WATER GLOBAL PRACTICE • ANNEXES

Managing Urban Water Scarcity in Morocco

Annexes to Sections 2 to 4

NOVEMBER 2017

WORLD BANK GROUP

WATER PARTNERSHIP PROGRAM

Acknowledgement & disclaimer

1818 H Street NW, Washington, DC 20433

Telephone: 202-473-1000; Internet: www.worldbank.org

Please cite the work as follows: Dahan Stephane, 2017: Managing Urban Water Scarcity in Morocco. World Bank, Washington, DC.

Cover design: Jean Franz, Franz & Company, Inc.

Contents

ANNEX I - Legal, institutional and policy framework of the water sector in Morocco 4

ANNEX II - Water Scarcity in Morocco and Impacts of Climate Change 14

ANNEX III - Demographic and water demand projections for Morocco's urban population 21

ANNEX IV - Alternative supply and demand reduction measures aimed at achieving urban water security 30

ANNEX V - Evaluation of the impacts of water reallocation from irrigation to potable water....... 62

ANNEX I - Legal, institutional and policy framework of the water sector in Morocco

The institutional analysis of the water sector in general and its urban component shows that, in general, Morocco has equipped itself with institutions, instruments, rules and processes capable of responding to needs and challenges of an Integrated Water Resources Management (IWRM) and to respond effectively to the risks of urban water shortage. The legal framework is from this comprehensive point of view and governs all qualitative and quantitative aspects, planning and control of mobilization, water resource management, protection and control of uses. Institutions have been set up at all levels of government and rules are in place to involve civil society and the private sector in water management. However, this legal and institutional framework reveals substantial gaps that need to be addressed in order to efficiently and effectively implement the potential options for an Integrated Urban Water Management (IUWM). It goes without saying that the effort to correct the institutional framework will be significantly different and will include at the same time general measures and specific measures for each of the options that could be chosen to be implemented at the level of a given city dependent on a specific hydraulic basin.

1. Legal and regulatory framework

Regulatory, legal and institutional aspects of urban water management are addressed in many policy documents of sectoral policies, the most important of which is the Water Sector Development Strategy and the National Water Plan of 2010 in relation to other strategies and plans that have a strong water dimension. These include the National Health and Environmental Action Plan, the National Program for the Prevention of Industrial Pollution (PNPPI), the Green Morocco Plan, the National Sanitation Plan, National Wastewater Reuse Plan ", and the" National Household Waste Program "among others. All these plans, programs and strategies are reflected totally or partially within the legal and regulatory framework governing water resources management.

From these strategies and plans, Morocco has been able to extract principles, rules, standards and procedures which it has included in a comprehensive legal and regulatory framework and includes many texts, the essential basic text of which is Law 36-15 on the water that repealed Law 10-95 by keeping the rules that have had positive effects on water management. Law 36-15 is important in that it devotes directly and strongly the concept of integrated water resources management which finds application in the IUWM. Indeed, Article 1 of the Law stipulates that: "This law lays down the rules for the integrated, decentralized and participatory management of water resources to guarantee the right of citizens to access to water and with a view to a rational and sustainable use and a better quantitative and qualitative valuation of water, aquatic environments and the public hydraulic domain in general, as well as the rules for the prevention of water-related risks for the protection and the safety of people, property and the environment. [It] [Law 36-150] also refers to the establishment of rules and tools for water planning including wastewater, desalinated seawater and others to increase the national water potential by taking into account climate change in order to adapt to it. "

In addition to these substantive and normative aspects, Law 36-15 states that its objective is to strengthen basin agencies and the participation of users, local communities and the private sector in the management of water resources, through contractual relations. It also aims to provide a strong legal basis for sustainable development programs through the promotion of water savings, clean-up, development and active management of watersheds, the establishment of financial and regulatory instruments necessary to implementation of an effective IWRM.

Law 36-15 is being implemented through new implementing legislation, however, Article 162 of the Act states that "pending the publication of the texts for the application of this Law, application of Law No. 10-95 on water remain in force ". From this provision, it follows that the main implementing decrees of Law 10-95 remain applicable pending an inventory of those of their rules that would be inconsistent or contradictory with the provisions of Law 36-15. In addition to Law 36-15, the water sector is partially governed by sectoral laws that have specific provisions relating to the normative, institutional and / or organizational aspects of the water sector, including urban water. The following laws and their implementing instruments, including those relating to urban planning, protection and development of the environment, and sustainable development, can be cited. These are important for the promotion and implementation of IUWM.

To these fundamental laws which generally define the principles, rules, standards and procedures for the management and conservation of national water resources, there are also specific implementing texts for their implementation. Implementing texts include: (a) conditions for access to water resources, (b) fees for the use of water in the public water supply, (c) (d) spills, discharges, discharges, direct or indirect deposits in surface or ground water, (e) the use of waste water, (f) environmental impact studies of water infrastructure projects, etc..

2. Institutional framework and sector governance

Morocco has adopted organizational and institutional texts that govern the responsibilities, organization and functioning of the institutions in charge of a general or specific mandate related to water management. These institutions are numerous and diverse and reflect the system of water governance in Morocco, which is decentralized and inclusive in that it makes room for each of the categories of stakeholders (central government, local authorities, private sector, institutions public, user associations, etc.).

In general, tasks related to the governance of the water sector are divided between the advisory function, the political and regulatory function, the management function and the enforcement functions:

a. The consultative function is carried out, mainly by: the Higher Council for Water and Climate (CSTC), the National Environment Council (CNE), the Interministerial Water Commission (CIE), and the Council Superior of Territorial Development (CSAT). These institutions have a mandate to review the various water strategy and planning documents and to make recommendations for its adaptation to the challenges of national development.

b. The political and regulatory function: it is the primary and essential function of the Ministry in charge of water for the policy, planning, supervision and control aspects of the water sector. But other government departments have jurisdictional plots and mandates that influence the development and adoption of policies and regulations related to the management of the water sector. This applies to ministries in charge of environment and finance, and ministries that can be described as water "consumers", such as agriculture, industry, the local authorities. Through their decisions, these ministries can contribute to the adoption of measures and authorize the decentralized and decentralized bodies to use and implement the instruments necessary for the management of water resources, including financial, environmental, technical and financial instruments. planning.

c. The management of the resource is mainly entrusted to the Basin Agency for the overall management of water resources on the territory entrusted to it. The tasks assigned to it by Law 36-15 and the implementing regulations in force are important and their implementation will enable the deployment of the policy of sustainable management and conservation of water resources as defined in IWRM. The Basin Agency has administrative and management bodies (Board of Directors and Hydraulic Basin Council) which include representatives of stakeholders and users in the decision-making process and works to implement participatory approaches to take the expectations and demands of all these stakeholders in its planning and activities. It manages water resources in accordance with a Master Plan for Integrated Water Resources Management (PDAR), which it develops and has approved by the Ministry in charge of water to ensure compliance with the PNE. Finally, the ABH has the power to conclude groundwater contracts with the users and some agencies already have them.

d. The level of implementation: the Moroccan institutional model of urban water management is decentralized in terms of policy implementation missions. Thus, with the recent creation of the region, the mission of ensuring the "proper use of natural resources, their valorization and their safeguarding" is entrusted to the Region under Organic Law 111-14 of 2015. The Regional Council sees itself to develop a "regional strategy for the conservation of energy and water in accordance with the National Sector Strategy. This innovation will certainly complement the institutional framework that includes the prefectural and provincial water commissions. These committees have an important mission to approve local water management plans and, above all, to contribute to water management during periods of shortages in order to ensure the satisfactory supply of populations and to contribute to raising awareness the protection of water resources and the preservation of the hydraulic public domain and its optimal use. Finally, the task of organizing and carrying out the tasks relating to the supply of drinking water to the population and sanitation are the responsibility of the municipality under the municipal charter. However, municipalities can entrust these two substantial water supply and sanitation missions to ONEE, municipal, semi-public or private institutions that are given a critical role in the use rational and efficient use of water resources and their conservation by deploying appropriate management instruments (technologies, finance, control). Just as ORMVAs have a similar role in supplying irrigation water to farmers. It should also be noted that, at the regional level, since 1995, the Moroccan government has established Regional Environmental Councils (CRE), as well as at the local level, the governor or the wali may establish Vigilance Committees whose mission seems to be limited to monitoring and controlling water wastage in urban centers.

