3/day.

21. Industrial pollution is mainly due to the food industry, such as the manufacture of dairy products and cheeses, olive (oil) and tomato processing (oil) and sugar production.Industrial discharges not connected to the ONAS network are estimated at 221 m^3/day.This industry accounts for 90% of industrial discharges and 5% of discharges into the Medjerda watercourses.Other industries, such as the textile, plastics and automobile industries, generate releases of 0.44% in the watercourses.Such liquid waste, estimated at 221 m^3/day, contributes to a high level of Chemical Oxygen Demand (COD).

22. Urban domestic pollution is mainly due to domestic wastewater discharges of untreated urban water estimated at 1.27 million m^3/year and to water discharges of treated sewage from 19 ONAS wastewater treatment plants estimated at 12 million m^3/year.Pollutant loads discharged into water courses are 886 kg/day of Biological Oxygen Demand (BOD5) or 2,142 kg/day of nitrogen and 315 kg/day of phosphorus. These loads are responsible for eutrophication observed in the reservoirs of the Sidi Salem and Siliana dams.In addition, wastewater from villages is not treated.Bacteriological analyses have shown amounts of faecal germs exceeding 11,000 total coliforms/100 ml in water points in Jandouba, BouSalemm the Polluted Water Treatment Station (STEP) in Beja and at the West of Siliana.

23. Urban pollution is also due to part of the solid waste estimated at 149,000 tons per year for the four Northwest governorates of Medjerda.[17] This figure is tripled when all 6 governorates of Medjerda are taken into account. Waste collection, representing 0.71 kg/day/inhabitant on average, has a rate of almost total coverage in urban, suburban centres and some municipalities (covering approximately 30% of the population of the basin). However, the problem lies with after-collection management.Thus, waste collected in the four Northwest governorates is buried in 38 landfills listed by GIZ (2011): 7 landfills (including Beja, Mejez el Bab, Jandouba and Ain Drahem commissioned in 1999) are considered semi-controlled but they are effectively unregulated dumps as concerns their impact on the environment with mismanagement of waste burial, leachate (basin overflow and rare treatment by ONAS) and degassing (methane); 24 municipal landfills are considered unregulated and are located on the banks of the Medjerda and its tributaries; and 7 landfills, which are apparently not under any institution, are also considered unregulated. Waste from these landfills generates a significant amount of leachate flowing into outlying areas and neighboringwadis. To this, the sludge from the 19 STEPs of ONAS may be added (5,580 tons of dry stabilized sludge whose quality meets the country standards, part of which is used as fertilizer); this is either stored in the enclosure the STEPs or discharged into wadis and sometimes mixed with leachate. In addition, debris from the destruction/construction (49,000 tons) are also discharged in part with these discharges while the rest ends up in the wasteland, wilderness or in the wadis. Finally, agricultural residues and agro-industrial wastes present an opportunity to generate electricity but are mostly already recycled. ECO-lef has initiated a recycling project for plastics with a little less than 600 tons recycled in 2010. As part of the National Programme for Integrated Sustainable Solid Waste Management, a study by GIZ has taken up the conclusions of a feasibility study conducted in 2005 to set up a centralized waste management system including at least two landfills and transfer centres, in order to enable the management of waste generated in 38 municipalities.

24. Rural pollution from solid and liquid waste remains a problem in the Medjerda Basin. Also, the rate of coverage for improved sanitation does not exceed 5%, while solid waste is not collected thus increasing the risk of the drainage affecting the basin. In addition, agricultural residues and agro-industrial wastes present an opportunity to generate electricity but are mostly already recycled.

[17] Feasibility Study: Management of Municipal Waste of the Valley of the MedjerdaANGed 2010.

25. Regarding the parameters related to the quality of the resource,[18] the basin water quality varies depending on the particular wadi and the climate in 2010, but it is generally regarded as fair.The salinity of the wadi waters demonstrates great fluctuations and tends to drop after floods while increasing in times of drought (see here below and Figure 3.2). Dissolved oxygen findings comply with standards except for the Kassebwadi because of releases of organic matter content from the food industries. COD values are usually below the standard with the exception of the Kasseb and Jdaidawadis. Suspended solids are generally all above the norm, especially for the Battan, Jdaida, and Gantaret Bizerte wadis. However, COD pollution caused by suspended solids is not organic for these three wadis. Regarding nitrates, the whole basin is of fair quality, with peaks in the Kasseb, Beja, Siliana, Kalled and Zargawadis, especially in December which may promote eutrophication. Concentrations of phosphate content exceed the standards and the waters are mostly poor to very poor quality due to the effects of agricultural runoff loaded with fertilizers after flooding. Bacteriological analysis indicates fair water quality with Jendouba, Bou Salem, Beja STEP, and Siliana being particularly affected by the presence of faecal germs in large quantities. This concerns the total number of coliforms and enterococci indicating possible contamination by raw sewage. However, the presence of enterococci in high enough numbers shows that there is a fairly old water contamination.[19]

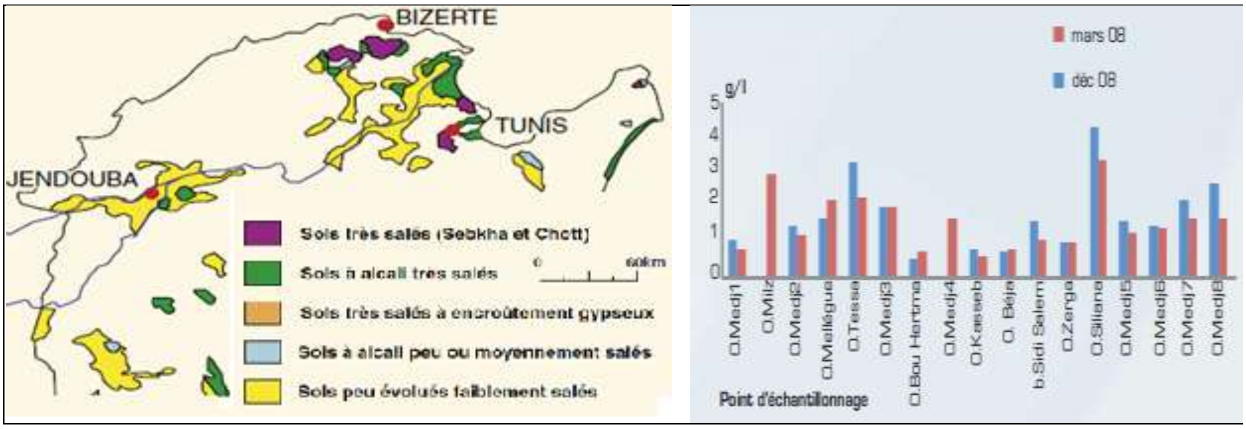
26. Concerning surface sediments along the Medjerda, tests have confirmed fluctuating prevalence especially of heavy metals and PCBs in sediments.For example, OuedKasseb exhibits very strong contamination by PCBs and heavy metals, primarily arsenic, cadmium, lead and zinc,[20] but also copper, antimony and barium.[21] These heavy metals from industrial activities or outside food processing, fertilizers used in agriculture such as arsenic and copper in waste dumps and the 12 old mines of lead, zinc, iron and cadmium.

27. Indeed, almost all of these mines, whose operation began in the late nineteenth century, have been abandoned in the area of Medjerda over recent decades. Remains: the production of iron ore to Jerrissa in the governorate of Kef (107,000 tonnes in 2010), the production of iron ore (363,690 tons), zinc (76 560 tonnes) and lead (9,890 tonnes) of Bougrine always Kef, and the imminent reopening of the phosphate mines of Sra Ouertane in the governorate of Kef.[22] However, various studies highlight the persistent risk of transfer of heavy metals in the food chain downstream of the old mines such as the levels of lead, zinc and cadmium very high downstream of the old mine in the governorate AkhouetSiliana.[23]

28. Concerning surface water resources, the salinity of the main river course is generally high (Figure 3.2). This is mainly due to water inflow from tributaries of the right bank (Siliana and Tessa wadis) whose salinity is high, but also the absence of flooding during this period and the drop of the Medjerda water level by evaporation resulting in salt concentration. On the other hand, it is at the Kassebwadi (left bank) that we find the lowest salinity levels. In addition, the salinity increases significantly in December as compared to the month of March.[24] Still, Tunisia has implemented several enhancement works for the salt-affected soils, especially in the central and southern regions, thus acquiring a unique experience.

Figure 3.2: Soil and water salinity in the Medjerda Basin

[18]Pollution characterisation in the MedjerdaWadi (2011).
[19] Ibid.
[20]Hélali M.A. et al. 2009. Mediterranean Review of the Environment 3 (2009) 485-497 496.
[21] Ibid.
[22]USDI (2012).
[23]INGREF.200-.Studies on the mobility of heavy metals from mining waste of the Akhouat site.
[24]Copeau Bulletin No.2 (2008).



Source: Hachicha (2007), and Copeau Bulletin No. 2 (2008). 2 (2008).

29. Concerning soil salinity, scarcity and variability of rainfall as well as high evaporation affect the water and salt balance in the soil, with several areas of the Medjerda basin consisting of soluble salts. Thus, runoff and drainage enriched soluble elements, which are natural and/or anthropogenic (runoff irrigation water charged nitrogen) flow to the lower parts of watersheds.[25] According to Figure 3.2, the Jendouba and low Medjerda have evolved slightly salty soils bit except the hillside on the left bank (Siliana and Tessa) and the mouth of the river include alkali soils very salty.

30. In summary, the water and agricultural land quality is affected by salinity with an impact on the water quality of the Greater Tunis (salt levels) and agricultural productivity in some areas of the basin. Depending on the season (wet or dry, with the intensity and frequency set to be exacerbated by climate change), erosion along the Medjerda affects the storage capacity of dams, while the management thereof during large floods requires releases flooding agricultural plains downstream, thus placing sediments along the wadi beds, "delta-ising" the coastal areas and affecting biodiversity. Also, the quality of water resources is largely affected by water pollution sources of anthropogenic origin and consist of the following:

- Industrial waste water not connected to the ONAS network;
- Discharges of treated wastewater from STEPs;
- Discharges of untreated urban wastewater;
- Drainage of untreated rural wastewater;
- Drainage of pesticides, phosphates and nitrates used for agricultural activities;
- Drainage of wastewater due to stock raising activities;
- Drainage from slaughterhouses;
- The transfer of heavy metals from old mines and one mine still in operation; and
- Drainage from solid waste and leachate, especially during the rainy season.

3.3. ORGANISATIONAL AND INSTITUTIONAL FRAMEWORK IN THE MEDJERDA BASIN

31. The main public institutions responsible for pollution management and/or contributing to pollution control in the Medjerda basin are:

a) Ministry for Agriculture (MoA);
b) Ministry for the Environment (MdE); and

[25]Hachicha (2007).

c) Ministry for Public Health (MdSP).

3.3.1. Ministry for Agriculture

32. Pursuant to Article 2 of Decree No. 2001-419, the MoA is responsible for water management.It is also responsible for agriculture, natural resources, soil conservation, plant science and forestry as well as the management of large dams.The Ministry carries out its functions at its headquarters through the central directorates and outside the headquarters through semi-autonomous institutions such as the Regional Committees for Agricultural Development (CRDA), the Office for Sylvo-Pastoral Development of the North-West (ODESYPANO) and public enterprises such as the National Association for Water Exploitation and Distribution (SONEDE).For Medjerda, the following general directorates and institutions are involved at central level:

a) **The General Directorate for Dams and Hydraulic Works (DGBGTH)** is responsible for the management, regulation and monitoring of dam water quality and infrastructure.The DGBGTH is responsible for the implementation of dam policy and prepares a daily report on the state of dams, their capacity, their level of siltation that has not been controlled during their construction.With JICA assistance, the DGBGTH has prepared a study relating to the Integrated Basin Management Focused on the Regulation of Flooding in the Medjerda Basin.The main objective of this study is to prepare a blueprint on the integrated management of the basin focusing on flooding the Medjerdawadi.

b) **The Directorate General of Water Resources (DGRE)** is responsible for the Medjerda hydrometric network and its surface and ground water.The DGRE monitors salinity and nitrates in the Medjerda for agriculture and irrigation.

c) **The Directorate General for the Development and Conservation of Agricultural Land (DGACTA)** is responsible for the assessment of natural resources, soil conservation, preservation of hydrological and hydrogeological aspects.The DGACTA has begun to prepare inventories of watersheds and soil characterization.The DGACTA keeps track of its activities based on five indicators for target budgeting purposes as a function of: (i) agricultural land surveyed and monitored; (ii) agricultural land irrigated; (iii) land managed by the CES; (iv) land managed and maintained; and (v) agricultural land whose use has changed.

d) **The General Directorate of Rural Engineering and Water Exploitation (DGGREE)** provides education, management and distribution of agricultural water in irrigated areas including treated wastewater (EUT) as well as drinking water in rural areas. Irrigation water was more directed towards large hydraulic works and not enough towards small and medium works which still face basic problems due to lack of socio-economic studies.

e) **The General Directorate of Forestry (DGF**) has a mandate to ensure the protection and management of the forest area of the State in accordance with the revised Forestry Code (Law 88-20 of 04/13/1988), as well as decrees and opinions relating thereto.The DGF also has directorates in the Medjerda governorates.The DFG is the focal point for climate change adaptation and responsible for the sylvo-pastoral strategy which includes reforestation of watershed dams and hill lakes in the Medjerdawadi.

f) **The General Directorate of Agricultural Pesticides (APD)** is responsible for pesticide importation and monitoring, pesticide residue analysis in acericulture and arboriculture.

g) **SONEDE** is a public industrial and commercial enterprise with financial autonomy under the supervision of the MdA.It is responsible for the production and distribution of drinking water and industrial water management.For the Medjerdawadi, the Ghdir El Golla (GEG) complex, located northwest of the capital, **maintains reserve raw water for food security**, ensures drinking water treatment necessary for the Greater Tunis (governorates of Tunis, Ariana, Ben Arous and Manouba) and contributes an amount **to Cap Bon (governorate of Nabeul) and the governorates of Bizerte and Zaghouan as needed.**These waters come from two dams on the Sidi Salem at the Medjerdawadi as well as dams in the Northwest passing through the Medjerda/Cap Bon canal.The production capacity of the complex is 600,000 m³/day. The GEG complex, which undertakes physico-chemical testing at the entrance and exit of the complex, produces good quality water **with a low detection rate of 1.5% which is well below the standards of 5% set by the World Health Organization (WHO).** Effective, ingenious management of the GEG complex, based on a mixture of water from the Medjerda Canal (Medjez El Bab), the Kasseb Dam (Amdoun) and the BeniMetir Dam (Fernana), ensures drinking water without bacterial contamination after treatment, but problems may arise during water distribution, as it is sometimes contaminated by seepage, e.g. during network repair works.**In addition**, two water treatment stations in Belli, with a total capacity of 80,000 m^3/day, are located south of the Grombalia delegation, 42 km from Tunis. Raw water, from the dams of Northern Waters (Joumine, Sidi Salem and Sejnane) via the Medjerda/Cap Bon canal, is treated at these stations and supplies parts of Cap Bon, Sahel (governorates of Sousse, Monastir and Mahdia) and Sfax. Also, the station, located in the Ain Draham delegation, treats the Ben Metir dam water, produces a daily volume of 110,000 m^3/day conveyed to Tunis and allows for the supply of drinking water to several cities and villages of Northwest Tunisia along the way. All this is to say that there is a combination of the water resources of several watersheds serving the Greater Tunis and the surrounding areas. This combination does not allow for clear distinction as to the origin of the water but it allows, among other things, for the reduction of water salinity, especially in summer, intended for the Greater Tunis and its surrounding areas.

h) **The Association for the Exploitation of Canal and Water Supply Systems of the North (SECADENORD)** operates, manages, and maintains the canal and water transfer pipes from the dams of Sidi Salem, Lake Ichkeul, and the extreme north of Tunisia up to the point of use.This Association is responsible for the distribution and sale of dam water to various organizations such as SONEDE and CRDAs (see above).The SECADENORD sells the water at 0.37 DT/m^3 to SONEDE which resells it to the end user at 1.45 DT/m^3 for the first tranche. SONEDE covers the deficit of his own treasury: in essence the average cost of returns is 7.16 DT while the average cost of sale is DT 5.62 per m^3.Rates have been frozen since 2005, but an increase was authorized in 2010.

i) **The National Agronomic Institute of Tunisia (INAT)** is an institution of Agricultural Education and Research under the dual supervision of the MdA and the Ministry of Higher Education.The INAT has conducted physico-chemical testing as well as bioassays for nitrates, orthophosphates and nitrites. The centre is currently undertaking a risk assessment of the Medjerda water quality to be completed in 2013.