3. Axes of institutional improvement for the sector

The institutional framework is well structured and has rules and principles covering all aspects of the management and conservation of water resources, but also suffers from some shortcomings that need to be mentioned in order to recommend possible solutions. While the legal framework appears to be satisfactory, it is nevertheless complex and involves a multitude of actors who may have mandates that are defined in too general terms or which give rise to conflicts with the mandates of other institutions.

Institutional design is ambitious and includes many institutions with broadly defined mandates that are not sure that each can fully implement in the absence of humanly, technically and financially strengthened capacity. This design implies a constant flow of information in real time to ensure the optimum control of the efficient management of the resource and an intervention capacity of each of the institutions to make its objections to decisions of other institutions can have an impact on water management in quantity and quality. All this is not clear from the legal framework in force. For example, does the Basin Agency have a power directly linked to its mandate to conserve water from opposing urban buildings that consume large quantities of water? Can it impose, on the basis of an environmental impact assessment of a large infrastructure project, precise measures related to its mission of sustainable development of water resources? Does it have the material means to fulfill all its obligations of control of authorized and unauthorized water withdrawals?

4. Water sector management tools and instruments

Quantitative water management: in the case of a country where water management has long been focused mainly on the supply of resources, it is certain that the institutions in charge of water management, have the necessary tools to fulfill their mandate to manage the quantitative aspect. Demand management is no longer discussed (see below). First, Law 36-15 confirms the right of landowners and local governments to collect and use rainwater freely as was the case with Act 95-10. Law 36-15 adds a device to upgrade stormwater and make it a complement or even an alternative to the use of traditional waters in the public domain. To this end, the Act provides incentives to encourage such action. These incentives must be rapidly applied to allow the addition of rainwater to the ABH water stock.

From this point of view, it should also be mentioned that the state of the water transport infrastructure (pipeline in particular) is such that network rehabilitation, leak detection and accompanying measures can form a genuine instrument for making available additional quantities of water. However, in legal terms, it should be accompanied by a legal obligation for the authorities, concessionaires and large consumers of resources to make public and to report to the ABH concerned all the losses of water in the feeding systems and distribution networks. It is therefore necessary to establish a genuine legal obligation to make water balances [...] to specify the different categories of losses. Such an obligation has been made compulsory in some countries for its obvious benefits, in particular to encourage these authorities, concessionaires and large consumers of resources to conduct regular audits of their respective water supply and distribution systems and to alert the public authority and the real-time regulator which imposes on any water authority having a certain capacity that the ABH and the central regulator will have to define. Such an obligation will enable the ABH to obtain an annual audit of the losses of the past year and establish where the water is going and whether the loss results from metering, water theft or losses in the system to use this information to reduce operating costs, detect real-time resource losses or repair infrastructure before losses increase.

The Water Police: Law 99-12 provides for the establishment of an environmental police even though there is a water police whose mandate has been reinforced by Law 36-15. Article 35 of Law 99-12 provides: "An environmental police force shall be established to strengthen the power of the administrations concerned with regard to prevention, control and inspection. This article therefore assumes that the material content of the Police of the Environment (prevention, control, inspection is exercised by "relevant administrations" which must be strengthened.) Law 36-15 stipulates that the police of the " may be exercised by: "judicial police officers under the Criminal Procedure Act, water policemen commissioned for this purpose by the administration, water basin agencies and other public institutions concerned, and (Article 131), the environmental police should legitimately be referred to as environmental police, which may give rise to various interpretations, and to avoid them an enforcement text must specify the relationship between the two police forces. water authorities should also be clarified in relation to the authorities responsible for monitoring the quality of drinking water, particularly in urban areas (Min health department, hygiene department of the municipality). As in many countries, in order to reduce the multiplication of agents involved in the matter, a system of delegation of mandate should be implemented under which a single authority would be responsible for water policing at the municipal level and should centralize all information on infringements of quality and quantity of water. This water police located at the communal level could use the Water Watch Committees to fulfill its mandate. This single authority could report to the Basin Agency and relevant ministries and local authorities and have the mandate to use technical expertise where it exists. The results of the water policing exercise should also be disseminated as widely as possible in order to empower failing users and alert planners and decision-makers in the sector by providing real-time information .

The use of environmental impact assessment as an instrument for protecting watersheds and water resources: An important instrument in any strategy for monitoring and protecting the use of water resources is the study Environmental Impact Assessment (EIA). The EIA in Morocco is used as a procedural tool to authorize important infrastructure projects. It is not seen as an instrument to guide the design and implementation of projects that require the support of all stakeholders. Certain gaps characterize EIAs in relation to good international practice. In addition to the general regulations on EIA, there is a Joint Decree of the Minister of Infrastructure and the Minister for Spatial Planning, Urban Planning, Habitat and Environment defining the terms of the study of the effects on the hydraulic public domain. But to date no project having undergone such an impact study has seen the said study published in order to judge its specific contribution. The obvious shortcomings of the EIA system are (i) the lack of analysis of alternatives to the proposed project. For example, water-intensive projects are not subject to comparison with alternative projects that consume less water or to be carried out on sites that are less sensitive to water, (ii) (iii) lack of uniform criteria for evaluating EIAs, (iv) lack of a cost-benefit analysis to evaluate EIAs, and ensure that the environmental, social and financial benefits of the proposed project are greater than the costs, and (v) insufficient monitoring of the implementation of the mitigation measures proposed by the EIA. This inadequacy is in addition to the fact that the basin agency, which is responsible for the management, protection and conservation of the water resources of its territory, does not seem to have a decisive role in authorizing or prohibiting projects that would jeopardize the ecological balance of the basin over the long term

Compliance with water quality standards: this is an essential instrument for enabling the ABH to implement its mandate to manage water in an integrated manner (quantity and quality). It should be noted that the organization of the sector shows that there are several institutions that manage and control water quality (environment, health, industry, water / water) and this results in a confusion of responsibilities, inaction or cumbersomeness in the performance of the water quality management and control mission, in particular to face the potential risks of pollution of surface water and groundwater.

5. Water pricing policy

One of the most effective instruments in water management is the adjustment of prices to signal to the consumer the true price of the resource for society and to put it in a position to decide the level of use of the resource and therefore to calibrate its application. For well-established reasons, including those related to the right of everyone to access water, the price of water is established in Morocco, as in many countries on the basis of socio-economic data and can evolve with them.[1].

[1] http://www.elhyani.net/comparatif-des-tarifs-deau-et-delectricite-au-maroc/ provides a good comparison of water prices in the major cities of Morocco and shows for example that Marrakech has low rates compared to those of other major cities.

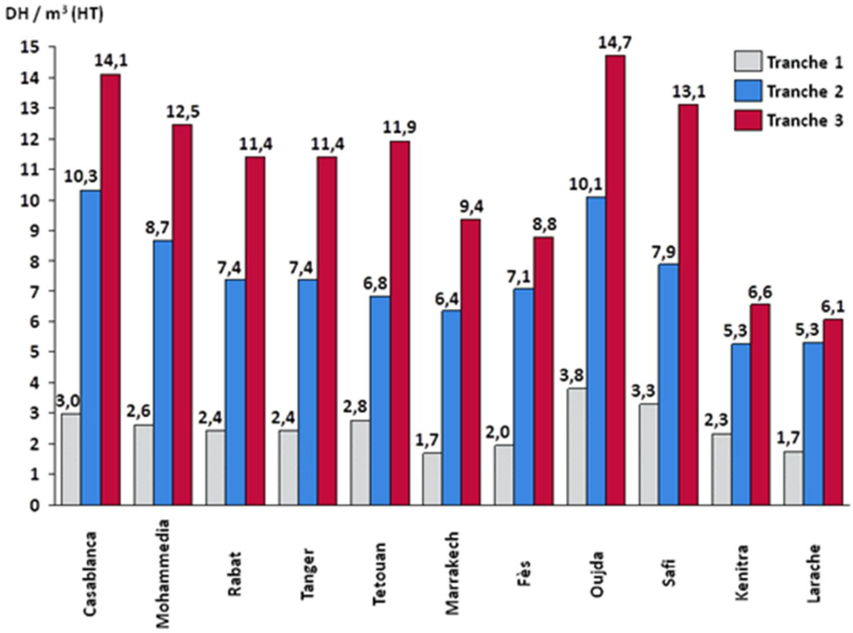


Figure I-1: Water supply tariff by city and by block

Under current law, the price of water in the urban sector covers the operating costs of the ONEE and / or water authorities and other water distribution agencies to end-users. Moreover, the price varies according to the uses and the quantity actually consumed by the end user of the resource. The tariff applied is progressive based on the consumption level with three installments of the lowest price for the first tranche (deemed lower social tariff than the cost of producing drinking water) and a progressively higher price to be higher than the cost of production from the third tranche. Additional charges for connection and a flat-rate subscription are added to this price. This system is not specific to Morocco and is practiced in many countries. But in the urban sector there are different prices paid by "preferential" users, in particular public water operators and standpipes, which have a single price to promote public hygiene and the right of access to water for citizens whose homes are not connected to the DWS system. Finally, there is the price for industrial water for large users for whom water is a means of production.

In order to fulfill their water supply mission, ONEE and the authorities have to pay levies for the removal and discharge of natural resources to the water basin agencies. These charges were introduced by the Water Act of 1995. Their level is low and does not allow basin agencies to cover their own administrative costs, not to mention the subsidies they should provide to finance the depollution investments foreseen by the law. Since their introduction, the levy level has not been revised, implying that the real value of the royalty decreases and the ABHs see their budget reduced accordingly, thus limiting their capacity to fulfill their missions.

The environmental cost is not taken into account in the calculation of the price paid by the end user. However, Morocco has introduced a sanitation levy based mainly on the amount of drinking water consumed. In fact, this system has the merit of making difficult trade-offs between the ministry in charge of water, which is subject, at the same time as the ABH, to technical constraints related to safety, quality and quantity of supply and the major consumer and regulatory ministries, which must ensure that the water needs of the populations and enterprises under their care are met in appropriate economic conditions. This is often difficult to achieve. It is increasingly clear that approximating the cost of water to its cost of production by including the cost of environmental degradation is a complex and difficult operation, but it is imperative to undertake a comprehensive participatory approach to analyze all contemporary aspects and future prospects, including the risks associated with climate change, in order to ensure that citizens integrate into their behavior towards water the values of economy, protection and of conservation.

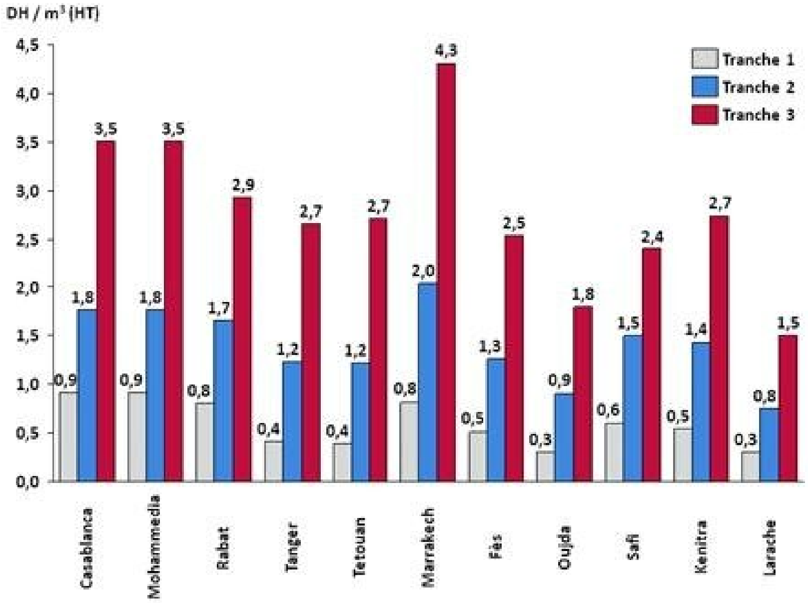


Figure I-2: Tarifs d'assainissement par ville et par tranche

At the same time, differentiations between water users could be further refined to make it possible to charge a full price covering the environmental aspect to any user / industrial consumer whose water constitutes a cost-effective and / or replaceable production factor including treated wastewater. The first step would be to provide incentives for these major users of the resource to invest in wastewater treatment and reuse technologies (for irrigation, energy and other). These incentives exist within the framework of FODEP, FNE, MVDIH, and can be further developed. It is important that these incentives be widely disseminated in order to sensitize industrialists and municipalities and to help them benefit from them. In some countries, the refusal to use such incentives and / or the introduction of wastewater treatment technologies and the reuse of such treated water has led governments to give full effect to the polluter-pays principle, which is enshrined in existing environmental laws in order to recover the total costs of the resource, including its scarcity and degradation. This would also allow for a more dynamic approach to demand management and to strengthen the water supplies available for other uses in Morocco.

6. National Strategy for the Development of Morocco's Water Sector by 2030

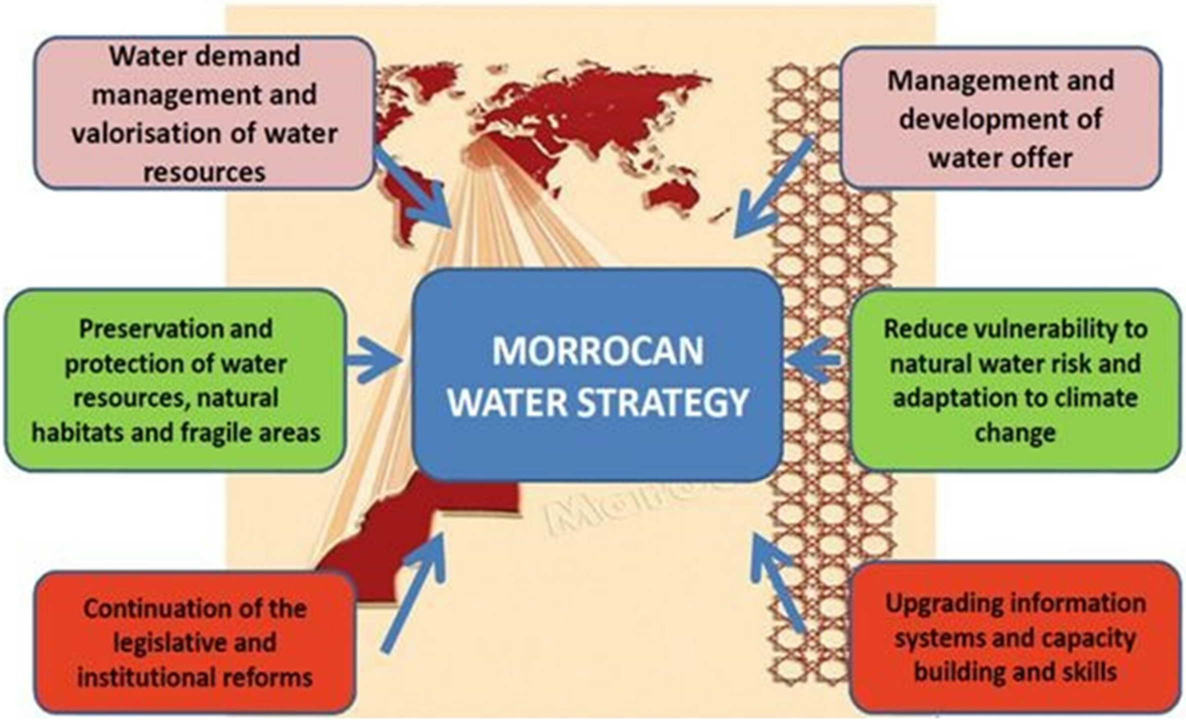
Morocco is committed to an Integrated Water Resources Management (IWRM) approach, under its national Water Sector Development Strategy (2009) and its new Water Law 36-15 (2016). The entire water sector is governed by Law 36-15, promulgated on the 10th of August 2016, commonly referred to as the "Water Law", which provides the framework for water resources management and created the necessary tools for its implementation. This concerns particularly the Hydraulic Basin Agencies (ABH), which are the authorities for planning, management and protection of the water resources of the country. Institutionally benefiting in principle from financial autonomy based on the principles of «user/pays" and "polluter/payer

", these basin agencies represent a modern, internationally acknowledged integrated water management approach. However, as a result of the de-facto impossibility to collect "polluter/payer" royalties, ABHs have not yet acquired financial autonomy.