33. The following institutions are involved in the Medjerda basin at regional and local level:

a) The CDRAs are responsible for the implementation of agricultural policy at local and regional levels and are under the supervision of the MdA.The CRDAs perform agricultural projects in conjunction the governor and in accordance with the laws and regulations in effect.The CRDAs perform land clearance operations and monitor the agrarian reform operations for agricultural land.They are also responsible for managing hydro-agricultural infrastructure and the supply of different areas.The 4 CRDAs, covering the 4 administrative governorates of the wadi, represent the central services of the MdA.

b) ODESYPANO is a semi-autonomous agent, under the supervision of the *MdA,* and a Public Establishment for Non-Administrative Character since 1996. Its mandate is the implementation of agricultural policy in mountainous areas and forests of the Northwest and the protection of vulnerable ecosystems and development of rural infrastructure in this region.It is a decentralized structure with headquarters at Beja and the regional jurisdiction to implement the national development policies in the six governorates of Beja, Jendouba, Le Kef, Siliana, Ariana and Manouba, all crossed by the Medjerda.The ODESYPANO and the CRDAs of the 6 governorates of the Medjerdawadi work closely together; however, activities and investments on mountainous areas are the responsibility of the ODESYPANO while activities and investments on the plains and grasslands are managed by the CRDAs.

3.3.2. Ministry for the Environment

34. The MoE has a mandate for the protection of natural resources, the fight against pollution, the protection of the quality of life and the fight against the impact of climate change and desertification. This Ministry is also involved in investment and pollution control through:

a) **The Directorate General for the Environment and Quality of Life (DGQEV)** is one of the key directorates for formulating and implementing national environmental policy.The DGQEV has undertaken a number of studies that include the Medjerdawadi, including the inventory of potential major pollution sources and the establishment of a national network for monitoring water pollution, which includes 25 monitoring stations along the Medjerda river, a biodiversity strategy and action plan, management plans for national parks, the National Strategy for Adaptation of Tunisian agriculture and ecosystems to climate change (with the assistance of GIZ), health and climate change as well as studies of olive oil production wastewater and unregulated landfills at the national level.The DGQEV also participates in the Investment Project in the Water Sector (PISEAU) II, which is funded by the World Bank, the French Development Agency and the African Development Bank and includes four of the CRDAs of the northwest.

b) **The National Agency for Environmental Protection[26] (ANPE)** has a mandate to fight against all sources of pollution and disturbance and control and monitor pollutants and waste treatment facilities of such discharges.The pollution control and monitoring department is responsible for the supervision and control of air, water and soil pollution.This department within the ANPE, with the assistance of the University of Liège, has implemented the COPEAU project, a Control Network for Water Pollution.The Department has published a comprehensive report concerning the Characterization of pollution at the Medjerdawadi in September 2011 in collaboration with the Cooperation Committee Marseille Provence Mediterranean.This report, which was used for the study of the degradation cost of water resources, identified sources of pollution throughout the Medjerdawadi, measured the quality of surface water in terms of physico-chemical and bacteriological aspects as well as the physico-chemical quality of the surface sediments.The department also conducted with the University of Liege-Aquapole a feasibility study[27] of a methodology for modelling watershed Medjerda to use the PEGASE model developed by Aquapole to establish a relationship pressure/impact loads of pollution and water quality of Medjerda. The report concluded that the PEGASE model could be applied through model adaptation to the local context of the basin.

c) The National Office of Sanitation (ONAS) has the prerogative of fighting against water pollution sources, as well as planning, management, operation and maintenance of sanitation stations in urban areas.ONAS has a plan for implementing sanitation in rural areas and more generally in the towns of over 4,000 inhabitants in 2021. A pilot study of rural sanitation has shown the extent of the problem: almost half of the population is not linked to a sewerage network and 20% of the population still uses

[26] Website of the National Agency for the Protection of the Environment: <www.environnement.gov.tn>.
[27] J-F.Delìège, T. Bourouag, C. Blockx, X. Detienne, E. Everbecq, A. Grard, report on the modeling studyon the global scale of the Medjerda watershed, AquapôleCampus of the University of Liege, September 2009.

septic tanks.Also the problem of industrial waste has not yet been resolved and treatment plants continue to receive industrial waste mixed with domestic wastewater without pre-treatment.There is also an institutional vacuum for the establishment and management of wastewater treatment plants in towns of over 4,000 habitats. Such villages do not fall under the mandates of ONAS, DGGREE or SONEDE.

d) **The National Agency for Waste Management (ANGed)** is a public institution founded in 2005 under the Ministry of Environment and constitutes a legal entity with financial autonomy.Its mission is to plan, promote and support local communities in the sustainable management of waste, primarily in landfills and household waste treatment.Before the establishment of the ANGed, four semi-controlled landfills were built in the valley of the Medjerda, Beja, Jendouba, Medjez el Bab, and Siliana with the assistance of the German Technical Cooperation and managed primarily by ONAS.In 2005, the German Government agreed in principle to finance a system for the integrated management of municipal waste in the region of the Medjerda Valley.A prefeasibility study was completed in 2007 and was followed by a feasibility study[28], which was completed in July 2010. This study proposes to treat all urban municipal waste (household, plastics, sludge WWTPs, industrial waste and waste health activities) to an annual average of 224,537 tons.However, the rural household waste will not be considered.

3.3.3. Ministry for Public Health

35. The MdSP[29] mandate includes planning, implementation and control of public health policy in the areas of prevention, care, medication, drugs and laboratories, as well as rehabilitation.One of the responsibilities in the area of prevention is to anticipate and prevent impact on the health of the population and in particular, water consumption.The Ministry conducts systematic tests of drinking water quality from treatment plant outlets to house tap.The Medjerda waters are waters rich in organic matter and susceptible to germs.This water is treated at the GEG through pre-chlorination, which may have an adverse effect in terms of health; therefore this treatment must be improved without pre-chlorination.Such improvement is under study with SONEDE.

3.3.4. Conclusions

36. Diagnoses and testing undertaken by so many institutions point to three conclusions:

- The intensification of natural resources (especially water and soil) and dam siltation are more important than water pollution.
- Institutions and agencies each works on programs and technical reports in the Medjerda basin in well defined areas; however, coordination and exchange of information and experience on the basin are low and horizontal reinforcement among these institutions should be considered.
- The qualitative and quantitative assessment of impacts on natural resources is generally understood under a technical point of view; however, the economic evaluation of such impact is almost nonexistent.

37. This is due to the lack of economic evaluations of impacts that focuses on costing degradation and in some cases restoration of water resources in the Medjerda basin. This assessment allows us to quantify, even if by approximation, and establish an order of magnitude of the economic costs associated with environmental

[28]Feasibility study: Waste Management, Municipalities of the Valley of the Medjerda, Phase 1 – Current Status Diagnostic and Definition of Objectives, July 2010.

[29]Website: <http://www.santetunisie.rns.tn/msp/presentation/role.html>.

impacts so as to draw a shortfall regionally and nationally. This evaluation also allows decision makers to prioritize sectors, through the sectoral breakdown of costs and profitability of the alternative cost of restoration.

4. REVIEW OF ENVIRONMENTAL DEGRADATION COSTS IN TUNISIA

38. Numerous studies on the environmental degradation at national, regional and sectoral level or the benefits arising from pollution reduction have been conducted in Tunisia over the past twelve years. The results of these evaluations, usually covering one base year, are shown in Figure 4.1.

39. The project METAP/World Bank,[30] Economic Research Forum, Egypt and the European Commission estimated the cost of environmental degradation at the national level, each using different methodologies. The results are as follows:

- **In 2004, the World Bank/METAP published the cost of environmental degradation using 1999 data covering 6 categories: air, water, waste, soil and biodiversity, coastal and cultural heritage and global environment.[31]** These costs have been estimated at between 383 and 662 million dinars in 1999 year, 1.5 to 2.7% of GDP, with an average estimate of 522 million DT or 2.1% of GDP.[32] To this must be added the cost of damage to the global environment estimated at around 0.6% of GDP. The degradation cost due to water was estimated at 0.61% of GDP, or 153 million dinars in 1999. In comparison with other countries in the region, these costs are relatively lower, and are in fact the lowest in terms of GDP percentage among the seven countries of the Region of Machrek and Maghreb where the degradation cost has been evaluated. However, these costs are not negligible and indicate that the greatest damage would be in two areas: (i) public health, especially in regard to water-borne diseases related to poor sanitation in the rural areas, respiratory diseases related to air pollution, and the impact of the lack of disposal and treatment of waste, and (ii) the productivity of natural resources, including the loss of agricultural productivity due to soil degradation and impact on property values due to lack of disposal and treatment of waste.[33]
- In 2007, the World Bank assessed the degradation of surface water, groundwater and coastal nationwide in Tunisia.[34] Costs have been estimated at about 0.5-0.7% of GDP, with an average of 0.6% of GDP or 203 million dinars in 2004. The report showed that the loss of irrigated agricultural productivity is the most significant, followed by that due to the overexploitation of groundwater. Agriculture is mainly affected as shown in Figure 4.1 by salinity (58%), followed by dam sedimentation (39%), but the effects on agriculture due to untreated wastewater is low (3%).
- **In 2011, the Economic Research Forum re-estimated the degradation cost covering three categories: air, water (waterborne diseases), and degradation of agricultural land.[35]** Costs have been estimated at approximately 2.5% of total GDP, the impact on the water was around 0.41% of GDP or 165 million DT waterborne diseases in 2008. Although this estimate was calculated 10 years after the World Bank, this assessment is of the same order of magnitude as that estimated by the World Bank study that refers to 1999.

- **In 2011, the European Commission estimated the increased benefits to the environment covering 5 categories: air, water, nature, waste, and global environment.[36]** The benefits were estimated at 4% of GDP from 71.6 billion DT in 2020, estimated if pollution were to be reduced by ± 50% by 2020 compared to 2008. The proportion of water in these benefits has been estimated at 0.7% of GDP in 2020 is

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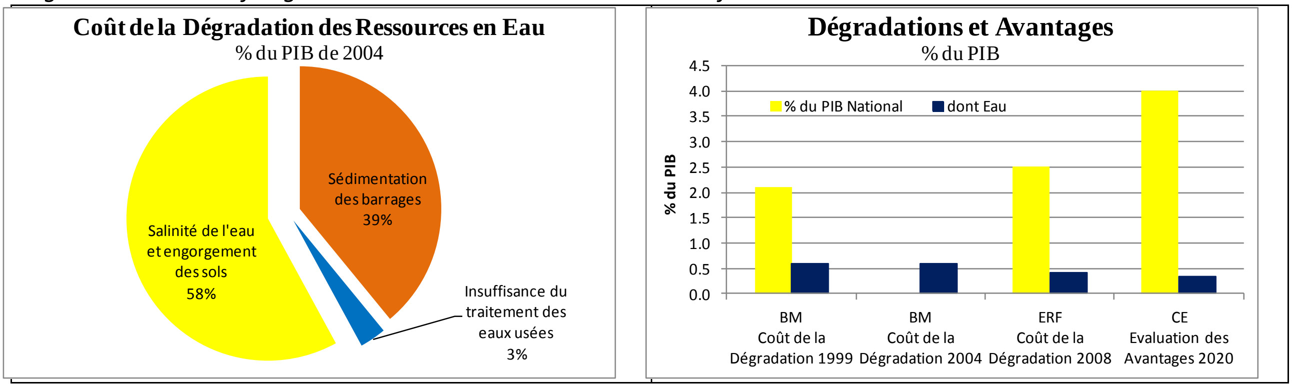
[30] World Bank website: <www.worldbank.org>.
[31] Sarraf et al. (2004).
[32] In 1999 the Tunisien GDP was estimated to be around 25 billion DT while it is actually 27.2 billion DT.
[33] It isimportant to note thatthe relatively lowcost ofenvironmental degradationdue to the problemofwaste management ismainlydue to the factthat itwas notpossible to initiatea comprehensive estimateof the impact ofwaste on human healthand natural resources. Thus, the impactof the lack oftreatment ofhazardousindustrial waste is notincluded in the estimate.
[34] World Bank (2007).
[35] ERF (2011).
[36] EC ENPI (2011).

514 million DT including waterborne diseases and degradation of water resources. In other words, in case pollution could not be reduced by 50% in 2020, the degradation cost considered as a lost benefit could reach at least the equivalent of 4% of GDP in 2020.

40. Based on the above sectoral study, in which a large part of water deterioration was also a result of watershed sedimentation such as dam siltation, the World Bank conducted a specific study on the creation of environmental benefits to improve watershed management in Tunisia[37] and especially in the Barbara watershed, located at the north of the Medjerda watershed. The study concluded that all land conservation practices in the basin during the period 1994-2008, such as reforestation with species of eucalyptus, acacia and oak cork, generated an additional net benefit for the country ranging between 3.3 and 23.8 million DT. In addition, dam siltation would be the result of watershed sedimentation and not land erosion whose sediments are deposited on the slopes and do not necessarily reach the reservoir of the Barbara dam.

Figure 4.1: Review of degradation costs and environmental benefits in Tunisia



Source: Sarraf et al. (2004), World Bank (2007), ERF (2011) and EC ENPI (2011).

41. The results of environmental degradation cost showed the same order of magnitude of water degradation in terms of GDP (0.4-0.6% of GDP) although these studies are not based on the same methodology, do not cover the same categories or number of categories, and do not have the same base year for assessment. However, in relative terms, the ratio was more or less maintained since the rate of GDP growth in Tunisia may exceed the growth rate of pollution such as the National Program Anti-Diarrhea, which reduced the cost of infant mortality by a factor of 10 between 1999 and 2004.[38] In absolute terms, the degradation cost will increase because actual GDP at current prices[39] has increased from 27.2 billion dinars in 1999 to 38.8 billion dinars in 2004 to 63.4 billion in 2010 despite the fact that DT rate decreased pollution is supposed, given the Government's ambitious agenda relating to drinking water, urban sanitation and waste management.

42. The study of the water resources degradation cost in the Medjerda basin will take these prior estimates into account but will focus effectively on the damage caused by water pollution and degradation of natural resources.

[37]Croitoru et al :Generation ofenvironmental benefitsto improvewatershed managementin Tunisia, World Bank, report No 50192-TN, November 2010.
[38]World Bank (2007).
[39]World Bank Indicators (2011).

5. METHODOLOGY, ASSESSMENT CALIBRATION AND LIMITS, AND CATEGORY

43. The costs of degradation were evaluated using available data whose source cannot be entirely reliable. In addition, gaps in the data have made it necessary to make several assumptions. The results are therefore considered **as an indication** and allow providing an order of magnitude. However, the results are considered useful to show the potential in relative values and can thus have a comparative use.

44. Moreover, it is difficult to define accurately environmental degradation that is strictly natural and that which is strictly of anthropogenic origin. In some cases, there is overlap between the two causes of degradation that occurs in mutual reinforcement, for example, the natural salinity of soil and water, which is exacerbated by human practices.

5.1 METHODOLOGY

45. The estimation techniques for impact assessment and economic valuation adopted mainly derived from proven methods and summarized in the Handbook of the World Bank on the **Degradation cost,**[40] the European Commission's Manual on **Benefit Assessment**[41] as well as othermanuals and other reference sources such as publications of **The Economics of Ecosystems and Biodiversity** (TEEB), also funded by the European Commission in cooperation with the German Government.[42] The main methods for estimating impacts are grouped around three pillars (Figure 5.1):

- *Change in production.*
- *Change in health condition through dose-response to establish the relationship between pollutant (inhalation, ingestion, absorption or exposure) and disease.*
- *Change of behaviour with two sub-impacts: revealed preferences, and stated preferences.*

46. The economic evaluation methods are grouped under each pillar (Figure 5.1).

47. For the impacts on production, three methods are suggested:

- Value of changes in productivity such as reduced agricultural productivity due to salinity and/or loss of nutrients in the soil;
- Opportunity cost approach, such as the shortfall of not re-using and re-sellingrecycled waste;
- Replacement cost approach when for example the cost of construction of a dam to replace a dam that was silted.