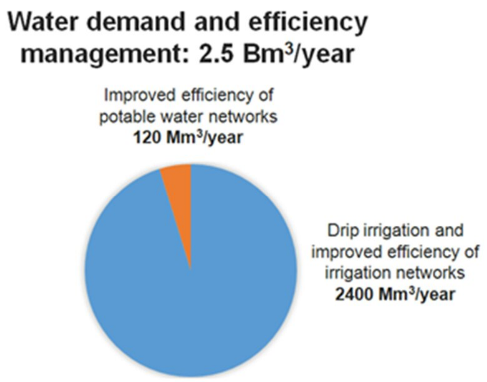
Since the adoption in 2009 of its National Strategy for the Development of the Water Sector, Morocco is committed to a policy of IWRM implementation, in six area, in support of other sectors such as agriculture, energy, industry, infrastructure, tourism, sustainable cities and the environment:

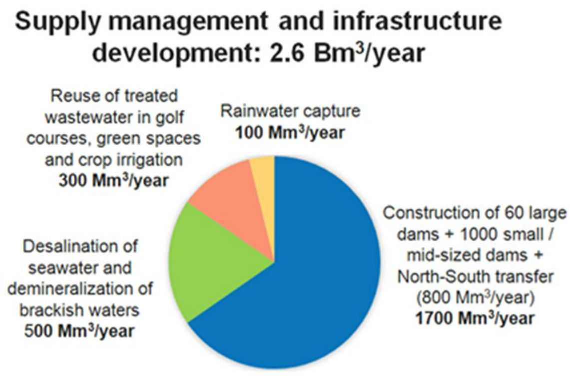
- Management of water demand and efficiency, and valuation of water
- Management and development of water supply
- Preservation and protection of water resources and natural resources
- Reducing vulnerability to natural hazards and adaptation to climate change
- Continuation of institutional and regulatory reforms
- Upgrading of information systems and capacity building

Figure I-3*: Morocco's national strategy for development of the water sector (source: ONEE-IEA, 2014)*



Improvement of the efficiency of water use, the desalination of sea and brackish water, the treatment and reuse of waste water, and rainwater harvesting feature prominently in the national water strategy. Targets, as most relevant for this report, include *inter alia (ONEE-IAE, 2014)*:





Water demand and efficiency management (2.5 Bm³/yr)

In agriculture, conversion to modern irrigation systems and improvement of existing irrigation systems with a potential to save 2.4 Bm^3/year[2].
Improvement of the efficiency of urban water supply networks (leakage reduction) and developing norms and incentives to use water efficient devices in the tourism industry, with a potential to save 120 Mm^3/year.
Revision of tariff systems; demand management

Supply management and development (2.6 Bm³/year)

Construction of 60 large dams (3 per year) and 1000 small and mid-sized dams by 2030: 1.7 Bm^3/yr, including a North-South transfer from the Loukkos and Sebou basins to the Bouregreg, Oum Er Rbia and Tensift basins (800 Mm^3/year).
Rainwater capture pilot projects which should lead to larger-scale deployment (100 Mm^3/year)
Desalination of seawater and demineralization of brackish waters: 500 Mm^3/year.
Reuse of treated wastewater in golf courses, green spaces and crop irrigation: 300 Mm^3/year.

Preservation and protection of water resources, natural habitats and sensitive areas

National sanitation waste water treatment plan for rural areas targeted at access rate of 90% (2030)
National Plan for the prevention and fight against Industrial Pollution.
Implementation of the National Plan for the Management of Household and Similar Waste.
Project to demineralize brackish waters for reuse in irrigation and drinking water
Limiting groundwater abstractions, artificially recharge aquifers and Contrat de nappe
Protection of watersheds, water source areas and fight against desertification

Major programs implemented under the National Water Sector Development Strategy include e.g.:

The National Water Sanitation and Treatment Plan, aiming at reaching 300 Wastewater Treatment Plants (STEP) by 2025.
The National Household Waste Plan (PNDM), embarking on a 15-year horizon.

---

[2] The SNE (2009) likely overestimated the potential for water savings due to the introduction of drip irrigation; it is often accompanied by agricultural intensification and leads then to higher farm incomes but much less to water savings (Molle, 2017)

The “Green Morocco” Project (Maroc Vert), embarking on objectives earmarked for 2020 and comprising a significant component for irrigation and water conservation.

The Integrated Water Resources Development and Management Plans (PDAIRE) prepared by each ABH for its respective basin, providing a long-term vision, subject to reviews on a five-year basis. The PDAIRE plans integrate for each basin other national plans and program objectives.

Areas where urban water utilities and ONEE can make substantive contributions to closing the gap between water demands and supplies in Morocco are desalination of seawater and brackish groundwater, treatment and reuse of waste water, rainwater harvesting, demand management and improving the efficiency of the water distribution networks through leakage reduction. The potential and cost of these and other measures are discussed in Chapter 4, highlighting as well experiences from other countries and cities exposed to water scarcity.

ANNEX II - Water Scarcity in Morocco and Impacts of Climate Change

Morocco is classified as a country with high water scarcity below the "water poverty level", facing possibly extreme water scarcity by 2050. Eighty percent of Morocco's territory is arid to semi-arid. Due to a combination of strong population growth in the 20th century (from 12.3 million people in 1960 to 34.4 million in 2015), economic development and a strong decline since 1980 in precipitation (-15% to -20%) and river runoff (-30% to 40%), water resources availability is already under severe pressure. Water availability in Morocco has dropped from 3,500 m^3 per person per year in 1960[3] to 731[4] m^3 per person in 2005 (SNE, 2009) for a population of 30.4 million, and 645 m^3 per person in 2015, well below the "water poverty level" of 1,000 m^3 per person per year. With a projected 43.7 million inhabitants by 2050 and no further change in water resources availability due to climate change, this would yield 510 m^3 per person per year by 2050, near the UN's "extreme water scarcity" level of 500 m^3 per capita. However, a severe future reduction of the available water resources with 25% to 50% due to climate change is well possible if not likely, which would push the country over the next decades on average far below the "extreme water scarcity" level.

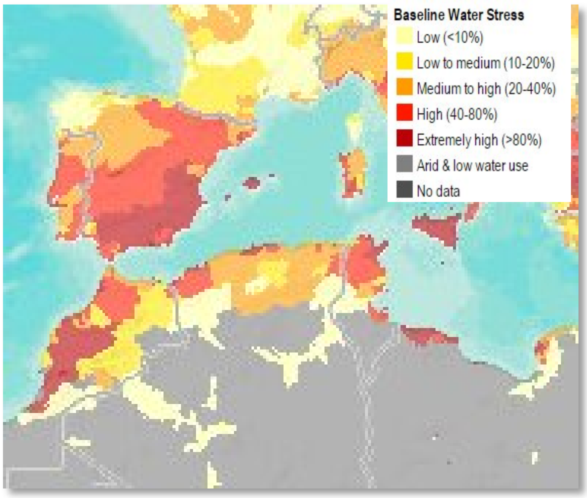


Figure II-1: Baseline water stress in the Maghreb)

The steady decline in available resources is aggravated by a degradation of water quality due to inadequate waste water treatment and agricultural pollution, an over-exploitation of aquifers, and the loss of regulated volumes of reservoirs due to sedimentation. Morocco is therefore classified as a country with high water scarcity in UN-Water 2013 and by the World Resources Institute (Luo et al, 2015); the latter indicating high water stress in 2010 and extremely high water stress in 2040. In this context of scarcity, the gap between supply and demand will increase each year. Currently, the water demand in Morocco is met from limited surface water resources and an over-exploitation of groundwater. The Plan National de l'Eau (PNE, 2015) estimates the current average regulated water resources for the country at a total of 12.5 Bm^3/year, 9.1 Bm^3/year of surface water regulated by 139 reservoirs and 3.4 Bm^3/year of groundwater.

[3] https://www.globalwaterjobs.com/News/countryinfocusmorocco.html

[4] This rate varies between 150m^3/person/year for areas known to be poor in water resources (Bouregreg, Atlas South, and Sahara) and 1,200 m^3/person/ year for the Loukkos and Sebou basins (SNE, 2009).

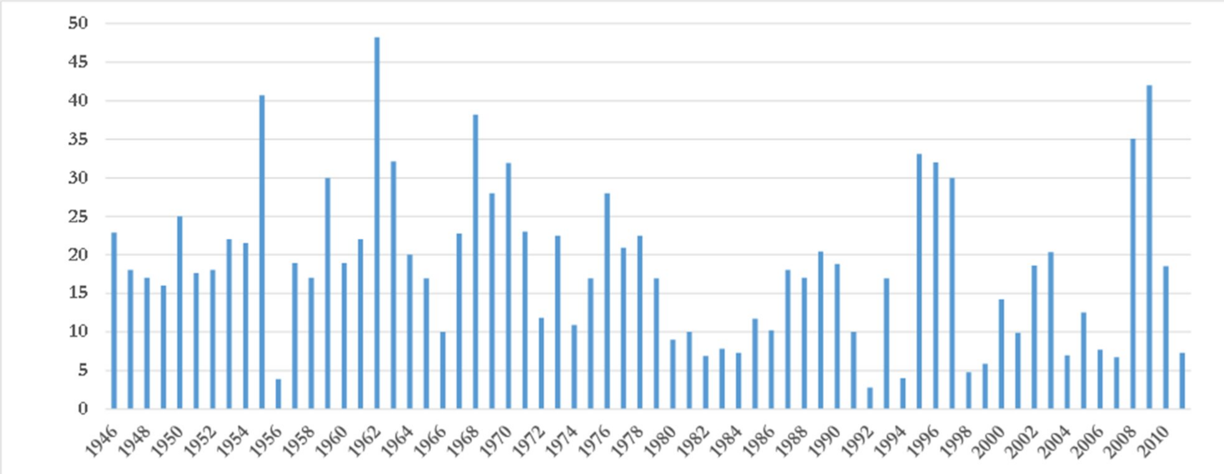


Figure II-2: Change in annual water inputs between 1946 and 2011 (billion cubic meters / year) in Morocco[5]

Since an abrupt change in rainfall occurred around 1980, annual availability of particularly surface water has been substantially less, hovering since 1980 between 5 and 20 Bm^3/year. The average annual inputs at the country level increased from 21.8 Bm3 / year between 1946 and 1967 to 17.7 Bm3 / y between 1968 and 1989 and then to 16.6 Bm3 / y between 1990 and 2011. In addition to this trend in the average decrease in contributions, this trend shows a trend towards increasing their inter-annual variability as shown by the evolution of their distribution over time. Indeed, during these three periods, the standard deviation of these contributions increased from 9.2 and 8.4 Bm3 / year during the first period and the second period to 11.2 Bm3 / year during the third period

Hydraulic balances of hydraulic basins in 2010: The PNE (2015) presents an analysis of the situation of the water balances of the different basins, based on the confrontation between the mobilized water resources and the water needs expressed by the various user sectors, namely drinking water, tourist and industrial water, irrigation water and the need to preserve the environment including the quality of water resources. The mobilized water resources correspond:

- to the volumes regularized by the structuring dams, which are the annual volumes guaranteed by the dams, respecting the criteria for satisfying water demand defined in the framework of the PDAIRE;
- to the volumes of run-of-river sampling on rivers, which are the direct sampling from the wadis upstream of the dams and the watercourses not controlled by the dams (generally intended for irrigation of the PMH perimeters along the watercourses).
- to the volumes of exploitable groundwater resources that are recommended harvests to ensure the sustainability of the exploitation of groundwater resources and avoid overexploitation.

Thus, the volumes regulated by the dams amount to 6,644 Mm3 / year, to which are added direct flows of 2,448 million m3 / year, bringing the total average mobilized volume of surface water to more than 9,092 million m3 / year. For groundwater, an estimated 3,416 Mm3 / year of water resources is estimated and the total water mobilizable volume is estimated at 12,508 Mm3 / year (surface water: 73%, groundwater: 27%).

[5] Source : Plan National de l'Eau, 2015 : Rapport General

Table II-1: Situation of the water balances (in Mm3 / year) of the hydraulic basins in 2010 according to the PDAIREs

Hydraulic basin	Ressources en eau (Mm³/an)												Water demand (Mm³/an)			Overall (Mm³)
	Surface water			Groundwater					Desal (d)	Import from O. E.R basin (e)	Export to Bouregreg and Tensift basins (f)	Overall (a + b + c + d +e- f)				
	Regulated (a)	Direct from river (b)	Mobilized (a+b)	Surface (km²)	Renewable	Exploited (g)	Potentially exploited (c)	Total (c – g)					Municipal + indus.	Irrigation	Total	
Loukkos, Laou, Tangérois and Coastal Mediterranean	430	140	570	12,805	180	126	146	20		0	0	716	164	262	426	290
Moulouya	516	326	842	74,145	450	460	430	-30		0	0	1,272	128	1,192	1,320	-48
Sebou	2,500	140	2,640	40,000	1,125	1,177	1,020	-157		0	0	3,660	286	2,873	3,159	501
Bou Regreg et la Chaouia	290	15	305	20,470	76	108	76	-32		120	0	501	371	135	506	-5
Oum Er Rbia	2,163	476	2,639	48,070	560	648	350	-298		0	320	2,669	200	3,526	3,726	-1,057
Tensift	125	645	770	24,00	554	686	506	-180		200	0	1,476	130	1,647	1,777	-301
Souss - Massa - Draa	539	321	860	126,480	666	921	666	-255		0	0	1,526	120	1,724	1,844	-318
Ziz, Rhéris, Guir	80	385	465	58,841	204	196	204	8		0	0	669	19	669	688	-19
Sahariens	1		1	305,239	18	21	18	-3	10	0	0	29	19	10	29	0
Total	6,644	2,448	9,092	710,850	3,833	4,343	3,416	-927	10	320	320	12,518	1,437	12,038	13,475	-957

The volume of exploited groundwater resources is estimated at 4,343 Mm3 / year. Thus, in relation to the exploitable potential, groundwater resources are overexploited of 927 Mm3 / year. The most overexploited aquifers are those located in the basins of Souss-Massa, Oum Er Rbia, Tensift and Sebou. The volumes overexploited in the aquifers of these basins are 255, 298, 180 and 157 million m3 / year, respectively.

Inter-basin water transfers consist of an average water export of 320 Mm3 / year from the Oum Er Rbia basin to those of Tensift (200 Mm3 / year) and Bouregreg-Chaouia (120 Mm3 / year) . For water demand, it is estimated at 13,475 Mm3 / year, distributed between 1,437 Mm3 / year for drinking water, industrial and tourist water (11%) and 12,038 million m3 / irrigation.

The analysis of the hydraulic balances resulting from the comparison between the mobilized water resources and the demand for water for the different users shows that the Sebou basins (+501 million m3 / year), Loukoss, Tangérois, Laou and of the Mediterranean coastlines (+290 million m3 / year) are surplus thanks in particular to the availability of surface water resources. On the other hand, other basins are in deficit, namely Oum Er Rbia (-1,057 million m3 / year), Souss-Massa-Draa (-318 million m3 / year), Tensift (-301 million m3 / and Moulouya (-48 million m3 / year).