48. For the impacts on health, two methods are suggested:

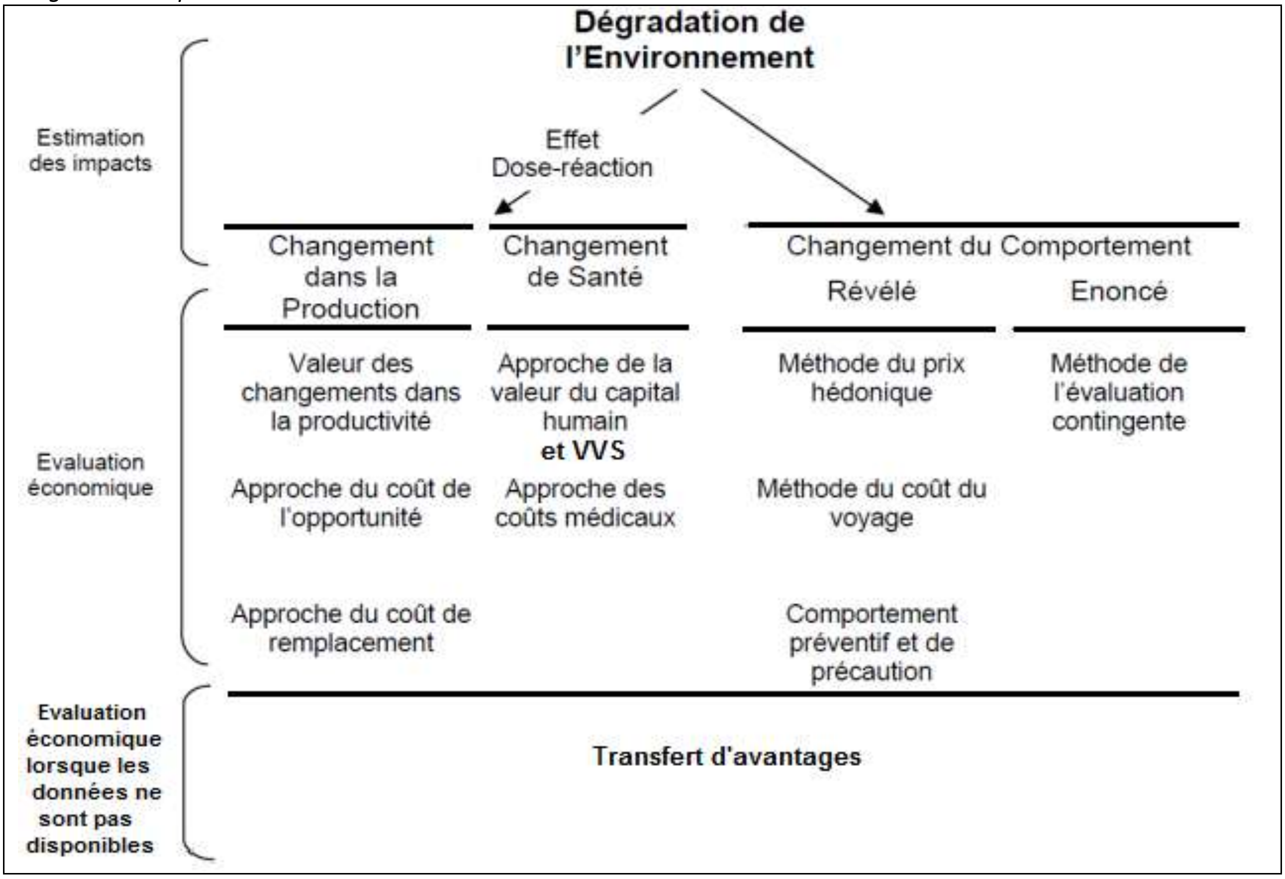
- The value associated with mortality through two methods: the ageshortfall due to premature death, and the willingness to pay to reduce the risk of premature death. Only the latter method is used in this study.
- The medical cost approach, such as the cost generated when a child of under 5 years is taken to hospital to be cured of diarrhoea.

[40] World Bank website: <www.worlddbank.org>.
[41] EC ENPI BA website: <www.environment-benefits.eu>.
[42] TEEB website: <www.teebtest.org>.

49. For behaviour change, two methods are suggested:
- Behaviour revealed by deriving the costs associated with behaviour: the hedonic cost, e.g. the cost of land around a landfill; the method of trying to derive trip travel costs to visit a specific place like Lake Ichkeul; preventive behaviour as when a household buys a filter for drinking water.
- Behaviour stated where a contingent valuation is used, through a survey for example, to derive willingness to pay to improve the quality of water resources.

50. In cases where data are not available, a benefit transfer can be made from studies made in other countries, by adjusting the results for differential income, education, preferences, etc.. The original results are based on one of the methods of economic evaluation of the three pillars mentioned above.

Figure 5.1: Impact estimate and economic evaluation



Source: Adapted from Bolt et al. (2005).

51. 2010 was used as the base year for the estimation of degradation costs. The evaluation of benefits (reduced degradation cost over a year) will be used to derive the restoration costs calculated for certain priority sub-categories. Restoration costs are based on a cost/benefit analysis (C/A) estimated on a case-by-case basis, covering the life of each investment (investment costs and the flow of benefits generated during restoration) when this is considered in the evaluation. Three indicators are taken into account in the C/A analysis to determine the profitability of the project with an economic discount rate of 10%:
- The net present value (NPV) is the difference between benefits and total discounted costs;
- The internal rate of return (IRR) is the discount rate that resets the NPV or the interest rate that makes the NPV of all cash flows equal to zero, and
- The B/C ratio, which is the ratio of the discounted value of benefits to the discounted value of costs over the life of the project, must be equal or greater than 1.

5.2 ASSESSMENT CALIBRATION AND LIMITS

52. In addition to resource and timeconstraints, the techniques used have their own methodological limitations. In general, in the process of fact-finding, it was clear that the availability, accessibility and update of information has posed many problems; however, these were overcome by persistence, appropriate key contacts and experience in dealing with local authorities.

53. The results allow for a margin of error due to sensitivity ranges (minimum, maximum) taken into account. In addition, a marginal analysis has been attempted in some cases to assess the benefits (reduction in the cost of environmental degradation) and investment costs.

54. Most valuation techniques used have their inherent limitations in terms of bias, hypothetical premise, and uncertainty, especially when it comes to non-tradables. In addition, the results are of course context-sensitive. The use of benefit transfer may therefore exacerbate the bias of results and uncertainties. Therefore, some results are mentioned in the text and should require a more thorough analysis when investments will be considered.

5.3 EVALUATED CATEGORIES

55. Four main categories were selected for evaluation of the watershed: water, waste, biodiversity, and the effects of of natural disasters and climate change. Sub-categories were also selected to meet the diverse impacts affecting the watershed shown in Table 5.1. However, air pollution has been selected only when there are emissions of greenhouse gases (GHG) and when hydropower generation is substituted by fossil fuels in times of drought and when there are methane emissions from landfills. Effects on coastal areas have been covered in this study only to the extent of the marine environment pollution (behaviour stated on improving the quality of water resources).In addition, certain investments considered for a given sub-category might as well have a positive impact on other categories; for example, better management of waste (urban and rural waste subcategory) could have a positive impact on the quality of water resources subcategory and/or the Biodiversity category.

56. , The degradation cost coverstherefore all subcategories while the cost of restoration covers only four subcategories. The selection criterion for calculating the restoration costs was based on subcategories experiencing significant degradation.

57. Categories, sub-categories, impacts and methods to assess the degradation cost and restoration of the environment are discussed in Table 5.1. The general and specific description of the methods of subcategories are found in Annexes II to IV.

Table 5.1: Sub-categories Categories, impacts and methods used for evaluating the degradation and restoration of Medjerda

Category	Sub-category	Impact	Degradation cost	Restoration cost
Water	**Quality and treatment:** drinking water in urban and rural areas	Consumer preference (tap water vs. Bottled water); see **Quality of Services** for waterborne diseases	CR and CC (cost plus processing)	Desalination of drinking water for dilution and investments upstream (see below)
	Quality of services: water and sanitation in urban and rural areas, and irrigation	Diseases related to water supply and quality, sanitation and hygiene; costs of alternative water sources (bottled, tank, wells, etc.); technical losses; and time loss while carrying water	CH/VVS and CS CR	Better service, service efficiency and coverage of drinking water, sanitation and hygiene awareness
	Quality of the resource (anthropogenic): discharges, effluents runoff (see **Waste**)	Surface water quality affecting: water use (domestic, agricultural, fisheries, industry and mining), basin ecosystem and (eutrophication, etc.) coastal areas; land, and eco-tourism	EC (restoration of water quality)	Investments in STEPs, reducing industrial waste (olive oil production wastewater) and reduction of use of pesticides and nitrates (see **Waste**)
		Groundwater quality affecting: water use (industrial, agricultural and drinking); the basin/coastal ecosystem; and eco-tourism	EC and RC (restoration of water quality)	Artificial recharge for dilution; substitution wells or desalination/water transport
	Salinity (anthropogenic and natural): surface and ground water, approx. marine and soil	Soil salinity, effects on health **(see Quality and treatment**), reduction of agricultural and fishery productivity, and effects on the ecosystem	CP (agricultural productivity)	Increased fertilizers (short-term measures) and land management (long-term measures to reduce salinity)
	Quantity (anthropogenic and natural): reducing the flow of surface water and lowering of groundwater levels	Surface: use of wastewater treated or untreated which can cause contamination of the food chain, and in extreme cases, require substitution via desalination	CP (agricultural productivity and additional cost of pumping/substitution)	Opportunity costs of water treated and reused, and of water desalination/transport
		Groundwater: deeper pumping, substitution wells or desalination (rapid lowering or fossil water) to meet domestic needs and/or maintain agricultural productivity	CP (agricultural productivity and additional cost of pumping/substitution)	Opportunity costs of pumping/substitution water
	Erosion and Storage: management is affected by erosion and exacerbated by climate change	Loss of land nutrients, sedimentation and siltation of dams, mountain lakes, river beds and coasts exacerbated by improper use of soil upstream due to deforestation, irresponsible soil management, water and wind erosion, etc.	CP and RC (dredging, raising dams or building new lakes/dams)	Costs: Land planning to prevent/reduce erosion
	Hydro-electric power: affected by a longer drought cycle	Reduced production in drought and substitution by fossil fuel plants (emissions of pollutants and greenhouse gases)	RC, CC (substitution by fossil fuel plants)	Costs: substitution by renewable energy plants
Waste	**Solid waste chain including sludge:** urban, rural, agro-industrial and agricultural	Discomfort, health, visual, olfactory, auditory pollution, pollution of air, soil and water (leachate runoff) and impact on the cost of land/buildings/apartments	CP, CR, RC, PH and CC	Costs: collection, transfer stations, separation and recycling stations, sanitary landfills

	Chain of medical and hazardous waste	Discomfort, health, visual, olfactory, auditory pollution, pollution of air, soil and water (toxic runoff and radioactive contamination) and impact on the cost of land/buildings/apartments	Not covered	Not covered
Biodiversity	**Various encroachments**	Loss of ecosystems and medicinal plants	EC meta-analysis; CR	Investments upstream (see above)
Natural disasters and general environment	**Floods, droughts, extreme events, etc**	Exacerbation of the intensity and frequency with impact on: health (mortality, injury, drowning, contagious diseases); property; services, infrastructure, productivity, resources (failure with resource reduction and effects on the ecosystem); etc.	CH/VVS and CS AR, CP, RC and RC	State of preparation and efficiency of response
	GHG emissions	5 variables of climate change and effects on land use, water, evapotranspiration, agriculture, etc.	CP, RC, RC and CC	Miscellaneous investments for adaptation, mitigation and resilience in progress or planned

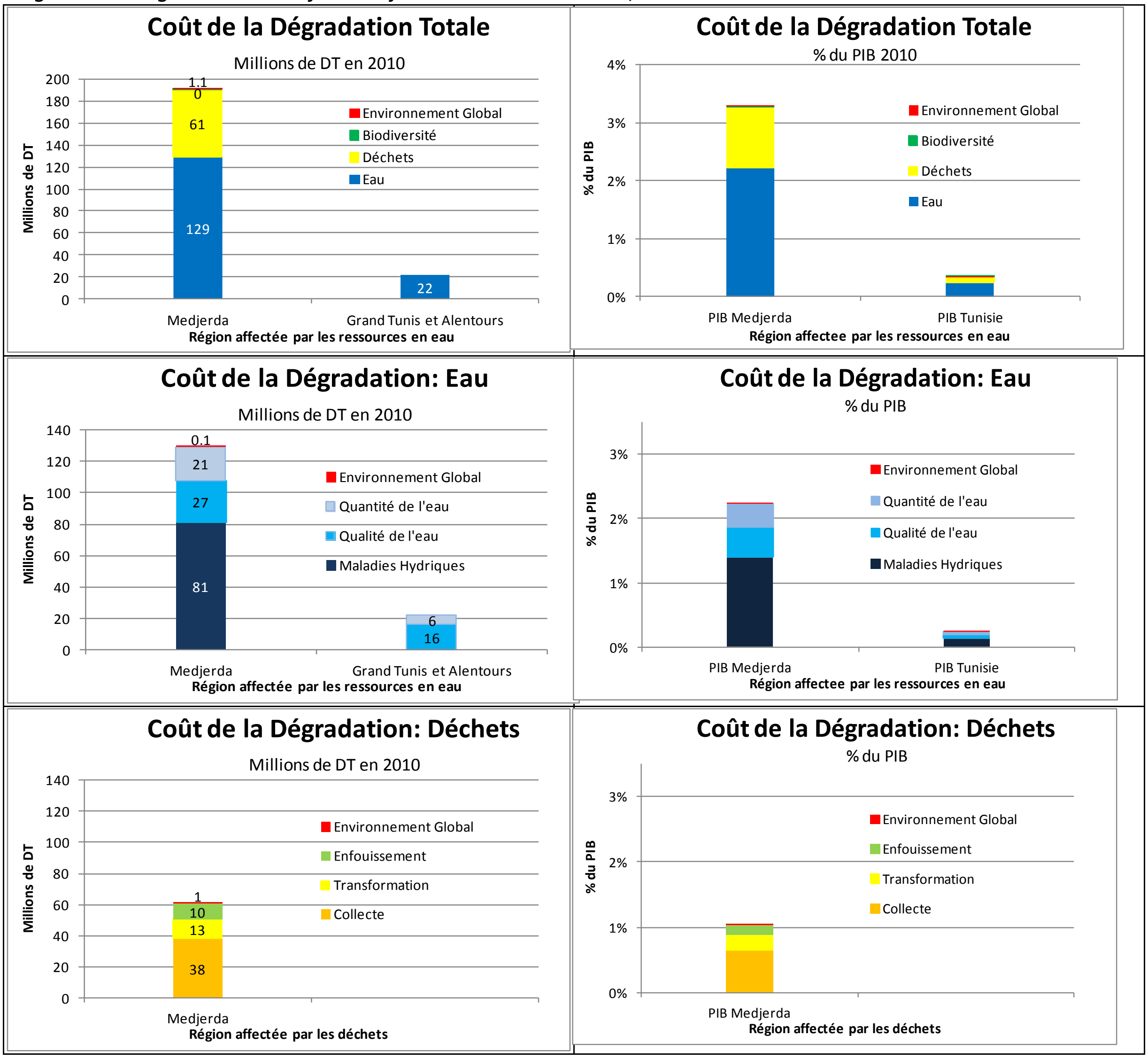
Note: CC: behaviour change, CS: cost of care CP: change of production CR: cost of restoration, PH: hedonic price, EC: contingent valuation, CH: human capital, AR: risk analysis, RC: replacement cost; VSL: value of a statistical life, and CC: carbon credits. Source: Authors.

6. DEGRADATION COST OF THE MEDJERDA BASIN

6.1 GENERAL OVERVIEW OF DEGRADATION COSTS

58. The results of the degradation cost of the Medjerda are shown in Table 6.1 and Figure 6.1. It should be noted that the total costs of the Medjerda and Greater Tunis are compared to Tunisian GDP (63.4 billion dinars in 2010) while the costs the Medjerda Basin (intramural) are compared to the Medjerda GDP (5.8 billion dinars in 2010) which has been extrapolated using GDP per capita for the Medjerda Basin (4,058 DT/capita in 2010) and multiplying by the number of inhabitants. The disaggregated results are available in Annex VI.

Figure 6.1: Degradation cost for Medjerda and Greater Tunis, 2010 in million DT



Source: Authors.

59. For Medjerda and Greater Tunis, this cost reaches 214 million DT in 2010,rangingfrom 149 to324 millionDT on average equivalentto around0.34% of the current GDP but0.85%of the constant GDP (as compared to2000)of Tunisiain 2010.As concerns Medjerda, the degradation costs are 192milliondinars in2010, rangingfrom 132 to296 millionDT on average equivalentto around3.3% of the Basin region GDP. The cost attributable to human health is 81 million DT in 2010 or 42.5% of the degradation cost of the Medjerda and 63% of the water category.(Table 6.1 and Figure 6.1).

Table 6.1: Degradation cost for Medjerda and Greater Tunis, 2010 in million DT

Categories	Medjerda	%	Minimum	Maximum	Greater Tunis	Minimum	Maximum	Total Medjerda and Greater Tunis	%	Minimum	Maximum
Water	129.5	68%	99.1	164.5	22.3	17.5	28.1	151.8	71%	116.6	192.6
Waste	60.5	32%	32.1	131.3	-	-	-	60.5	28%	33.7	130.9
Biodiversity	0.5	0%	0.4	-	-	-	-	0.5	0%	0.4	-
Natural disasters and General environment	1.1	1%	-	-	-	-	-	1.1	1%	-	-
Total	191.5	100 %	131.6	295.8	22.3	17.5	28.1	213.9	100 %	149.1	323.9
% GDP Medjerda	3.3%		2.3%	5.1%							
% GDP Tunisia								0.34%		0.24 %	0.51 %

Source: Authors.

60. Broken down by category, water degradation is the largest in Greater Tunis and Medjerda in relative value, with 68% of the total in 2010. Wastes come second with 32% relatively, biodiversity with 0.01% and the overall environment with 1%. There were no natural disasters in the Medjerda basin in 2010 and therefore they have not been taken into account in this assessment.

61. Broken down by the water subcategory (130 million dinars in 2010), waterborne diseases account for the majority of costs in the Medjerda Basin (81 million DT), followed by water quality (27 million DT), water quantity (21 million DT, relatively low amount since 2010 was a wet season) and finally the overall environment (1 million DT).

62. Broken down by the waste sub-category (61 million DT in 2010), collection represents the majority of costs in the Medjerda Basin (38 million DT) followed by waste processing (13 million DT), landfills (10 million DT) and finally general environment (1 million DT).