Deficits are structural in the Souss-Massa, Tensift and Moulouya basins because of the limitation of natural renewable water resources in relation to water demand. For the Oum Er Rbia basin, the deficit is generated by strong development and hydro-irrigation in the basin, which exceeds its hydraulic capacity, as well as water transfers to areas outside the basin. basin. The cumulative deficit of all the basins is of the order of 1,750 Mm3 / year.

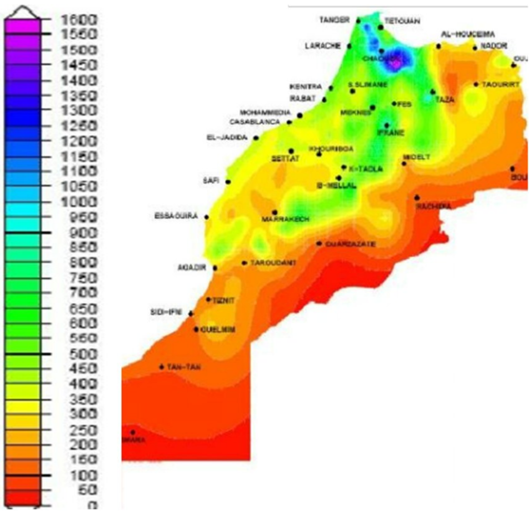


Figure II-3: Rainfall variability (source : ONEE-IEA, 2014)

In addition to the large interannual variability, surface water supplies show a highly contrasted spatial distribution. The country spreads from north to south of a well-watered Mediterranean zone (over 800 mm of rain on average per year), to the borders of the great Sahara, where precipitation is very limited, if not practically absent. Just as the Atlas mountains share the country between relatively well-watered west-facing slopes and east-facing slopes that are arid. The northwest and central part of the country concentrate the bulk of surface water supplies, while the eastern and southern parts of the country suffer from a chronic shortage of water.

Due to its arid to semi-arid climate, characterized by a very high spatial and temporal variability of precipitation, the mobilization and rationalization of water resources management has been a constancy of Moroccan economic policies. In this sense, considerable efforts have been made during the last decades in terms of public investments in the water sector. These investments have provided the country with an important hydraulic infrastructure consisting of 139 dams with a storage capacity of 18.5 Bm3 and several thousand boreholes and wells for collecting groundwater (SNE, 2009).

However, despite its low water potential, Morocco has made agriculture a key sector of its economic and social development. Faced with the independence of a large rural population, whose main source of employment and income is agriculture, and with a view to ensuring a minimum level of food security for the country, the authorities have concentrated their efforts on agriculture. The quasi-tax exemption of agricultural income, exemption from duties and taxes on imports of agricultural inputs and capital goods, direct subsidies to agricultural investments, indirect subsidies through public investment or the subsidization of certain inputs, and particularly energy, as well as the border protection of the main agricultural products, are all instruments of this policy.

Irrigation was the cornerstone of this policy. In this way, between 1968 and 2004, the State equipped almost 550,000 ha irrigated with surface water from large hydro (GH) works and rehabilitated nearly 330,000 ha irrigated by surface water in of small and medium hydraulic perimeters. This has resulted in a reduction of the area irrigated by surface water to 1.033 million hectares at present. Until recently, and given the hierarchy of water use priorities by the different sectors, the high water consumption of the agricultural sector (over 80%) did not have any negative impacts, at least directly, on the development of other sectors of the economy. The priority in water supply in a situation of shortage is generally given to the municipal water. Indeed, until the mid-1990s, agricultural policy was mainly oriented towards food security and, consequently, to the annual crops that served as irrigation schemes for large-scale irrigation schemes for regulating water demand. In a situation of water shortage, the reduction of irrigation water to summer crops, first, and to second-hand winters, made it possible to reduce considerably the consumption of surface water and to secure water supply for other priority water use sectors.

To solve this problem, the present report discusses a specific approach for the development of the Water Sector (SNE, 2009), which and aims to close the future gap between demand and supply, by increasing supplies with 2.5 Bm3 / year and reduced demands with 2.5 Bm3 / year.

Climatic challenges and climate change impacts on water availability

Morocco will be subject to the severe and negative impacts of climate change, as evidenced by studies to date. It is generally expected that irrigated agriculture and other socio-economic developments related to water resources in the Moroccan Water Basins will be severely exposed to future climate change. Since the 1980s, Morocco has already been subject to a sudden reduction in rainfall (-15%) and runoff (-30% to -40%). It is possible that the country will face a drier future, possibly with new reductions in rainfall (about 20%) and in runoff (about 50%), similar to the reductions that have already taken place around 1980. Most projections of global circulation models (GCMs) predict a drier and warmer future in the North Africa and Morocco region. This downward trend in precipitation will inevitably result in a decrease in runoff and a decrease in groundwater recharge.

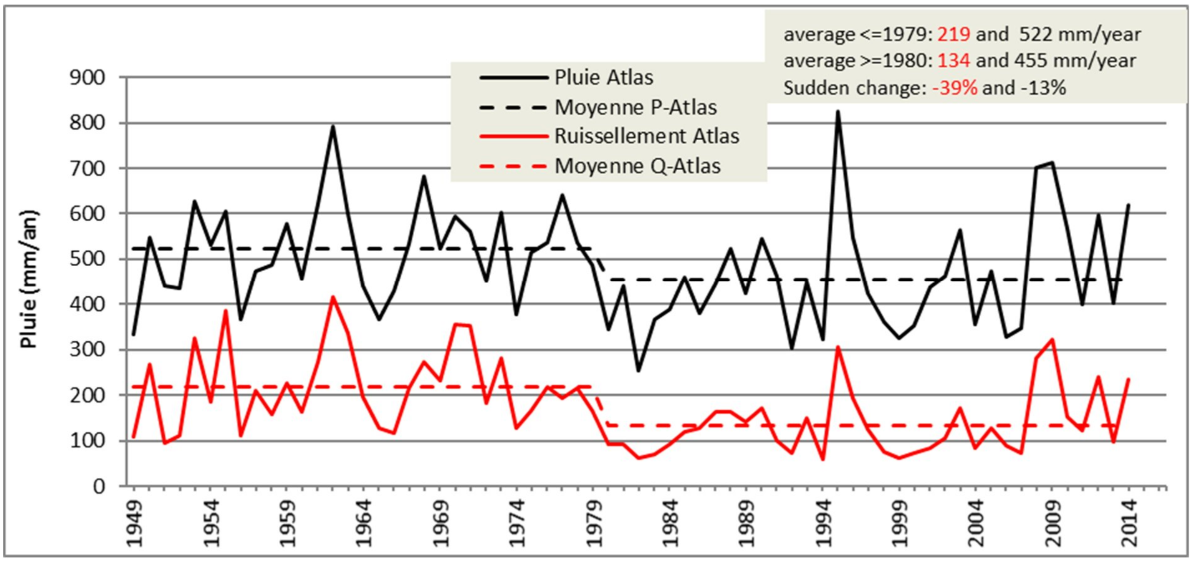


Figure II-4: Annual precipitation and runoff for the Atlas region of the Oum Er Rbia (OER) basin

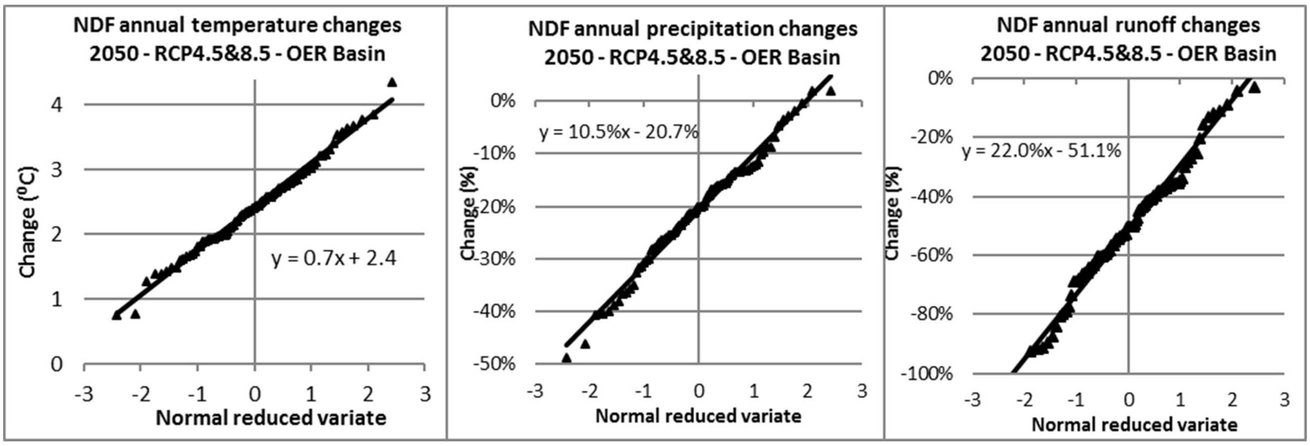


Figure II-5: Projected average annual temperature, precipitation and runoff changes for the OER Basin (2050)

Projected annual temperature, precipitation and runoff changes for 23 CMIP5 – GCMs[6] and RCPs 4.5 and 8.5 (obtained from www.climatewizard.org) are plotted on the above figure on a normal probability scale, for the Oum Er Rbia (OER) river basin (ABHOER, 2017), which would also be representative for the neighboring Tensift basin. The differences for the RCP4.5 and RCP8.5 scenarios are still modest for 2050. Overall, we can expect a change of 2.4 ^{0}C in the annual temperature by 2050, with a standard deviation of 0.7 ^{0}C across the 23 GCMs. GCMs project a decrease of about 20% in annual precipitation by 2050, with a standard deviation of about 10% across the 23 models. The variation of precipitation projections across all GCMs is thus large, with projections for 2050 ranging between -50% and 0% (no change). The right panel of the above figure shows projections of future changes in OER basin runoff for 2050, derived from the projected temperature and precipitation changes, based on assessed climate elasticities of runoff.

[6] GCM = Global Circulation Model ; RCP = Representative Concentration Pathway

The Basin of the Oum Er Rbia provides most of the water resources in the Marrakech area by the Rocade Canal and soon also by the project financed by the AfDB to secure the city's drinking water supply. Marrakech and its neighboring agglomerations from the Al Massira dam on the river Oum Er Rbia. The conclusions of the study of future climate change, carried out by the Oum Er Rbia Water Basin Agency (ABHOER) with the support of the World Bank, are as follows:Projections of future precipitation and temperature vary largely for the Oum Er Rbia Basin across multiple GCM models. The OER basin and Morocco in general face overall a much drier future. All projected future runoff changes are negative.

- The spread between individual precipitation projections is significant, with a standard deviation of 10% by 2050. Most precipitation projections are between -40% and 0% change in precipitation.
- On average a decrease in precipitation in the order of 20% is projected by 2050 and a temperature increase in the order of 2.5 ^{0}C, yielding across all GCMs an average reduction in runoff of about 50%.
- The following climate change induced runoff scenarios were recommended for further analysis of the climate robustness of water resources development projects in the OER basin, for the 2050 investment horizon (these recommendations would also be valid for the neighboring Tensift basin):
    - Most optimistic climate change scenario: no change in annual precipitation, a temperature increase of 2.5 ^{0}C and a reduction in runoff with 10%;
    - Modest climate change scenario: decrease of 10% in annual precipitation, a temperature increase of 2.5 ^{0}C and a decrease of annual runoff with 30%;
    - Average climate change scenario: decrease of annual precipitation with 20%, increase of temperature with 2.5 ^{0}C and decrease of annual runoff with 50%;
    - Worst case scenario: decrease of annual precipitation with 30%, increase of temperature with 2.5 ^{0}C and decrease of annual runoff with 70%;
    - By 2050 irrigation water demands for crops will increase by about 8% for an increase in temperature with 2.5 ^{0}C. Meanwhile, the net precipitation contributing to crops water demands will reduce, thereby also contributing to increased crop water demands for irrigation.

Given the substantial uncertainty of the climate projections from the multiple GCMs and the potentially adverse effects on runoff, it is therefore important to mainstream the Climate Risk Assessment (ERC) into the sector in the preparation of the PDAIRE, and in planning for the future EAF at the level of the ONEE and the Régies.

ANNEX III - Demographic and water demand projections for Morocco's urban population

1. Demographic growth

Population growth, rapid urbanization, changes in the household structure and increasing economic prosperity will lead to increasing urban water demands. According to World Bank statistics the total population of Morocco was 34.4 million in 2015 (http://data.worldbank.org/country/morocco), at an overall growth rate of 1.35% per year. However, the rural population had become stagnant at 13.7 million (39.8% of the total population), while the urban population of 20.7 million (60.3%) grew in that year at a rate of 2.2%/year. Past demographic statistics and projections for the future are shown in the figure below and summarized in table below for the period 1960 to 2050, sourced from UNDESA (2015) and www.knoema.com[7].

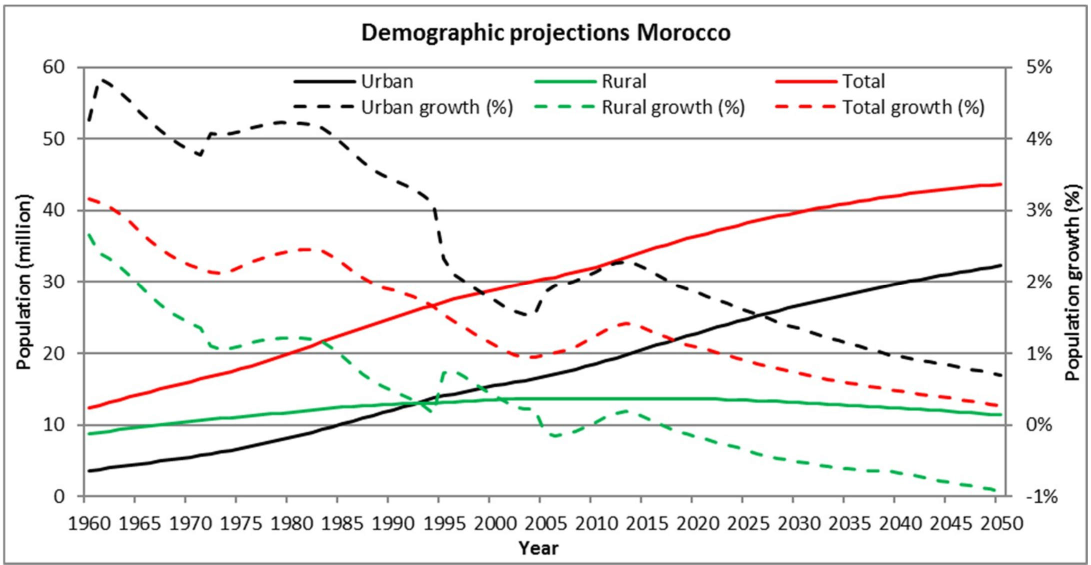


Figure III-1: Demographic statistics and projections for Morocco

Year	Urban population Morocco			Rural population Morocco			Total population	
	million	Annual growth (%)	Urban pop. as %	million	Annual growth (%)	Rural pop. as %	million	Annual growth (%)
2010	18.5	2.1%	57.7%	13.6	0.0%	42.3%	32.1	1.2%
2015	***20.7***	***2.2%***	***60.2%***	***13.7***	***0.1%***	***39.8%***	***34.4***	***1.3%***
2020	22.8	1.9%	62.6%	13.6	-0.2%	37.4%	36.4	1.1%
2025	24.8	1.6%	64.9%	13.4	-0.4%	35.1%	38.3	0.9%
2030	***26.7***	***1.3%***	***67.0%***	***13.1***	***-0.5%***	***33.0%***	***39.8***	***0.7%***
2035	28.3	1.1%	69.0%	12.8	-0.6%	31.0%	41.1	0.6%
2040	29.8	1.0%	70.7%	12.3	-0.7%	29.3%	42.1	0.5%
2045	31.1	0.8%	72.4%	11.9	-0.8%	27.6%	43.0	0.4%
2050	***32.3***	***0.7%***	***74.0%***	***11.4***	***-0.9%***	***26.0%***	***43.7***	***0.3%***