6.2 WATER CATEGORY AND SUB-CATEGORIES

6.2.1 Drinking water quality and treatment

63. The perception of water quality reflects a different picture and varies among consumers in Tunisia with 66.8% of consumers having confidence in tap water, while 32.2% having no confidence. Still, it is mainly the salinity of the water problem with an average salinity of the water distributed between 1 and 1.5 g/l according to SONEDE,[43] against a maximum of 0.2 g/l recommended by the European Directive 98/83 EC.However, in terms of taste, 95.2% of consumers prefer mineral water and by extension bottled

[43]SONEDE website: <www.sonede.com.tn>.

water. In fact, the consumption of bottled water is increasing with morethan 45 litres of bottled water consumed per household per year in 2008, but with a reduction of a quarter of the rural consumption.[44]

64. The degradation cost was derived from this overuse of bottled water in the basin of theMedjerdaand Greater Tunis. This excess seems to be partly due to consumer perception of the poor quality of water but also water taste because of the high salt content of tap water. The degradation cost amounts to 19.3 million DT with a range of between 12.9 and 25.8 million DT (Table 6.2). This amount remains conservative in view of the annual growth of the use of bottled water by the consumer.

Table 6.2:Degradation cost due to drinking water quality, 2010

Region	Population	Number per household	Household number	Bottled water consumption	Average cost of bottled water	Urban	Rural	Total	Equivalent cost of unused water network	Net degradation cost
	million	#	million	l/household/year	DT/l	million DT	million DT	million DT	million DT	million DT
Greater Tunis	1.6	4	0.39	45-60	0.4-0,6	10.6		10.6	0.05	10.6
Medjerda Basin: urban	0.6	5	0.13	45-60	0.4-0.6	3.4		3.4	0.02	3.4
Medjerda Basin: rural	1.6	6	0.27	34-45	0.4-0.6		5.4	5.4	0.03	5.4
Total in million DT						14.0	5.4	19.4	0.10	**19.3**
Minimum in million DT										*12.9*
Maximum in million DT										*25.8*

Note:77% of the rural population has access to drinking water (Table 7.3).
Source:Authors.

6.2.2 Quality of Water and Sanitation Services

65. The rate of access to drinking water is almost 100% in urban and 94% in rural areas in 2010,[45] according to official sources. Exceptionally, some peripheral suburbs may have access equivalent to 85% as some neighbourhoods in Greater Tunis. On the other hand, the rate of sanitation coverage reaches 99%[46] in urban areas but rural households connected to the sewage system do not exceed 5%, always according to official sources.[47] However, it is difficult to have an exact rate of coverage for both drinking water and sanitation, due to the duality of institutional responsibilities (see Section 2); Table 6.3 would reflect a more realistic coverage for drinking water and sanitation in urban and rural areas in Tunisia in 2010.

Table 6.3: Typology of access to drinking water and sanitation,% population considered, 2010

Typology of access in Tunisia	Urban	Rural	Total
Drinking Water			
Improved access	94%	39%	76%
Other access improved	5%	45%	18%
Access not improved	1%	16%	6%
Sanitation			

[44] Quotidien Le Temps website: <www.turess.com/fr/letemps/24223>.
[45]HédiBelhaj'spresentation: <www.w-e-x.com/downloads/l'eaupotableentunisie (1erepartie).pdf>.
[46] Khalil Attia'spresentation: < http://www.oecd.org/mena/governance/43316523.pdf>.
[47]MdE (2012).

Toilet connected to sewer	82%	5%	56%
Other sanitation improved	15%	62%	31%
Sanitation not improved	3%	33%	13%
- Out of which: defecation in nature	*0%*	*14%*	*5%*

Source: adapted from Van Acoleyen and Baouendi (2011).

66. The prevalence of diarrhoea and mortality due to diarrhoea in the basin of rural Medjerda were derived from national statistics with 1 death on 15.1 newborns per 1,000 inhabitants in 2010. The prevalence of diarrhoea was 2.5 cases per child under 5 years and 0.5 cases per population equal to or more than 5 years.[48] The cost of damage amounted to 81 million TD in 2010, with a range of between 68 and 94 million TD (Table 6.4).

Table 6.4: Degradation cost associated with access to drinking water and sanitation, 2010

Rural population	2010	Diarrhoea coefficient	Mortality due to diarrhoea	Cases of diarrhoea	Value per case	Degradation cost
		#	#	Million	DT	Million DT
Medjerda population (million)	1,564					
Birth rate (Number of newborns per 1,000 inhabitants)	15.1	1.0	138		378,643	52.4
Population < 5 years (million)	0.121	2.5		0.3	45	13.6
Population ≥ 5 years (million)	1,443	0.5		0.7	21	15.3
Total						**81.3**
Minimum						*68.2*
Maximum						*94.4*

Sources: adaptedfrom Bassi et al. (2011); World Development Indicators (2011); Tunisian Annual Statistics 2006-2010 (2011); and authors.

67. The American Water Works Association[49] suggests a reference point (benchmark) of 10% water losses acceptable for service providers. A range of more than 10% to 25% is considered intermediate and should be a focus for reducing losses to less than 10%. Water losses above 25% are considered chronic and require immediate attention. In fact, the production of drinking water in Tunisia records losses especially in the network, averaging 26%[50] or 136.4 million m^3 in 2010, equivalent to a loss of 12.8 m^3 per capita. Thus, 16% of the production could be considered a cost borne by taxpayers with no return on investment equivalent to 7.8 m^3 per capita loss or 37.3 m^3 per household in Greater Tunis.

68. The amount of the loss per capita has been examined for the population in the Medjerda Basin in non-rural areas as well as the Greater Tunis and its Surroundings. The opportunity cost was considered equal to the third level of the progressive rate equivalent to 0.315 DT per m^3 which was introduced in 2010. Thus the degradation cost rises to 1.5 million DT for the Medjerda population and 6.1 million DT for Greater Tunis with a total of 7.6 million DT and a variation of 6.5 to 8.8 million DT in 2010 (Table 6.5).

[48] Bassi et al. (2011).
[49] AWWA website: <www.awwa.org>.
[50] Tunisian Annual Statistics 2006-2010 (2011).

69.

Table 6.5: Degradation cost associated with preventable technical losses of distribution, 2010

Services in the Greater Tunis and Surroundings	Production	Annual Production	Preventable technical losses (16%)	Degradation cost for Greater Tunis	Degradation cost for the Basin in non rural areas	Total degradation cost
	m^3/day	million m^3/year	million m^3/year	million DT	million DT	million DT
Winter (8 months)	280,000	67.2	10.8	3.4		3.4
Summer (4 months)	450,000	54	8.6	2.7		2.7
Total				**6.1**	1.5	**7.6**
Minimum				*5.2*	1.3	*6.5*
Maximum				*7.0*	1.8	*8.8*

Source: Annual Report SONEDE (2011), Statistical Yearbook of Tunisia 2006-2010 (2011).

70. The cost of irrigation inefficiency in the Medjerda basin and in areas where water is transferred, such as the Cap Bon, has not been calculated due to lack of reliable data.

6.2.3 Quality of water resources

71. Given the multiplicity of sources of pollution and the number of pollutants along the Medjerda and its mouth, a method based on ***stated preferences*** was used for evaluation.In addition, certain investments in pollution abatement are underway but the estimation of all the investments needed to reduce pollution and the restoration or maintenance of ecosystem **functions** and services exceed the scope of this study. Baker et al. (2007) have recently conducted a survey to estimate the economic value placed by households in England and Wales to improve water quality at both watersheds and coastal areas in the context of the implementation of the EC Water Directive (see Annex II). Transfer of benefits is thus considered to derive the degradation cost of the Medjerda Basin. After the transfer of benefits, the willingness to pay amounts to 14.3 DT per household per year for a tangible improvement after 6 years. Thus, the degradation cost amounts to 5.6 million DT for the population in Medjerda and 5.6 million DT for the Greater Tunis and its Surroundings with a total of 11.3 million and a variation of 10.5 to 13.9 million dinars in 2010 (Table 6.6).

Table 6.6: Degradation cost of water quality in Medjerda, 2010

Area	Population	Number of inhabitants per household	Willingness to pay DT/year			Degradation cost Million DT		
	Million	#	*Minimum*	**Average**	*Maximum*	*Minimum*	**Average**	*Maximum*
Greater Tunis	1.6	4	13.4	14.3	17.6	5.3	5.6	6.9
Medjerda Urban	0.6	5	13.4	14.3	17.6	1.7	1.8	2.2
Medjerda Rural	1.6	6	13.4	14.3	17.6	3.6	3.8	4.7
Total						10.5	11.3	13.9

Source: Baker et al. (2007); World Bank (2011); and Authors.

6.2.4 Salinity

72. The average salinity of 3.0 deciSiemens per meter (dS/m) is commonly used in the region of Medjerda but overall soil salinity is usually positively correlated with that of the irrigation water, which can produce lower or higher averages in parts of the Medjerda. Only the three main crops in Medjerda have been considered because of the difficulty in obtaining agricultural production information by region: tomatoes, wheat and olives. However, the opportunity cost of the capital loss associated with the agro-industrial production of the three crops has not been considered (e.g., olive oil, etc.).

73. Salinity, even at low doses, can affect agricultural production. Thus, salinity levels and reductions in productivity were developed by Kotuby-Amacher et al. (2003) and Evans (2006)[51] for each crop and are based on the electrical conductivity of saturated soils (CEs) expressed in dS/m. However, other factors could affect the tolerance level of crops (variety, climate, etc.) and therefore the thresholds are merely suggested as a guide. The reduced productivity due to salinity affecting agricultural production affects only the production of tomatoes and olives because wheat has a high salt tolerance. Lost productivity amounts to 37 million DT with a variation from 29.6 to 44.3 million dinars in 2010 (Table 6.7). This amount, which takes only three cultures into account, is very conservative and this analysis would be worth expanding. However, the additional use of fertilizers should compensate for this loss of productivity while creating a vicious cycle (runoff), but it is not possible to determine the cost of such *preventive behaviour.*Thus, we estimate that despite the use of fertilizers, a third of the productivity loss is due to degradation as a result of soil salinity. Thus, the degradation cost totals 12.3 million DT with a variation from 9.9 to 14.8 million dinars in 2010.

Table 6.7: Losses of agricultural productivity due to salinity, 2010

Main crops	Medjerda	Salinity level CEs	Reduction in crop yield CEs				Gross price	Productivity losses at -10%		
								Average	*Minimum*	*Maximum*
	Tons	dS/m	-10% with dS/m at:	-25% with dS/m at:	-10% Tons	-25% Tons	DT/ton	Million DT	Million DT	Million DT
Tomatoes	366,667	2.5	3.5	5.0	18,333	91,667	422	7.7	6.2	9.3
Wheat	479,190	4.7	6.0	8.0	0	119,798	550	0	0	0
Olives	584,267	2.6	3.0	3.5	58,427	146,067	500	29.2	23.4	35.1
Total								**37.0**	29.6	44.3
Degradation cost								**12.3**	9.9	14.8

Note: the reduction in the yield of tomatoes is estimated at 5% to reach 3 dS/m thus accounting for linear reduction. The production of tomatoes and olives is an estimate and represents more than half of national production in 2010.
Source: MoA website <www.adriportail.tn>; Kotuby-Amacher et al. (2003) ; and Evans (2006).

6.2.5 Quantity

74. For groundwater resources, the amount of water is affected by a drop in the groundwater level and deep resources by 0.4 m per year requiring additional pumping. Thus, the ***change in production*** is taken into account to derive the additional cost of pumping equivalent to the degradation cost. The degradation cost thus rises to 0.45 million DT with a variation from 0.38 to 0.52 million DT in 2010 (Table 6.8).

[51] Australian Government website: <www.dpi.nsw.gov.au/agriculture/resources/soils/salinity/crops/tolerance-irrigated>.

Table 6.8: Additional cost for pumping in the Medjerda basin, 2010

Pumping cost	Unit	Groundwater resources	Deep resources	Degradation cost
Resources affected by the drop	Million m^3	252	28	
Average use of diesel	l/m of depth/m^3	0.004	0.004	
Annual average drop of groundwater level	m	0.4	0.4	
Market price	DT/litre of Diesel	1,010	1,010	
Annual cost of diesel-driven pumping	**DT/year**	**407,232**	**45,248**	**452,480**
Minimum				*384,608*
Maximum				*520,352*

Source: adapted from the World Bank (2007).

75. For surface resources, the non-replacement of the dam lost capacity due to siltation can lead to the reduction of water availability for users (see Storage below). Since agriculture is a major consumer of water from dams in Tunisia, the impact of siltation on irrigated agriculture has been assessed following the **change in production**. Considering a consumption of 5,000 m^3/ha for intensive irrigation, a shortfall would be the difference between the value added of agricultural production between intensive and non-intensive irrigation. All other factors remaining constant, a shortfall of 2,007 DT/ha for all crops was selected.[52] The degradation cost amounted to 4.3 million TD with a variation from 3.9 to 4.8 million dinars in 2010 (Table 6.9).

Table 6.9: Agricultural impairment due to loss of dam storage in the Medjerda, 2010:

Dam	Siltation in 2010	Allocation for intensive irrigation	Agricultural added value due to intensive irrigation	Degradation cost
	Million m^3	M^3/ha	DT/ha	Million DT
Nebeur-Mellegue	2.5	5,000	2,007	1.00
Ben Metir		5,000	2,007	-
Kasseb	0.2	5,000	2,007	0.08
BouHertma	0.2	5,000	2,007	0.08
Sidi Salem	6.8	5,000	2,007	2.73
Siliana	1.1	5,000	2,007	0.43
Lakhmess	0.0	5,000	2,007	0.01
Rmel		5,000	2,007	-
Laaroussia		5,000	2,007	-
Total	**10.8**	5,000	2,007	**4.32**
Minimum				*3.89*
Maximum				*4.76*

Source: Data provided by the MoA, Large Dams and Hydraulic Works, Operations Directorate of Dams and Hydraulic Structures Maintenance (2010), World Bank (2007) and World Development Indicators (2011).

6.2.6 Erosion and Storage:

76. In agricultural lands, soil erosion occurs mainly by widespread and pernicious soil stripping and gullies located on steep slopes. The complex relationship between erosive rainfall events and the annual rate of soil loss can be explained by two important factors. The first is related to the cycle of soil degradation which determines the potential of soil erosion in the basin. The second factor is the orientation of the degradation, which in this case has north-west and south-east direction. Remote detection studies have

[52] World Bank (2007).

identified a loss of 14.5 tons per hectare throughout the Ridge.[53] In fact, this soil erosion results in nutrient loss which should be compensated by fertilizers. In addition, erosion is also responsible for a loss of carbon sequestration not calculated in this study.

77. In addition, mountainous lakes and dams also undergo this erosion, exacerbated by climate change and reducing the life of mountainous lakes to 14 years[54] in the Ridge as well as storage capacity of at least 6 out of 9 dams in the Medjerda Basin (see above Quality and Treatment of Drinking Water).

78. The ***replacement cost*** for calculating the degradation cost of agricultural productivity due to erosion is the loss of the soil nutritional because of fertilizers. A total of 27.1 DT per ha of fertilizer is based on a mix of chemical and organic fertilizers. Thus, the degradation cost amounted to 7.4 million DT with a variation from 3.7 to 14.8 million TD in 2010 (Table 6.10).

Table 6.10: Soil nutrient loss due to soil erosion in the Medjerda, 2010

Governorate	Cultivated surface area	Surface area affected			Erosion	Cost of fertilizers	Degradation cost		
		1/4: Average	***1/8 : Minimum***	***1/2 : Maximum***			**Average**	***Minimum***	***Maximum***
	Ha	Ha	Ha	Ha	Ton/ha	DT/ton	Million DT		
Ariana	20,830	5,208	2,604	10,415	14.5	27.1	0.1	0.1	0.3
Manouba	80,700	20,175	10,088	40,350	14.5	27.1	0.5	0.3	1.1
Beja	250,210	62,553	31,276	125,105	14.5	27.1	1.7	0.8	3.4
Jandouba	165,780	41,445	20,723	82,890	14.5	27.1	1.1	0.6	2.2
Le Kef	288,470	72,118	36,059	144,235	14.5	27.1	2.0	1.0	3.9
Siliana	284,580	71,145	35,573	142,290	14.5	27.1	1.9	1.0	3.9
Total	1,090,570	272,643	136,321	545,285			7.4	3.7	14.8

Source: MoA website <www.agriportail.tn>; and Jebari (2009).

79. The ***replacement cost*** for calculating the degradation cost of dams, which are only considered in this study, is based on the World Bank (2007) with a lower limit comprising of build-up of dams to replace the lost storage volumes (based on the cost of the build-up of the Mellegue dam); this amounts to 0.006 DT/m^3, with a maximum consisting in the construction of new dams and amounting to 1.31 DT/m^3 in 2010. Thus, the degradation cost amounts to 7.1 million DT with a variation from 0.1 to 14.1 million dinars in 2010 (Table 6.11). It is important to note that the cost of dredging has not been considered given sediment quality (content of heavy metals from old mines), which could have a negative impact in areas where they would be discharged.

Table 6.11: Dam siltation in the Medjerda, 2010

Dam	Siltation in 2010	Replacement costs Minimum		Replacement costs Maximum		Degradation cost
	Million m^3	DT/m^3	Million DT	DT/m^3	Million DT	Million DT
Nebeur-Mellegue	2.5	0.006	0.01	1.31	3.26	1.64
Ben Metir		0.006	-	1.31	-	-
Kasseb	0.2	0.006	0.00	1.31	0.26	0.13
BouHertma	0.2	0.006	0.00	1.31	0.25	0.13
Sidi Salem	6.8	0.006	0.04	1.31	8.91	4.47
Siliana	1.1	0.006	0.01	1.31	1.39	0.70
Lakhmess	0.0	0.006	0.00	1.31	0.04	0.02
Rmel		0.006	-	1.31	-	-
Laaroussia		0.006	-	1.31	-	-
Total	**10.8**		**0.06**		**14.11**	**7.09**

[53] Jebari (2009).

[54] Ibid.

Source: Data provided by the MoA, Large Dams and Hydraulic Works, Operations Directorate of Dams and Hydraulic Structures Maintenance (2010), World Bank (2007), World Development Indicators (2011), and Authors.

6.2.7 Hydro-electric power:

80. Hydroelectric (HE) power production, which is concentrated in the north of Tunisia, strongly correlated with rainfall in the north-east and north-west of Tunisia between 2000 and 2010 (correlation coefficient 0.85). The annual average over the period was 89 million kW/h with an average of 0.7% of the total electricity production (Table 6.12).

Table 6.12: Correlation between rainfall and hydropower, 2000-2010

Corelation data	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Rainfall in the North (mm)	452	501	397	762	758	691	551	545	444	697	710
HE production (Million kW/h)	64	54	64	166	154	145	92	48	31	78	83
HE production (% of the total)	0.60	0.47	0.54	1.34	1.18	1.05	0.65	0.33	0.20	0.50	0.51
Total Production (Million kW/h)	10.596	11.392	11.841	12.411	13.067	13.793	14.122	14.661	15.303	15.693	16.251

Source: Global Perspective website: <www.perspective.usherbrooke.ca>; Rainfall Yearbook (2011); and Authors.

81. The degradation cost is related to hydropower generation in northern Tunisia which is offset by gas or fuel-based production in drought years. The degradation cost was calculated using the cost of production factors for the substitution of electricity generation and the cost of carbon for GHG emissions. However, the effects of environmental pollutant emissions associated with the use of fossil fuels have not been evaluated. Based on an average of 11 years, the loss of hydropower is 5.97 million kW/h in 2010. The degradation cost thus rises to 0.76 million DT from 0.66 million DT as cost alternative for producing electricity using fossil fuels and 99,987 DT for equivalent carbon emissions in 2010 due to fluctuating water flows (Table 6.12). Also, 2008 seems to have been the driest year of the decade with a loss of HE production of 58.4 million kW/h and degradation cost of almost 7.5 million DT (including 6.5 million DT representing the cost of substitution) as opposed to 2003, which is a wet season and led to HE gains as compared to the average with a negative degradation cost of 9.9 million DT (including -8.6 million DT representing the cost of substitution) in 2010 prices (Table 6.13).

Table 6.13: Cost of hydroelectric degradation due to changes in water flow, 2010

Effects of Water Flow Fluctuations	Loss of HE production as compared to the average (11 years)	HE: CO_2 emissions	Fuel/Gas: CO_2 emissions	Net CO_2 emissions	Total CO_2 emissions	Overall cost of CO_2 emissions	Production factors	Degradation cost
	Million kW/h	CO_2/kW/h	CO_2/kW/h	CO_2/kW/h	Ton	DT/ton	DT/kW/h	Million DT
Substitution cost: 2010	**5.97**						**0.11**	**0.66**
Minimum	*5.97*						*0.09*	*0.54*
Maximum	*5.97*						*0.13*	*0.78*
Excess GHG: 2010	**5.97**	**0.004**	**0.887**	**0.883**	**0.005**	**19**		**0.09**
Minimum: 2008	*58.4*	*0.004*	*0.887*	*0.883*	*0.052*	*19*		*0.98*
Maximum: 2003	*-77.3*	*0.004*	*0.887*	*0.883*	*-0.068*	*19*		*-1.29*

Total	**0.76**

Source: Green It website <www.greenit.fr>; Tunisian Industry website: <www.industrietunisienne.nat.tn>; Global Perspective website: <www.perspective.usherbrooke.ca>; and Authors.

6.3 SOLID WASTE CATEGORY

82. Waste management in the Medjerda basin remains problematic especially in rural areas. However, it is not the entire waste chain that has a direct impact on water resources: it is mainly landfills with leachate runoffs. However, the degradation cost of the chain of domestic, agricultural and agro-industrial waste is considered in this study.

Table 6.14: Degradation costs due to waste, 2010 in million DT

Results	Collection in rural areas	Cost of landfill cleaning for waste generated	Recycling shortfall	Biomass-based power production shortfall	Depreciation of land adjacent to landfills	Future shortfall for electricity production discounted at 5%	GHG non-avoided in future discounted at 5%	Total
Degradation cost	**26.8**	**11.2**	**7.6**	**5.2**	**6.5**	**3.3**	**1.0**	**60.5**
Minimum	13.4	5.8	5.3	0.0	4.3	0.0	0.0	28.8
Maximum	40.2	12.6	8.4	58.3	8.6	3.3	1.0	132.4

Source: Annex IV.

83. Degradation costs due to waste amount to 61 million DT in 2010 with a variation from 29 to 132 million dinars in 2010 (Table 6.14). The degradation costs include: non-collection in rural areas, the cost of cleaning landfills for waste generated in 2010, the shortfall in recycling in 2010, the shortfall in power generation through biomass (agricultural waste), the depreciation of land near landfills, the future shortfall of electricity generation expected at 5% (discounted at the present time) and GHG not avoided in future expected at 5% (discounted at the present time).The description of the methodology and calculations are included in Annex IV.

6.4 BIODIVERSITY CATEGORY

84. The role of wetlands as usage values (e.g. in agriculture, fishing, flood mitigation, groundwater recharge) and non-usage values (as habitat for aquatic species) have been validated in several studies in Tunisia.[55] The degradation of biodiversity is reflected both by the decrease in wet areas as well as the reduction in the wealth of fauna and flora.Although the construction of dams has increased the area of wetlands to 22,400 ha since 1945 and sewage water settling ponds in the treatment stations constitute artificial wetlands, the latter cannot replace natural wetlands that provide habitats and ecosystems more favourable to the survival of many plant and animal species. In addition, the highly non-stationary release of water for flood management, including optimizing the production of electricity (Sidi Salem Dam) causes the most significant and most obvious changes in the flow regime thus resulting into direct impact on the morphology of the riverbed and loss of biodiversity.

[55] World Bank (2007).

85. The main causes of wetland loss in the Medjerda are drainage, urbanization in medium-sized cities along the river, the effect of old and new mines, agricultural expansion, and the creation of dams and hillside lakes upstream. In addition, these wetlands are polluted by sources mentioned above in the Water and Waste sections. According to Karem et al. (1999), Medjerda has lost 10,440 hectares of wetlands.

86. It is very difficult to assess the actual loss of biodiversity in the Medjerda. However, considering the average adopted by the World Bank (2007) for the Medjerda basin, the annual loss would be 10 hectares of wetlands. *Replacement cost* was used to assess the degradation cost. It is important to note that this approach is affected by significant limitations. On the one hand, the use of actual expenditures may underestimate the damage costs because they can rarely compensate for all services previously provided by the original ecosystem especially with respect to the effect of dam water releases on biodiversity. TEEB[56] has estimated the cost of replacement of a wetland based on a comprehensive meta-analysis. The cost amounts to 47,091 DT per ha. The average wetlands lost per year in the Medjerda, as derived from the World Bank (2007), is 10 ha. Thus, the degradation cost, which remains highly underestimated, amounts to 470,910 dinars in 2010 with a minimum of 400,000 DT and an unspecified maximum.

6.5 NATURAL DISASTERS AND GENERAL ENVIRONMENT CATEGORY

6.5.1 Natural disasters

87. Several projects are underway to reduce the risk of flooding in Tunisia. One of them is the PISEAU II project, with part of $EU 170 million intended for the management of water resources in river basins at risk. A project of 140 million DT, partially funded by JICA, covers priority flood zones in Tunis that require the construction of several drainage channels. In addition, JICA has also funded a study to reduce flooding in the Medjerda watershed. Greater Tunis has been the object of a study funded by the BAfD to diagnose the current situation in all catchment areas for four governorates (Tunis, Ariana, Ben Arous and Manouba) and recommend investments to reduce flooding. In addition, a study by the World Bank has focused on the vulnerability of the Greater Tunis to climate change, in this case, the accelerated rise in sea level and neighbourhoods at high risk of flooding.

88. The evidence provided by climate projections indicate potential increased frequency of flood flows that in the Medjerda that would affect Greater Tunis. However, the year 2010 was relatively free of major events regarding natural disasters, including floods, especially when compared to 2009 when several flooding episodes occurred with casualties and damage being reported. Thus, the cost of environmental degradation associated with natural disasters is not considered for the year 2010.

6.5.2 Overall Environment

89. Theimbalance between surface water use compared to groundwater use to the detriment of the former will become more pronounced in the future. This imbalance will be further exacerbated with the effects of climate change. Indeed, in addition to the expected increase in temperature, leadingtoincreased evapotranspiration, reduced rainfall should also be expected. This could lead to both a lower recharge of aquifers as well as increased use of these aquifers by farmers to offset the growing deficit between rainfall and evapotranspiration.

90. However, only GHG emissions were considered in the context of general environment and were covered under Hydroelectric Production and Solid Waste, amounting to 1.1 million dinars in 2010.

[56] TEEB website: <www.teeb.org>.

6.6 CONCLUSIONS

91. The cost estimate of water resource degradation has resulted in the following conclusions:
    a) The cost of water salinity (11 million DT) within and beyond the Medjerda basin is almost equal to the salinity cost in agricultural production (12.3 million DT) within the same basin.
    b) Damage due to lack of access to drinking water and rural sanitation (81 million DT) in the Medjerda basin is significantly higher than damage due to drinking water salinity.
    c) Poor collection and lack of solidwaste treatment result in less important damages (61 million DT) than those due to lack of access to safe drinking water and sanitation in rural areas (81 million DT).
    d) Damages affecting the River Medjerda water quality are less pronounced (17 million DT), which suggests that land-based pollution is not fully discharged into the river.
    e) Damages created by erosion in dam siltation of dams are around 7.1 million DT, which may mean that dam siltation may be the result of sediments in watersheds and not necessarily erosion of land sediments that do not always reach dam reservoirs. These damages are almost equivalent to soil nutrient losses due to erosion (7.4 million DT).

92. Based on these findings, four priorities emerge for the short- and the medium-term:
    a) Treatment of drinking water salinity;
    b) Sanitation in rural areas;
    c) Solid Waste collection and treatment; and
    d) Effectiveness of land planning for dam siltation reduction.

7. COST OF REMEDIATION OF THE MEDJERDA BASIN

7.1 GENERAL OVERVIEW OF REMEDIATION COSTS

93. Based on the priorities identified in the previous section, four intervention scenarios were considered but only three were implemented. Only the drinking water salinity, water and sanitation in rural areas and muncipalwaste management have been evaluated as categories. Interventions related to land use for erosion reduction and, thus, dam siltation have not been considered due to lack of studies establishing a causal link between land use and siltation reduction in order to perform economic assessment.

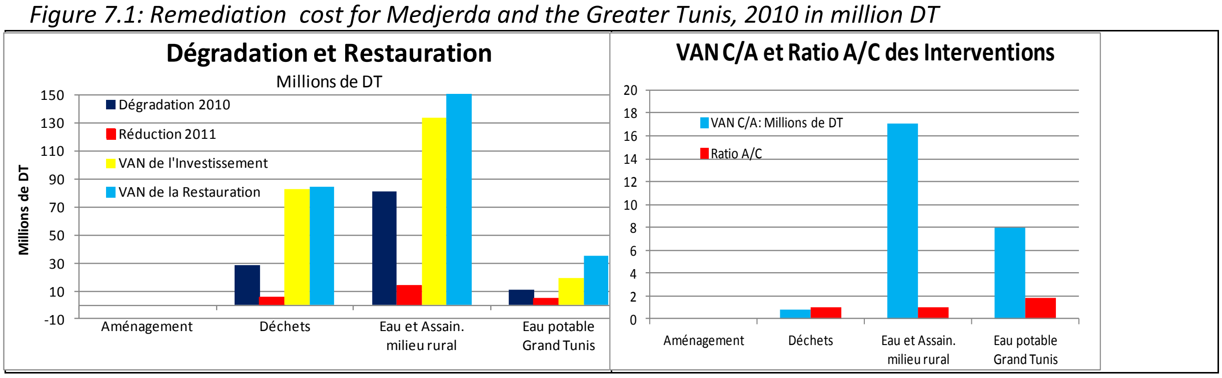
94. The most efficient scenarios were selected and are shown in Table 7.1 and Figure 7.1. On water and sanitation in rural areas, the combination of the *sanitation* scenario and *drinking water and sanitation* scenario can make the latter profitable. Concerning drinking water in Greater Tunis, desalination of part of the water resources in order to dilute the drinking water salinity is profitable. However, this alternative has not been compared to the cost of transporting water from the Barbara Basin dams, and it would become unprofitable if the threshold of 30,000 m^3/day over three months of desalination is exceeded. The strategic reserve of the Barbara Basin can ensure not only the safety of the resource, but also achieve water dilution when the salt content is high in summer, especially during dry seasons. For waste alone, any alternative to landfill with electricity generation in cells is profitable. The segregation and recycling alternatives are not profitable because they are too costly. Thus, to overcome this shortcoming, a multicriteria analysis could be considered for decision making with the focus not only on the C/A analysis but also on employment creation, poverty reduction, etc.

Table 7.1: Remediation cost for Medjerda and the Greater Tunis, 2010 in million DT

Medjerda and Greater Tunis	Degradation 2010	Reduction 2011	Investment NPV	Restoration NPV	C/P Analysis NPV
	Million DT	Million DT	Million DT	Million DT	Million DT
Planning	0	0	0	0	940-5,050 DT/ha 1,100-5,400 DT/ha
Waste	28.6	5.7	83	84	0.9
Water and Sanitation in rural areas	81.3	13.7	133.7	150.7	17.1
Drinking water in Greater Tunis	10.6	4.4	19	35	8.0

Source: Authors.

Figure 7.1: Remediation cost for Medjerda and the Greater Tunis, 2010 in million DT



Source: Authors.

95. The remediation cost analysis of three categories based on the net present value (NPV) of the investment over 20 years (24 years for waste) with a rate of 10% discount and internal rate of return (IRR), has identified the most efficient investments as follows:

a) For drinking water, desalination of 20,000 m^3/day over three months will have an NPV of DT 8 million and an IRR of 32% with an B/C ratio greater than 1.

b) Sanitation is profitable with or without drinking water and will create an NPV of 32 million DT with IRR 22%.However, the water and sanitation combined matching investments are more profitable with an NPV of 17 million DT, an IRR of over 10% and a B/C ratio greater than 1.

c) Transfer and disposal of municipal waste are only profitable if a transfer station and a landfill are established with power production capacity from methane emissions in each governorate. These investments will have an NPV of 0.9 million DT, an IRR of 10% and a B/C ratio greater than 1.

7.2 DRINKING WATER QUALITY

96. The cost of the remediation of drinking water by reducing salinity was derived by estimating three volumes/day of water (20,000, 30,000 and 40,000 m^3/day during the three months in the summer when the water content increases due to lack of rain). This requires desalination pre-treatment for 20 years to effect a dilution allowing for tap water of acceptable sodium standards. Thus, desalination is needed to improve water quality and is therefore not considered as a measure to increase the water resource because of its rarity. Costs of scenarios 1, 2 and 3 are respectively 1.4, 2.2 and 2.9 million DT per year over 20 years (Table 7.2).

Table 7.2:Remeidation cost due for drinking water quality, 2010

Desalination scenario **Investment duration: 20 years**	Scenario 1: 20,000 m^3/day over 3 months	Scenario 2: 30,000 m^3/day over 3 months	Scenario 3: 40,000 m^3/day over 3 months
Average cost/year in million DT	**1.4**	**2.2**	**2.9**
***Minimum in million* DT**	*2.3*	*3.4*	*4.5*
***Maximum in million* DT**	*2.1*	*3.2*	*4.3*

Note: 0.8 $EU/$m^3$ was selected as dynamic cost of desalination of the Medjerda water and includes the recovery rate of investment as well as maintenance.However, the social cost is not taken into account (emissions from fossil fuels to generate additional electricity needed for desalination and impact of brackish water discharge).
Source:Authors.

97. The introduction of desalination of the Medjerda water during summer or drought periods would marginally improve the quality of the water distributed via dilution by SONEDE in the Medjerda Basin and in the Greater Tunis region. This improvement in water quality would reduce the consumption of bottled water, especially non-mineralized water, which represents one third of the consumption of bottled water according to the survey mentioned above (Table 7.3). Though very conservative, reducing the consumption of bottled water has been considered at 1/5 of current consumption (4.4 million DT) for the C/A analysis over 20 years while considering the consumption of bottled water and the target population constant over the period (which is very uncertain due to the strong increasing tendency of consumption in recent years).

98. Scenario 1, consisting of desalinating 20,000 m^3/day over 3 months, is profitable with a positive NPV of 8 million DT, an IRR of over 10% and the VA/C ratio greater than 1. Scenario 2, consisting of desalinating 30,000 m^3/day over 3 months, can reach a tipping point threshold at which the alternative would become unprofitable and which serves as a sensitivity analysis. Scenario 3 is rejected (Table 7.4).

Table 7.3: Investments and discounted benefits for drinking water quality, 2011-30

Water and sanitation in rural areas	Initial investment in 2011	Total investments at 10% over 20 years	Initial benefit in 2012	Total benefit at 10% over 20 years
	Million DT	*Million DT*	*Million DT*	*Million DT*
Scenario 1: 20,000 de m^3/day over 3 months/year	15.8	19.3	3.9	33.0
Scenario 2: 30,000 m^3/day over 3 months/year	23.7	28.9	3.9	33.0
Scenario 3: 40,000 m^3/day over 3 months/year	31.7	38.5	3.9	33.0

Source: Authors.

Table 7.4: Cost/Benefit analysis for the remediation of drinking water quality, 2010

Indicators Of the C/B analysis	Profitability criterion **(discount rate of 10% and investment duration of 20 years)**	Scenario 1 20,000 m^3/day over 3 months/year	Scenario 2 30,000 m^3/day over 3 months/year	Scenario 3 40,000 m^3/day over 3 months/year
NPV million DT	**>0**	**8.0**	**0.5**	**-11.3**
IRR	**≥10%**	**32%**	**11%**	**--**
B/C ratio (current value)	**>1**	**1.7**	**1.1**	**0.9**
Results		**To be considered**	**To be considered**	**To reject**

Note: the flow of benefits occurs with a delay of 1 to 2 years.
Source:Authors.

99. This analysis deserves further investigation to derive the elasticity of demand for drinking tap water with improved taste (reducing salinity in summer) of the latter. Still, the three scenarios suggested only marginally reduce the water salt content andcould be considered as back-up for drought years when salinity in the Medjerda increases substantially. In addition, an effort upstream, that is actions as part of better land management, would allow for a positive impact on water resources and hence on the quality of drinking water.

7.3 WATER AND SANITATION IN RURAL AREAS

100.Many projects such as PISEAU II (Section 2) with a total cost of $EU 170 million are underway to improve drinking water especially in rural areas. In addition, a particular effort is underway by ONAS in collaboration with the AfD and the World Bank to catch up with the rate of sanitation coverage in rural areas especially in the governorate of Beja.

101.Achievable reductions in cases of diarrhoea and mortality due to diarrhoea after improving water supply, sanitation and hygiene measures are based on recent meta-analyzes shown in Table 7.5. The cases in the figure where: (i) drinking water supply exists when the connection to the sewer does not exist, and (ii) where drinking water supply does not exist and the connection to the sewer does not exist have been selected: On average, reductions would be 50% and 60% respectively (Table 7.3) and this taking into account the state of hygiene in households.[57]

[57]Bassi et al. (2011).

102.Investment and awareness costs related to the improvement of water supply, sanitation and hygiene measures are shown in Table 7.3 with wide variations. Average reductions of 50% for sanitation and 60% for water and sanitation have been adopted to derive gains amounting to 9 million DT in 2011 **(Table 7.6)** if investments were to be immediately realized in the Basin of Medjerda in rural areas. Intervention would increase the rate of sanitation coverage from 17% in 2010 and will include population growth until 2030 in rural areas. Intervention would increase the coverage of water and sanitation from 16% in 2010 and will include population growth until 2030 in rural areas.

Table 7.5: Feasible reduction of diarrhoea cases with improvement of services

Water and sanitation coverage rate	*Population distribution 2010*	*Improvement of water and sanitation*	Feasible reduction of diarrhoea cases when:	
			Good hygiene at household level is verified	*Hygiene improvement at the household level is necessary*
Drinking water supply and sewage network connection	56%	Improved reliability and quality of water (to ensure water supply adequately and safely) to those of the population currently having problems with water supply reliability and quality	15%	45%
Drinking water supply and no connection to the sewage network	**21%**	a) Improved reliability and quality of running water (to ensure water supply adequately and safely) to those of the population currently having problems with water supply reliability and quality b) Connection of wastewater (and flush for those with toilets or no toilets) for this entire population.	**35%**	**65%**
No drinking water supply and sewage network connection	1%	Reliable and safe water supply locally for this entire population	25%	55%
No drinking water supply and no sewage network connection	**22%**	Reliable and safe water supply and connection for wastewater (and flush for those with toilets or no toilets) for this entire population.	**45%**	**75%**
Total	**100%**		**28%**	**60%**

Source: adaptedfrom Bassi et al. (2011).

Table 7.6: Investment and discounted benefits for water and sanitation, 2011-30

Water and sanitation in rural areas	Investment per inhabitant		Initial investment 2011	Total investment at 10% over 20 years	Initial benefit 2012	Total benefit at 10% over 20 years
	Minimum DT/inhab.	*Maximum* DT/inhab.	Million DT	Million DT	Million DT	Million DT
Water	143	171				
Sanitation	64	100				
Hygiene awareness	6	11				
scenario 1 Sanitation and Awareness			30	38	6.3	77
scenario 2			75	95	7.4	89

Water, Sanitation and Awareness						
scenario 3 scenarios 1 and 2			105	134	13.7	151

Note: maintenance costs 4% for water supply and sanitation for the initial investment were considered with a net increase of 3% per annum over the period. The cost of sensitisation is allocated in the first year with annual media reminders.

Source: WASH website: <www.sanitationupdates.wordpress.com/2012/10/16/wash-by-numbers-the-latest-on-cost-benchmarks-economic-returns-and-handwashing/>; and Authors.

103.Scenario 1 ensuring improved sanitation to 313,519 inhabitants[58] between 2011 and 2030 is profitable with a positive NPV of 32 million DT, an IRR of over 10% and VA/C ratio greater than 1. Scenario 2 ensuring safe drinking water and improved sanitation to 295,076 inhabitants between 2011 and 2030 is not profitable. However, when the scenario 3, which includes scenario 1 and 2, is considered, the investment becomes profitable with a positive NPV of 17 million DT, an IRR of over 10% and the VA of the B/C ratio of over 1 (Table 7.7). In other words, sanitation with or without drinking water justifies the investments and reduces the pollution of water resources drastically.

Table 7.7: Cost/Benefit analysis for the restoration of rural water and sanitation, 2010

Indicators of C/P analysis	Profitability criterion **(discount rate of 10% and investment duration of 20 years)**	Scenario 1 Water and awareness over 20 years	Scenario 2 Water, sanitation and awareness over 20 years	Scenario 3 Scenarios 1 and 2 over 20 years
NPV million DT	**>0**	**32**	**-15**	**17**
IRR	**≥10%**	**22%**	**7%**	**12%**
B/C ratio (current value)	**>1**	**2.0**	**0.9**	**1.1**
Results		**To be considered**	**To reject**	**To be considered**

Note: the flow of benefits occurs with a delay of 1 to 2 years.
Source: Authors.

7.4 IMPROVEMENT OFMUNICIPAL WASTE MANAGEMENT

104.The 2011 GIZ report on the waste chain management excludes the rural population because of the dispersion of villages resulting in high technical costs. Hence, the difficulty in linking them with a centralized system covering cities, municipalities and some mixed regions. Thus, for the rural population, community and participatory approaches are recommended eventually.

105.The GIZ report includes 4 of 6 governorates in the Medjerda, namely, Beja, Jandouba, Le Kef and Siliana. Waste generation reached 183,369 tons of municipal waste and 39,600 tons of inert waste in 2009: household waste (150,000 tons, including 544 tons recycled by EcoLef), sludge from STEPs (13,000 tons of dried sludge); construction debris (49,500 tons), common industrial waste (9,000 tons), healthcare waste (556 tons) and waste from slaughterhouses (1,089). Agricultural waste (2 million tons) is added to this total, but a value creation option was used in the degradation cost up here. For STEPs, 6 scenarios are developed with an estimate of nearly 8,000 tons of dry matter in 2033 at a cost ranging between 88 DT per ton for all discharge to 180 DT per ton for sludge recovery.

[58]Tunisian Annual Statistics 2006-2010 (2011).

Table 7.8: Investments and discounted benefits for waste, 2011-34

Water and sanitation in rural areas	Initial investment 2011	Total investment at 10% over 24 years	Initial benefit 2012	Total benefit at 10% over 24 years
	Million DT	*Million DT*	*Million DT*	*Million DT*
scenario 1: Transfer Station, Segregation, 15% recycling, 15% composting and landfill	134	229	7.2	71
scenario 2: Transfer Station, Segregation, 10% recycling, 10% composting and landfill	129	222	6.4	63
scenario 3: Transfer Station, landfill and electricity generation	31	83	5.0	84

Note: maintenance costs of 5% for initial investments were considered with a net increase of 3% per annum over the period.
Source: World Bank (2011), World Bank (2012); and Authors.

106.Investment costs relate to the improvement of a portion of the domestic waste chain and cover transfer stations to the landfill for waste generated in cities, municipalities and some mixed regions with population of nearly 650,000 in 2010 and reaching 835,000 inhabitants in 2033 (Table 7.8).

107.Thus, three scenarios were selected over 24 years for the governorates of the Northwest: scenario 1 ensuring, in each governorate, one transfer station, one segregation station with 15% recycling and 15% composting with burial of the residual volume in landfills; scenario 2 ensuring, in each governorate, one transfer station, one segregation station with 10% recycling and 10% composting with burial of the residual volume in landfills; and scenario 3 ensuring, in each governorate, one transfer station and a landfill allowing for the construction of plants for electricity generation. Thus, investment costs vary between 31 and 134 million DT with the cost for transportation (0.2 DT per km/ton), for transfer stations, for segregation and for the landfills, as well as for operation and maintenance included in the analysis.Gains in the first year vary between 5.0 and 7.2 million DT (Table 7.9).

Table 7.9: Cost /Benefit analysis for the restoration of domestic waste, 2010

Indicators of C/A analysis	Profitability criterion **(discount rate of 10% and duration of investments of 24 years)**	Scenario 1 Transfer station, segregation, 15% recycling, 15% composting and landfill	Scenario 2 Transfer station, segregation, 10% recycling, 10% composting and landfill	Scenario 3 Transfer station, landfill and electricity production
NPV million DT	**>0**	**-158**	**-159**	**0,9**
IRR	**≥10%**	**--**	**--**	**10%**
B/C ratio (current value)	**>1**	**0.3**	**0.3**	**1.0**
Results		**To reject**	**To reject**	**To be considered**

108.A C/A analysis was conducted concerning the improvement of part of the chain of domestic waste management and results are shown in Table 7.6. (See Annex V for detailed analysis). Scenarios 1 and 2 are not economically viable because they are too expensive**. However, scenario 3 is profitable with a positive NPV of 0.9 million DT, an IRR of over 10% and VA of B/C ratio greater than 1 (Table 7.6).**

7.5 REDUCTION OF EROSION UPSTREAM TO REDUCE DAM SILTATION

109.A program of the 2002-2011 National Conservation Strategy for water and soil conservation, and the protection of dams against siltation has been formulated and a global development project for watersheds of all dams has been prepared and scheduled in Tunisia successfully. This approach is preventive and more effective than ***replacement costs*** used to calculate the costs of degradation above and is worth considering as a possible calculation of the restoration costs.

110.Thus, ODESYPANO interventions and, to a lesser extent, those of the Regional Commissary for Agricultural Development have generated benefits in the targeted regions. Nevertheless, it is very difficult to assess the exact impact of erosion control for the control and mobilization of surface water or agricultural land management. Still, the World Bank (2010) evaluated the interventions of these two institutions in the Barbara Basin, on the north of the Medjerda basin, where many watersheds have the same topography and are subject to the same climatic conditions and the same erosion. However, the evaluation takes the direct benefits of conservation practices, such as planning or planting wheat, trees, etc., as well as indirect, such as carbon sequestration, without really trying to establish a causal relationship between interventions and the reduction of dam siltation.

111.NPV with a discount rate of 10% over 20 years is 940-5,050 DT/ha in the area targeted for ODESYPANO interventions. Agroforestry (olives/cereals intermittently), rangeland improvement, permanent grassland and planting sulla (Forage Crops Genetic Resources) on farmland contribute most to this result, because interventions are most profitable from the social point of view. Cords and dry stone thresholds appear profitable only in combination with agroforestry.An NPV of 1,100-5,400 DT/ha is added to these benefits at the level of general environment. The interventions of the Regional Commissary for Agricultural Development give similar results with almost 2,700 DT/ha of the discount rate of 2% in the area targeted.

112.Also, the third Mountainous Areas Development Project, funded by the World Bank, has recently been completed successfully, also producing significant gains albeit not showing decreased erosion. This project contributes to: (i) an increase in plant and forest cover, rising from 32% to 38%, (ii) an increase in the percentage of land benefiting from investments in water and soil conservation, rising from 0.3% to 13% and covering 20,700 hectares of fragile lands, and (iii) significant progress resulting in higher yields, diversification of agricultural production systems and rationalization of land allocation.

113.A planning study for CES management in the governorate of Jendouba also resulted in positive benefits when social groups are taken into account but without really deriving a C/A for erosion and dam siltation.

114.A study conducted by Daly-Hasen (2008) evaluated the benefit of forest direct and indirect values with more than of 14 DT/ha for the prevention of erosion (Box 7.1).

Box 7.1:Usage value of a forest

The value of usage of a forest and the distribution of benefits were calculated by Daly-Hassen et. al (2008) for all returns that the government or the local population receive from forests, external and social services (services for the whole society in general, biodiversity, for example, the prevention of soil degradation). The results showed that private benefits amounted to 96.8 $EU/ha in 2005 (equally shared between the government and local users). Wood pasture and fodder were the most valuable products generating 41.4 million and 34.2 $EU/ha respectively. External benefits reached an average of 24.9 $EU/ha. Its main components are the prevention of erosion (9.8 $EU/ha), carbon sequestration (11.8 $EU/ha) and biodiversity conservation (3.2 $EU/ha). However, leisure is the least rewarding part of the economic benefit amounting to 0.1 $EU/ha, despite the existence of several national parks and reserves in the study area.

115.There remaining only the difficulty to derive usable costs for erosion prevention, no C/A analysis will be conducted in this case; however, there is an urgent need to launch a comparative study using multivariate analysis to correlate topography, land use, precipitation and dam siltation on at least three dams in the Medjerda. This will allow for establishing the determinants of siltation necessary for the design and implementation of upstream interventions that reduce siltation of dams.

8. RECOMMENDATIONS

116.The diagnosis and analysis that have been developed in the previous chapters have allowed us to reach three general conclusions:

a) the priority given to investments aimed primarily at increasing the quality of urban life and not providing much investment and institutions for the improvement of rural life while the Medjerda basin has a rural fabric;

b) qualitative assessment of impacts on natural resources is generally understood under a technical point of view; however, the economic evaluation of such impact is almost nonexistent; and

c) the "sectorisation" of decision making so that environmental issues are the sole competence of the environmental authorities of the country and are treated as advice or counsel, and this lack of “horizontal” integration and reflection and accurate accountability of existing institutions to achieve the overall objectives of sustainable development in the Medjerda basin.

117. Five intervention areas are proposed for the integrated and sustainable management of the Medjerda water resources underlying the recommendations of this study:

a) ***The gradual shift in the policy of intensifying natural resources exploitation*****,** especially through mobilization of water resources. This shift can be achieved based on criteria that explicitly include economic performance and degradation as well as the scarcity of the Medjerda Basin resources.This should allow for better exploitation of water resources and secondly integrate heritage conservation concerns for "land and water" with improved productivity.

b) ***Focusing primarily on efficient investment for domestic pollution control in rural and peri-urban areas*** that have been neglected in the past. Priority would be:

1. Firstly, State investment in the extension of drinking water and sanitation in rural areas of the basin where poverty is predominant, using appropriate technologies. The findings of this study will allow ONAS to develop the sanitation strategy based on persuasive economic and environmental elements and provide monitoring indicators such as the reduction of the degradation cost of water resources.
2. Planned investments by ANGed with the assistance of KfW should include not only the type of traditional landfills but also the generation of additional revenue in the form of electricity as well as processing and closing of unregulated dumps in the Medjerda Basin.

c) ***Planning of upstream interventions that reduce dam siltation*** in order to conclude upon the determinants of siltation and assess with precision the impact of anti-erosion measures in relation to control and mobilization of surface water as well as adapt erosion control methods based on their effective use by farmers.

d) ***A decentralized information network for continuous observation, tracking, monitoring of the environment and natural resources in the Medjerda basin.*** This network should be reoriented in partnership with the institutions of the water and the environment. This network will aim to:

1. define and validate continuous protocols of exchange and cooperation with other information sources and databases
2. undertake measures for state of soil and water (already begun under the PISEAU and COPEAU);
3. reflect the understanding and assessment of the environment and its impact on health and degradation of the natural capital so as to contribute to decision-making based on accurate, regular data and information; and
4. provide all users with all information and data on the nature and quality of water and soil as well as the constraints and incentives.

e) **<u>The establishment of horizontal system for overall, integrated water management in the Medjerda watershed is strongly recommended.</u>** Effective and efficient investments are not sufficient to ensure multi-sectoral cooperation between ministries and beneficiaries. A "horizontal" system should be established to reflect the comprehensive and integrated water management in the Medjerda watershed. It is strongly recommended that the actions implemented are supported by a permanent group established in the MoA headquarters which would gather all sources of information and scientific and technical expertise from the same ministry and its institutions (SONEDE INAT, CRDA, ODESYPANO) as well as external departments involved such as the MoE (ONAS ANGed, CITET) and MdSP and user representatives.This permanent policy and monitoring group of the Medjerda Basin can be established under the aegis of the Directorate General of the Office of Planning and Hydraulic Equilibria of MoA and should, in the first place:

a) develop expertise in the assessment of benefits and damages and water conservation, and a consultancy regarding ways and means of integrating this aspect into sectoral development programs and strategies, and

b) implement a system of monitoring and evaluation for investments and activities in the Medjerda basin.

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10. ANNEX I IDENTIFICATION MISSION

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Tunis, from July 30 to August 04, 2012

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Consultation Workshop on the Degradation cost of the Environment of the Medjerda Basin in Tunisia: List of Participants
Tunis, 7 December 2012

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11. ANNEX II GENERAL METHODOLOGY FOR THE EVALUATION OF THE COSTS OF DEGRADATION

Water Category and Sub-Categories

Drinking water quality and treatment. Treatment of drinking water can occur at two levels: at treatment stations for drinking water and at household level. The degradation cost is calculated by determining the ***change in production*** and, deriving the additional cost of treatment required at stations (e.g., when olive oil production wastewater is discharged into the watershed without treatment) and determining ***revealed preferences*** at the household level (e.g. when a household uses a filter, boils water and/or in an extreme case buys bottled water when the drinking water quality is poor). For the cost of restoration, the benefits can be derived by dilution (***change in production***) during the desalination of one part of the volume of water intended for domestic consumption as well as other investments that cover all other sub- categories in order to reduce anthropogenic and natural pollution of the resource.

Quality of the services of drinking water or household water and of sanitation in urban and rural areas as well as of irrigation systems. The state of services is not considered in this case but could also be evaluated by deriving ***replacement costs*** associated with alternative sources of domestic water (bottles, wells, tanks, etc.) or production costs associated with cleaning/scouring septic tanks in case of deficiency of service. ***Opportunity costs*** can also be calculated for technical losses in the distribution network, which are considered in this study, or the time spent carrying water or clean/drain septic tanks. The ***change in health status*** is also considered in this subcategory. Some parameters of water quality do not affect the taste of water as does the excess of dissolved solids and sulfates.In addition, the bacteriological quality of the water can cause diseases such as typhoid, hepatitis A, trachoma and nematodes. In addition, the physico-chemical quality of the water can cause diseases such as excess red blood cells, hypertension and methemoglobinaemia which are respectively attributed to the excess of chlorides, sodium and nitrates.However, the causal relationship between water quality and certain diseases is very difficult to establish definitively, especially when it comes to cancer linked to ingestion of pesticides that contaminate drinking water or the food chain. Thus, the most reliable causality is that between diarrhoea that is transmitted via biological contamination on the one hand and the lack of water or water quality including drinking water, inadequate state of sanitation within the household and lack of hygiene measures (scarce use of soap) by household members on the other. Thus, a dose-response function, which has largely been established by a large number of studies, was used to assess water-borne diseases, including premature mortality and morbidity from diarrhoea affecting children under 5 years.Thus, the prevalence of diarrhoea in the region and the level of coverage of drinking water and sanitation have been considered in the dose-response function to derive the results. On **mortality**, it is difficult to assign a value to a premature death and this is a controversial issue. Yet the value of a human statistical life (VVS), which represents the reduction of premature death risk, has been used and is equal to 378,643 DT for all premature mortality in Tunisia. Also, the cost of care was considered for **morbidity** (hospitals, doctors, nursing assistants, medication, number of days of inactivity, etc.) at 45 DT on average per case of diarrhoea for children under 5 years and 21 DT for population equal to or older than 5 years.[59] The cost of restoration includes investments to increase the coverage of water supply and sanitation. This should be accompanied by a good service and the launch of an awareness campaign for a change of behaviour in terms of hygiene within the household. In addition, an increase in the efficiency of irrigation systems is achieved using the ***change in productivity.***

Quality of water resources. This subcategory is exclusively anthropogenic in origin and is affected by the discharge of domestic wastewater, industrial, mining and fishing (fresh water fish farming) effluents as well as runoff due to nitrates and pesticides used in the agricultural sector. Leachates are however covered under **Waste**. Pollution of surface water and groundwater affects water use (domestic, agricultural and industrial), the ecosystem (eutrophication, effects on direct, indirect values and options, etc.) of the watershed and coastal areas, the cost of land, housing and apartments (hedonic method) along the polluted areas, and eco-tourism (loss of opportunity especially along the riverbanks and coasts polluted). However, it is very difficult to evaluate the degradation of water quality per impact. Thus, surveys using contingent valuation allow to derive the user's ***revealed preferences*** (willingness-to-pay) in order to restore the desired state of the resource.This method is used based on a ***transfer of benefits*** (see Annex III).Moreover, to restore the quality of the resource, investments usually include: a choice ranging from the use of simple and inexpensive processes, such as natural sanitation using reeds, to the construction of STEPs with primary, secondary or tertiary treatment for the discharges of domestic wastewater; the change of the production process and/or the individual or collective treatment of industrial effluents; an awareness campaign among farmers to optimize the use of pesticides and nitrates or adopt organic farming; and in an extreme case where the resource is unrecoverable, a substitution of the resource by water supply from further distance or desalination with the transport of water resources being considered.

Salinity. Salinity of surface water and groundwater is natural and anthropogenic (soil erosion due to human activity), and has effects on health, if water is used for domestic purposes (see above **Quality of Drinking Water**), agricultural productivity and ecosystems. Only the effects on agriculture are taken into account in this case with the use of a ***production change*** to derive the degradation cost. On the other hand, the cost of restoration may include several alternatives: the salinity compensation using more fertilizers (with a contrary effect, though, which pollutes water resources); dilution of groundwater resources by injecting treated wastewater; better land use by implementing a land strategy which may include planning instruments such as reforestation, responsible soil management, prevention or mitigation of soil erosion by water and wind, etc; and in an extreme case where the resource is unrecoverable, resource substitution by more distant water supply or desalination and transportation of water resources can be considered.

Quantity. The scarcity of water resources is natural and anthropogenic, and is manifested by reduced flow or runoff, which is exacerbated by the increased use of resources to address population growth and cover economic activities.Moreover, the lengthening and disruption of drought cycles (frequencies and intensities) affect surface water and groundwater undergoing a lowering of groundwater levels and groundwater depth. The lack of flow is usually compensated: in an emergency, by the spontaneous use of treated or untreated wastewater which can cause contamination of the food chain; in an intermediate case, by pumping in more depth (rapid lowering or use of fossil water therefore non-renewable) groundwater resources is necessary to address

[59] Bassi et al. (2011).

domestic needs and/or maintain agricultural productivity; and in extreme cases, a substitution of the resource requiring water supply from a further distance or desalination and transport of water resources is considered for the surface water. The ***change in production, opportunity*** costs (shortfall) and ***replacement costs*** are considered for the calculation of the degradation cost while the cost of the restoration depends on the alternative chosen.

Erosion and Storage. Management of water resources is affected by erosion and exacerbated by climate change reducing the storage capacity. The siltation and sedimentation of dams, mountain lakes, beds of rivers and coasts are compounded by inadequate land use upstream (such as deforestation, irresponsible soil management, water and wind erosion of soils, etc.) and exacerbated by climate change manifested in increased frequency and intensity of floods during the wet seasons.***Replacement costs*** can be calculated by considering the decline in soil nutrient value which must be compensated by fertilizers, ***opportunity costs*** (releases necessary to disgorge basins) of water lost and damage to the ecosystem, ***defensive expenditures*** (dredging, construction of hillside lakes to absorb excess sedimentation); ***replacement costs*** (adding height to dams or building new dams); ***opportunity costs(shortfall)*** due to the reduction of the volume of water stored and reduction of the lifespan of dams and hill lakes; reduction of ecosystem services.In addition, the cost of restoration are in some cases the same costs used to assess degradation such as investments for the construction of new dams. However, restoration costs may also include the implementation of a land planning strategy which may include instruments such as reforestation, responsible soil management, prevention or mitigation of erosion by water and wind soils, etc.

Hydroelectric power. Output reduction is recorded in drought periods and the exacerbation of drought due to climate change could lead to power outages. The degradation cost considers the ***social cost of substitution*** for electricity generation by power plants fueled by fossil fuels.This cost includes the effects of pollutants and greenhouse gases. The cost of restoration or adaptation includes the substitution of fossil fuel power plants by renewable energy plants.

Waste Category and Sub-Categories

Chain of solid waste in urban and rural areas, including sludge from STEPs. Pollution from domestic and agricultural waste is of anthropogenic origin. Thus, the poor management of domestic solid waste and sludge (and possibly salt deposits with desalination performed by SONEDE in the south) and agricultural wastes can result in several impacts such as: discomfort, health, visual, olfactory, auditory pollution, air, soil and water (leachate runoff) pollution, unregulated dumps can cause explosions and fires, reduction of the price of land/buildings/apartments around the landfill, etc. The degradation costs consider the entire chain of waste. **Collection:** allocation of 1% of household disposable income for households without coverage for solid waste while the sludge is collected by providers, but generally rejected wild in nature (wadis, landfills, etc.). **Landfills:** cleaning cost per m^3. **Separation and recycling:** the opportunity cost of recyclables using the market rate for non-recycled materials. Shortfall of energy production **because of the lack of use of agricultural waste**. **Reduction in land prices around the landfill (*revealed preferences*** using the hedonic method) or wadis where sludge from STEPs is rejected: lower prices for land, buildings and apartments at ± 15% in a circumference up to 30 m of the landfill, and ± 10% in a circumference of 30 to 100 m around the landfill.[60]**Methane capture in sanitary landfills:** shortfall of energy production and carbon footprint

[60]Nelson (1978).

in the absence of a sanitary landfill. In addition, the cost of restoration depends on selected alternatives for the collection, transfer stations, stations for separation and recycling and sanitary landfills with or without methane capture.

Chain of medical and hazardous waste. This is not considered in this study, but the impact could be more important than domestic waste if the services managing medical and hazardous waste are not adequate.

Biodiversity category

Various encroachments are recorded across the basin resulting in loss of ecosystems and medicinal plants. TEEB has been considered for the degradation cost (loss of services) while all interventions under other subcategories can be considered as restoration costs.

Natural Disasters and Climatic Changes Category

Natural disasters and climate change impacts are considered in a continuum from short to long term.

Natural disasters. Floods, droughts, extreme events, etc. haveescalated in intensity and frequency over time. The costs of impacts include: health (mortality, injury, drowning, diseases, psycho-physical stress); property destroyed; impaired assets (revealed preferences using hedonic methods) in areas likely to be most affected by flooding (depreciation of land prices in floodplains), swells (depreciation of land prices in coastal areas due to the waves and coastal erosion), etc.; disruption of services; infrastructure affected; resources (releases with reduced resource and ecosystem effects) dilapidated, reduced economic productivity, etc.. The cost of restoration or prevention depends on the readiness and effectiveness of the response.

GHG emissions. Downscaling models to estimate the effects of climate change exist for Tunisia. However, in this case, only the GHG emissions with an impact on the general environment will be considered.The World Resources Institute has identified two tons of CO_2 per year per capita as the threshold not to exceed so as to limit the temperature increase by 2 degrees Celsius above which a dangerous and irreversible climate change will become inevitable. Thus, the degradation cost considered marginal carbon emissions that exceed 2 tons of CO_2 per year per capita (excess tons of CO_2 per year and per capita multiplied by the population and the price of carbon). The social cost of CO_2 present and future (2000-2099) represents the damage caused by a ton of current emissions in terms of floods, droughts, accelerated rise in sea level, decreased food production, species extinction, migration etc.. Several estimates are available for the social cost of CO_2 emissions ranging from $EU 3 to $EU 95 (Nordhaus, 2001; Stern, 2007; UNIPPC, 2007). Recently, the European Commission (EC 2008 and DECC 2009) considered $EU 6 per ton as the lowest consolidated value of CO_2 and the French study (Centre for Strategic Analysis, 2009) 11 $EU per ton as the upper limit of CO_2 in 2009. A range of $EU 11.3 to 15.4 per ton of CO_2 in 2010 are the prices considered as minimum and maximum based on Nordhaus, 2011, who re-estimated the social cost of carbon at the present time and until 2015, including uncertainty, action weighting, and risk aversion. The average price is considered at $EU 13.3 equivalent to 19 DT per ton of CO_2 ($EU 45.1 per ton of carbon) in $EU of 2010.

12. ANNEX III SPECIFIC METHODS FOR THE EVALUATION OF THE COSTS OF DEGRADATION FOR THE WATER CATEGORY

Methodology for Water Quality

Unlike transfers of unadjusted benefits where the willingness to pay (CAP) on the policy site is assumed to be equal to the average values of the CAP on the original site (CAPp = CAPs)Transfers tend to adjust the values by taking into account all the possible differences (e.g. socio-economic and environmental variables included in the benefits aggregate function) between the two sites (see Bateman et al. (2000) or Garrod et Willis (1999)). Equation 1 provides a conceptual representation of the benefit transfer function approach:

$$\text{Site Survey: } PAC = aS + + \beta s1Xs1\ \beta s2Xs2$$
$$\text{Site Policy: } CAPp = aS + + \beta s1Xp_1\ \beta s2Xp_2$$

Where s denotes the site survey, p the site policy and X_1 X_2 vectors specific features and characteristics of the population for each site (e.g., levels of income and education, at the baselines for water quality ...). Benefit transfer is considered a suitable tool for transferring CAP estimates adjusted between different locations where the vector of attributes and socio-economic characteristics (X_1. X_2) which determine the similarities and differences between the policy and the survey site cannot be established. When these differences exist and their magnitudes are known, it is possible to substitute the known variables in the original site investigation aggregated benefits function to provide estimates. This exercise involves the choice of factors included and omitted from the analysis because of the limitation of data availability.

Table A3.1: The annual CAP values for improving by 100% the water environment in 2016

Elicitation method/ Model for 100% improvement in 2015	England		Wales		England and Wales	
	CAP average £/hous./year	CAP median£/hous./year	CAP average £/hous./year	CAP median £/hous./year	CAP average £/hous./year	CAP median £/hous./year
PCCV sample statistics	49.2	30.0	62.6	50.0	50.4	30.0
PCCV MCO model	44.8	25.3	40.1	22.7	44.5	25.1
Logit DCCV model	167.0	167.0	181.4	181.4	167.9	167.9
Logit CE model	293.7	293.7	508.0	508.0	299.9	299.9

Source: Baker et al. (2007).

Baker et al. (2007) recently estimated the economic value placed by households in England and Wales to improve the water quality at local and national level as a result of the implementation of the Water Directive (Table A3.1). It is one of the few studies that have used an ecological series based on the water quality metrics for describing baselines and improvements. The results of this research are used by the *Department for Environment, Food and Rural Affairs* and the Environmental Agency in England and Wales to inform policy decisions necessary to comply with the directive.

Raw wastewater and industrial discharges and all contaminants from processes, such as liquid waste of domestic, industrial and agricultural (e.g. organic pollution, hazardous waste and pesticides) origin, in the water basin of the Medjerda affect this resource negatively in general. Non-market economic value of a change in water quality that could result from wastewater treatment and waste policy options is calculated for the quality of surface waters. A method of benefit transfer is used in this context. The proposed methodology covers the direct and indirect values resulting from the improvement of the quality of water resources (Table A3.2).

Table A3.2: Improvements of current usage and non-usage values of water resources

Benefit	**Types of water usage**			**Example**
Potential benefits of water quality	Current usage	Direct usage	Flow derived from resource utilisation	Recreation activities: fishing, swimming, boating
		Indirect usage	Flow derived along the banks	Recreation activities: Hiking, trekking
				Relaxation, peace and tranquillity
				Aesthetic, enjoyment of natural beauty
	Non Usage		Option	Preferences of future utilization of the resource for personal purposes
			Existence	Maintain a good environment for everyone's enjoyment
			Legs	Pleasure in the knowledge that future generations will be able to use the resource

Source: Adapted from Baker et al. (2007).

Table A3.3 : CAP per household based on the payment card and the double choice derived from benefit transfers, 2010

Willingness to pay	**Population**	**Member in each household**	**Scenario 3** **100% improvement after 6 years**		
	(# million)	(#)	Willingness to pay		
	2010	2010	2010		
			Minimum	Average	Maximum
Greater Tunis ($EU/year)	**2.5**	**4**	**9.4**	**10.0**	**12.3**
Medjerda Urban ($EU/year)	**0.4**	**5**	**9.4**	**10.0**	**12.3**
Medjerda Rural ($EU/year)	**0.8**	**6**	**9.4**	**10.0**	**12.3**
Greater Tunis (DT/year)	**2.5**	**4**	**13.4**	**14.3**	**17.6**
Medjerda Urban (DT/year)	**0.4**	**5**	**13.4**	**14.3**	**17.6**
Medjerda Rural (DT/year)	**0.8**	**6**	**13.4**	**14.3**	**17.6**

Note: $ PPP Gross Domestic Income per capita was used to adjust the income differential (0.21) between the UK and Tunisia income; elasticity is estimated at 1. Exchange rate used 1$EU = 1.4 DT.
Source: Baker et al. (2007); World Bank (2011); and Author.

The assessment of market and nonmarket goods is based on people's preferences for environmental improvement and values are measured either by a direct elicitation procedure or by the indirect analysis of transactions in markets where preferences for environmental goods are expected to affect the price of the marketed goods (Table A3.3). The value of the entire affected population is established by a foreign exchange transaction reflected in the sum of the value of every person to improve the environment. The service transfer method cannot be considered as an evaluation method in itself, but rather as a fast and inexpensive alternative for data transfer over the existing value.

13. ANNEX IV SPECIFIC METHODS FOR THE EVALUATION OF THE COSTS OF DEGRADATION FOR THE WASTE CATEGORY

Collection cost in rural areas. The cost of collection in rural areas for 1.6 million people in the Medjerda basin is equivalent to 1% of their revenue of 10,000 DT per household per year[61] ranging from 5,000 to 15,000 dinars per household.Therefore, the degradation cost for non-collection is equivalent to 26.8 million DT in 2010.

Cost of cleaning the waste discharged into unregulated dumps. The population considered is the peri-urban population of some towns and rural population reaching 2.2 million with 0.58 kg[62] generated per capita per day with a range of 0.30 to 0.65 kg.

The following assumptions are used:
• The depth of the landfill is 1 meter on average.
• The average density of waste dumped is 340 kg/m³.
• Reducing the volume through the wildfires in landfills is 2/3 leaving a balance of 1/3.

The total municipal waste uncollected in 2010 was 340,006 tons. These wastes have the potential to pollute 333,339 m^2 = (1.6 million * 365 * 0.58 kg) * 1/3 * 1/340. To clean the unregulated dumps, 32 DT per m^3 per ton (1 m^2 per 1 m depth) was adopted.[63] The cost of cleaning amounts to 11.2 million DT in 2010 with a variation from 6 to 13 million DT.

Table A4.1: Potentially recyclable waste in the Medjerda, 2010

	Population	**Generated waste**	**Generated waste**	**Metals**	**Glass**	**Paper/carton**	**Plastics**	**Textile**	**Compost**
	#	Kg/day	Tons/year	1.4%	0.6%	4.1%	5.5%	7.0%	20%
Population urban	393,716	0.75	107,780	1,509	647	4,419	5,928	7,545	21,556
Population periurban and town	86,020	0.58	18,210	255	109	747	1,002	1,275	3,642
Population rural	1,606,074	0.58	340,006	4,760	2,040	13,940	18,700	23,800	68,001
Total	2,085,810		465,996	6,524	2,796	19,106	25,630	32,620	93,199
Products recycled							600		
Products Recyclable net				6,524	2,796	19,106	25,030	32,620	93,199
Cost/ton (DT/ton)				117.6	19.9	32.4	65.9	26.1	39.2
Degradation cost				767,045	55,756	619,121	1,649,346	851,947	3,657,780
Degradation cost total									7,600,995
Minimum									5,320,697
Maximum									8,361,095

Source : GIZ (2011) ; Bassi et al. (2011) ; and Authors.

Recycling. Waste management in Tunisia has developed formal and informal systems for the recovery of materials with high impacts on the volume and weight of municipal waste for collection

[61] GIZ (2011).
[62] Ibid.
[63] Bassi et al. (2011).

and final disposal. Innovative methods of recycling have been developed such as ECO-Lef, which organizes the collection and recycling of plastics at the local level, and contributes to the creation of jobs and income. ECO-Lef deals only with plastics and has developed its activities almost exclusively in the governorate of Beja with approximately 600 tons of plastics collected in 2010. The results are shown in Table A4.1 and the degradation cost amounts to 7.6 million DT in 2010 with a variation from 5.3 to 8.4 million DT.

Electricity production with biomass. The Medjerda basin is oriented towards the major cereal crops and livestock. Agricultural waste, with waste from livestock estimated at 1.6 million tons, 0.3 million from prunings and 0.27 tons from cereal crops. In the GIZ report (2011). The electric potential achievable by the anaerobic digestion of agricultural biomass in the basin of Medjerda was calculated and is 71 MW of installed capacity with an annual production of 462,329 million kilowatts/h. Waste generated by the food industry may also represent an electrical potential of 10 MW or 65,116,761 kilowatts/h. This is equivalent to 51.1 and 7.0 million DT respectively atthe average rate of 0.1105 DT per kW/h. However, only 10% and 1% respectively of the amounts generated can be mobilized being the equivalent to 5.1 and 0.05 million DT in 2010 respectively.

Depreciation of land surrounding landfills. The hedonic cost methodology was used to derive the cost of depreciation of land surrounding the landfills.[64] Landfills have been studied in the form of a circle to derive the first ring and the second ring: ± 15% reduction in land prices in a circumference up to 30 m around the landfill, and ± 10% reduction in land prices in a circumference of 30 to 100 m around the landfill. Apartments and buildings were not considered, or higher impairment could be calculated. No distinction was made between semi-controlled and unregulated landfills in the basin of Medjerda. The smallest surface area listed by GIZ (2011) was assigned to landfills listed without surface area. The results are shown in Table A4.2.

Lost electricity production and GHG emitted as a result of non-capture of methane in future. The generation of solid waste in the basin of Medjerda reaches 465,996 tons. Within 3 years, 10% of the potential generation of methane could be captured and used to generate electricity. Thus, out of a potential of 67 million m^3 of methane, 3 million m^3 could be captured. Only one year has been considered in the future for the sake of simplification while the flow capture may extend over several years. The production of electricity that can be generated is 31.1 million kW/h using the following formula: 1 m^3 CH_4 = 9.8 kW/h at 100% efficiency. The monetary equivalent is 3.3 million DT when the NPV is calculated using a discount rate of 5% with an average rate of 0.1105 DT per kW/h to consider these lost benefits at the present time. The emission of methane that could be avoided within 3 years is equivalent to 2,185 tons, equivalent to 54,617 tons of CO_2 equiv. The monetary equivalent is 1 million DT when the NPV is calculated using a discount rate of 5%.

[64]Nelson (1978).

Table A4.2: Hedonic evaluation of land around the landfills, 2010

Landfill	Type	Surface area	D^2=S/Pi/4	Original diametre	Original radius	Radius 30 m	Radius 100 m	Surface area 30 m	Surface area 100 m	Losses 30 m	Losses 100 m	Land price	Losses 30 m 15% of the price	Losses 100 m 10% of the price
		m^2		m	m	m	m	m^2	m^2	m^2	m^2	DT/m^2	DT	DT
Beja	Controlled	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
Maagoula	Controlled	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Mejez el Bab	Controlled	25,000	31,831	178	89	119	158	44,642	78,632	19,642	33,989	30 (20-40)	88,391	101,967
Jendouba	Controlled	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
Boussalem	Controlled	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Tabarka	Controlled	300,000	381,972	618	309	339	378	361,076	448,929	61,076	87,853	30 (20-40)	274,843	263,559
Siliana	Controlled	18,000	22,918	151	76	106	145	35,095	65,773	17,095	30,678	30 (20-40)	76,929	92,034
Goubellat	Unregulated	15,000	19,099	138	69	99	138	30,852	59,914	15,852	29,062	30 (20-40)	71,335	87,186
Teboursouk	Unregulated	50,000	63,662	252	126	156	195	76,607	119,651	26,607	43,044	30 (20-40)	119,733	129,131
ZahretMedien	Unregulated	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
Ben Metir	Unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Ghardimaou	Unregulated	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
OuedMeliz	Unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Dahmani	Unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Jerissa	Unregulated	40,000	50,930	226	113	143	182	64,097	103,877	24,097	39,780	30 (20-40)	108,436	119,340
KalaatKashba	Unregulated	20,000	25,465	160	80	110	149	37,867	69,549	17,867	31,681	30 (20-40)	80,402	95,044
KalaatSenan	Unregulated	15,000	19,099	138	69	99	138	30,852	59,914	15,852	29,062	30 (20-40)	71,335	87,186
Ksour	Unregulated	20,000	25,465	160	80	110	149	37,867	69,549	17,867	31,681	30 (20-40)	80,402	95,044
Nabeur	Unregulated	2,500	3,183	56	28	58	97	10,645	29,687	8,145	19,042	30 (20-40)	36,652	57,127
Sakiet S Youssef	Unregulated	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
Sers	Unregulated	27,000	34,377	185	93	123	162	47,302	82,149	20,302	34,847	30 (20-40)	91,359	104,540
Tajerouine	Unregulated	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
Touiref	Unregulated	8,000	10,186	101	50	80	119	20,339	44,835	12,339	24,495	30 (20-40)	55,527	73,486
Aroussa	Unregulated	10,000	12,732	113	56	86	125	23,462	49,417	13,462	25,955	30 (20-40)	60,580	77,864
Bargou	Unregulated	25,000	31,831	178	89	119	158	44,642	78,632	19,642	33,989	30 (20-40)	88,391	101,967
Bouarada	Unregulated	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
Gaafour	Unregulated	20,000	25,465	160	80	110	149	37,867	69,549	17,867	31,681	30 (20-40)	80,402	95,044
Le Krib	Unregulated	20,000	25,465	160	80	110	149	37,867	69,549	17,867	31,681	30 (20-40)	80,402	95,044
Makhtar	Unregulated	20,000	25,465	160	80	110	149	37,867	69,549	17,867	31,681	30 (20-40)	80,402	95,044

Landfill	Type	Surface area	D^2=S/Pi/4	Original diametre	Original radius	Radius 30 m	Radius 100 m	Surface area 30 m	Surface area 100 m	Losses 30 m	Losses 100 m	Land price	Losses 30 m 15% of the price	Losses 100 m 10% of the price
		m^2		m	m	m	m	m^2	m^2	m^2	m^2	DT/m^2	DT	DT
Rouhia	Unregulated	15,000	19,099	138	69	99	138	30,852	59,914	15,852	29,062	30 (20-40)	71,335	87,186
SidiBouRouis	Unregulated	12,000	15,279	124	62	92	131	26,477	53,752	14,477	27,274	30 (20-40)	65,147	81,823
Nefza	Presumed unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Testour	Presumed unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Ain Draham	Presumed unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Fernana	Presumed unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
El Kef	Presumed unregulated	30,000	38,197	195	98	128	167	51,247	87,323	21,247	36,076	30 (20-40)	95,613	108,227
Menzel Salem	Presumed unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Kesra	Presumed unregulated	5,000	6,366	80	40	70	109	15,347	37,253	10,347	21,906	30 (20-40)	46,563	65,717
Sub-total													2,959,102	3,528,314
Total													**6,487,415**	
Minimum at 20 DT per m^2													*4,324,944*	
Maximum at 40 DT per m^2													*8,649,887*	

Source : Nelson (1978) ; Bassi et al. (2011) ; GIZ (2011) ; ImmoTunisie website : <www.immotunisie.com>; and Authors.

14. ANNEX V RESTORATION RESULTS

Benefits associated with access to improved sanitation and drinking water are shown in Table A5.1. Capacity, unit costs and investments required for the waste chain after collection are shown in Tables A5.2 to A5.4.

Table A5.1: Benefits associated with access to drinking water and sanitation, 2010

Medjerda rural population	2010	Diarrhoea reduction	Diarrhoea-caused mortality reduction	Reduction of diarrhoea cases	Value per case	Gains in 2010
			#	million	DT	Million DT
No access to sanitation (million)	0.266					
Birth rate (Number of newborns per 1000 inhabitants)	15.1	0.500	9		378,643	3.3
Population < 5 years (million)	0.025	1.25		0.03	45.0	1.4
Population ≥ 5 years (million)	0.241	0.250		0.06	21.2	1.3
Sub-Total						6.0
No access to water and sanitation (million)	0.250					
Birth rate (Number of newborns per 1000 inhabitants)	15.1	0.600	10		378,643	3.8
Population < 5 years (million)	0.025	1.50		0.04	45	1.7
Population ≥ 5 years (million)	0.225	0.300		0.07	21	1.4
Sub-Total						6.9
Total						**12.9**

Sources: adaptedfrom de Bassi et al. (2011); World Development Indicators (2011); Tunisian Annual Statistics 2006-2010 (2011); and Authors.

Table A5.2: Capacity required after waste collection for the North-West governorates, 2010-2034

	Capacity of transfer stations	Distance	Capacity of segregation stations	Recycling, composting and/or landfills			
				Surface area	Scenario1 15% R - 15% C	Scenario 2 10% R - 10% C	Scenario 3 0% R- 0% C
	Ton/d	*km*	*Ton/d*	*km^2*			
Beja	165	40-60	200	*20*	90	116	200
Jenjouba	226	40-60	250	*20*	113	145	250
Le Kef	140	40-60	200	*10*	90	116	200
Siliana	127	40-60	180	*10*	81	104	180
Total	658		*830*		374	481	830

Source: GIZ (2011); and Authors.

Table A5.3: Unit cost for the waste chain of the North-West governorates

	Transfer station capacity	Transport	Capacity of segregation stations	Recycling, composting and/or landfills			
				Surface area	Scenario1 15% R - 15% C	Scenario 2 10% R - 10% C	Scenario 3 0% R- 0% C
	DT/ton/d	*DT/km/ton*	*DT/ton/d*	*km^2*	*DT/Ton/d*	*DT/Ton/j*	*DT/Ton/d*
Beja	35,000	0.2	82,069	*50*	141,425	100,000	10,000
Jenjouba	35,000	0.2	82,069	*50*	141,425	100,000	10,000
Le Kef	35,000	0.2	82,069	*40*	141,425	100,000	10,000
Siliana	35,000	0.2	82,069	*40*	141,425	100,000	10,000

Source: GIZ (2011); and Authors.

Table A5.4: Investments for the waste chain of the North-West governorates

Governorate	Cost of transfer stations	Cost of transports	Cost of segregation stations	Cost of recycling, composting and landfills			Total cost of investment without transport		
				Scenario1 15% r - 40%	Scenario 2 12% r - 30%	Scenario 3 **0% r- 0% c**	Scenario1 15% r - 15%	Scenario 2 10% r - 10%	Scenario 3 **)% r- 0%**
	Million DT	Million DT	Million DT	Million DT	Million DT	Million DT	Million DT	Million DT	Million DT
Beja	8	1.8	16	13	12	3	37	36	27
Jenjouba	11	2.5	21	16	15	3	47	46	35
LeKef	7	1.5	16	13	12	3	36	35	26
Siliana	6	1.4	15	11	10	2	32	31	23
Total	32	7.2	68	53	48	11	153	148	111

Source: GIZ (2011); and Authors.

15. ANNEX VI DISAGGREGATED RESULTS OF DEGRADATION AND RESTORATION COSTS

Table A6.1: Disaggregated results on degradation cost

Category	Medjerda				Greater Tunis			Total
	Degradation cost Million DT	%	Minimum Million DT	Maximum Million DT	Degradation cost Million DT	Minimum Million DT	Maximum Million DT	Degradation cost Million DT
Water	129.5	68%	99.1	164.5	22.3	17.5	28.1	151.8
Waste	60.5	32%	32.1	131.3	-	-	-	60.5
Biodiversity	0.5	0%	0.4	-	-	-	-	0.5
Environmentgeneral	1.1	1%	-	-	-	-	-	1.1
Total	191.5	100%	131.6	295.8	22.3	17.5	28.1	213.9
% du GDP	3.3%		2.3%	5.1%				0.34%
Water	2.2%		1.7%	2.8%				0.2%
Waste	1.0%		0.6%	2.3%				0.1%
Biodiversity	0.0%		0.0%	0.0%				0.0%
Environmentgeneral	0.0%		0.0%	0.0%				0.0%
Total	3.3%		2.3%	5.1%				0.34%
WATER	129.5	67.6%	99.1	164.5	22.3	17.5	28.1	
Quality of drinking water	8.8	4.6%	5.8	11.7	10.6	7.1	14.1	47.4%
Waterborne diseases	81.3	42.5%	68.2	94.4				
Distribution	1.5	0.8%	1.3	1.8	6.1	5.2	7.0	27.3%
Quality of water resources	5.6	2.9%	5.3	6.9	5.6	5.3	6.9	25.2%
Quantity	4.8	2.5%	4.3	5.3				
Salinity	12.3	6.4%	9.9	14.8				
Erosion	7.4	3.9%	3.7	14.8				
Storage	7.1	3.7%	0.1	14.1				
Hydroelectricity	0.7	0.3%	0.5	0.8				
WASTE	60.5	31.6%	32.1	131.3				
Collection	26.8	14.0%	13.4	40.2				
Cleaning	11.2	5.9%	5.8	12.6				
Recycling	7.6	4.0%	5.3	8.4				
Biomass	5.2	2.7%	-	58.3				
Land depreciation	6.5	3.4%	4.3	8.6				
Energy	3.3	1.7%	3.2	3.3				
BIODIVERSITY	0.5	0.2%	0.4	≥0				
Wetlands	0.5	0.2%	0.4	≥0				
NATURAL DISASTER AND GENERAL ENVIRONMENT	1.1	0.6%						
Natural disaster	0.0	0.0%	0.0	0.0				
General environment	1.1	0.6%	1.1	2.3				
Hydroelectricity	0.1	0.1%	0.1	1.3				
Landfills	1.0	0.5%	1.0	1.0				

Source: Authors.