Table III-1: Summary of population projections for Morocco till 2050

[7] https://knoema.com/WBPEP2014/population-estimates-and-projections-1960-2050?country=1001320-morocco

The data sources project an increase in the population of Morocco from 34.4 million in 2015 to 39.8 million by 2030 (+16%) and 43.7 million by 2050 (+27%), at an annual growth rate slowing down from 1.3% in 2015 to 0.3% by 2050. The country is projected to reach its maximum population of 44.3 million a few years later. However, the rural population is projected to have peaked at 13.7 million by 2015 and is projected to decline to 13.1 million by 2030 (-4%) and 11.4 million by 2050 (-17%). Instead, the urban population would increase from 20.7 million in 2015 to 26.7 million by 2030 (+29%) to 32.3 million by 2050 (+56%), at an annual growth rate slowing down from 2.2% in 2015 to 0.7% by 2050. It is noted that the urban population of Morocco was 60.2% of its total population in 2015 (compared to 54% as world-wide average), which is projected to increase to 74% by 2050 (66% world-wide). Over the same period the urban population of China is projected to increase from 56% to 76%, while the urban population of much of the western world is projected to reach by 2050 between 85% and 95% of the total population. It may be noted that in 1960 the rural population constituted 70.6% of the total population of Morocco, and the country has witnessed a rapid urbanization ever since.

The table and figure below show population projections for the 20 largest cities and urban centers of Morocco (source: ONEE – branche Eau). The data shown concern the urban population served by ONEE. It is seen that these 20 cities represent 2/3rd of all urban population of Morocco. The largest growth in population is projected for Tanger, El Jadida and Berrechid, with more than 50% growth between 2014 and 2030 and more than a doubling of the population between 2014 and 2050. The one-million city of Marrakech, the fifth largest urban center of the country which represents 5% of the urban population of Morocco and has been selected for the case study documented in this report, is projected to grow with 25% by 2030 and with 65% by 2050, similar to the overall growth of the urban population of Morocco.

No.	Ville	2014 (serviced by ONEE)	Pop. 2020	Pop. 2030	Increase 2014-2030	Pop. 2040	Pop. 2050	Increase 2014-2050	Average Growth Rate/yr
1	Casablanca + Mohammedia	4,154,608	4,570,803	5,304,604	28%	6,156,209	7,144,532	72%	1.5%
2	Salé + Rabat	1,468,230	1,586,386	1,764,112	20%	1,893,487	2,057,443	40%	0.9%
3	Fès	1,126,259	1,245,875	1,445,889	28%	1,678,013	1,947,402	73%	1.5%
4	Tanger	997,823	1,214,210	1,516,750	52%	1,760,251	2,042,843	105%	2.0%
5	***Marrakech***	*986,580*	*1,074,764*	*1,235,073*	*25%*	*1,419,293*	*1,630,991*	*65%*	*1.4%*
6	Agadir + Ait Melloul	859,725	968,861	1,152,371	34%	1,337,374	1,552,077	81%	1.7%
7	Meknès	638,587	705,715	806,979	26%	891,407	984,668	54%	1.2%
8	Tétouan	621,261	718,584	875,950	41%	1,016,576	1,179,778	90%	1.8%
9	Oujda	494,252	560,533	683,287	38%	792,982	920,288	86%	1.7%
10	Kénitra	431,282	481,347	558,623	30%	648,305	752,384	74%	1.6%
11	Safi	308,508	323,704	357,571	16%	394,980	436,304	41%	1.0%
12	El Jadida	257,632	315,975	394,705	53%	458,071	531,610	106%	2.0%
13	Béni Mellal	203,519	222,669	258,416	27%	299,903	348,049	71%	1.5%
14	Khouribga	196,196	216,579	239,238	22%	264,268	291,916	49%	1.1%
15	Nador	174,846	185,385	204,780	17%	226,205	249,871	43%	1.0%
16	Taza	148,456	153,980	166,752	12%	180,582	195,560	32%	0.8%
17	Settat	142,250	160,299	195,404	37%	226,774	263,181	85%	1.7%
18	Berrechid	136,634	172,886	226,759	66%	276,418	336,952	147%	2.5%
19	Ouarzazate	102,139	120,274	146,614	44%	170,151	197,467	93%	1.9%
20	Errachidia	92,374	103,229	114,029	23%	125,959	139,137	51%	1.1%
	Total 20 Villes	13,541,161	15,102,058	17,647,906	30%	20,217,208	23,202,453	71%	1.5%
	Urban population MOR	20,250,619	22,815,000	26,658,000	32%	29,803,000	32,321,000	60%	1.3%
	Ratio 20 Villes/urban MOR	67%	66%	66%		68%	72%		

Table III-2: Population projections for the 20 largest cities in Morocco (2014 – 2050)

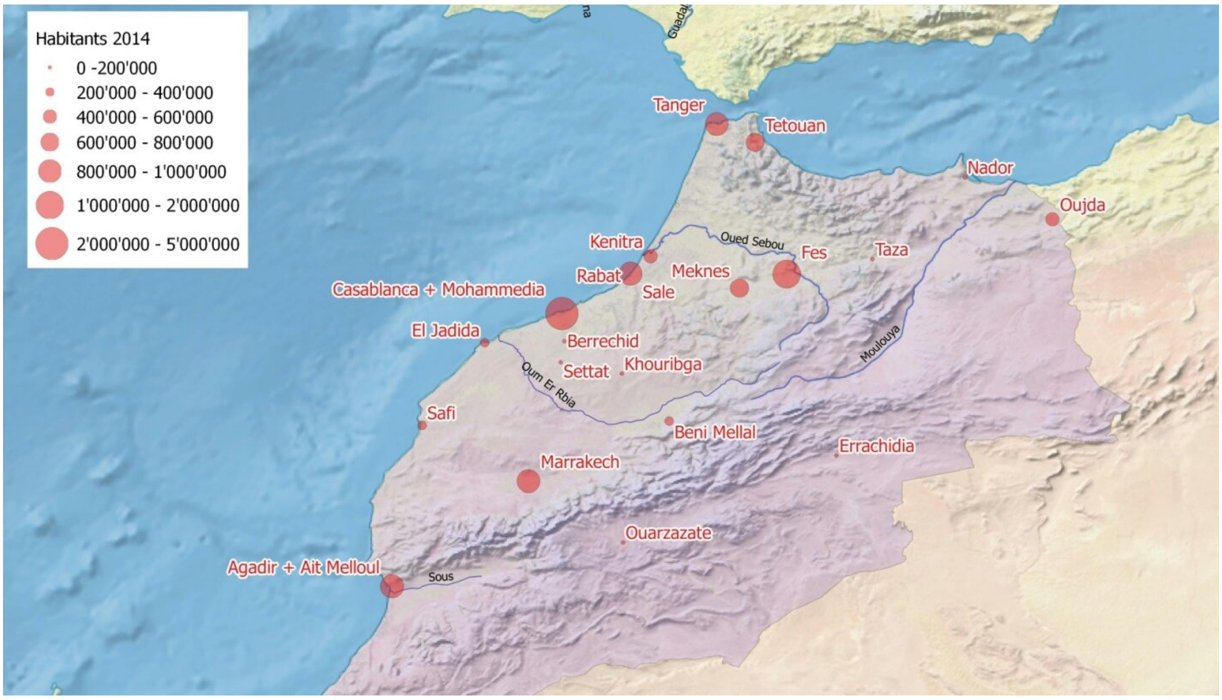


Figure III-2: Population of the twenty largest cities and urban centers of Morocco in 2014

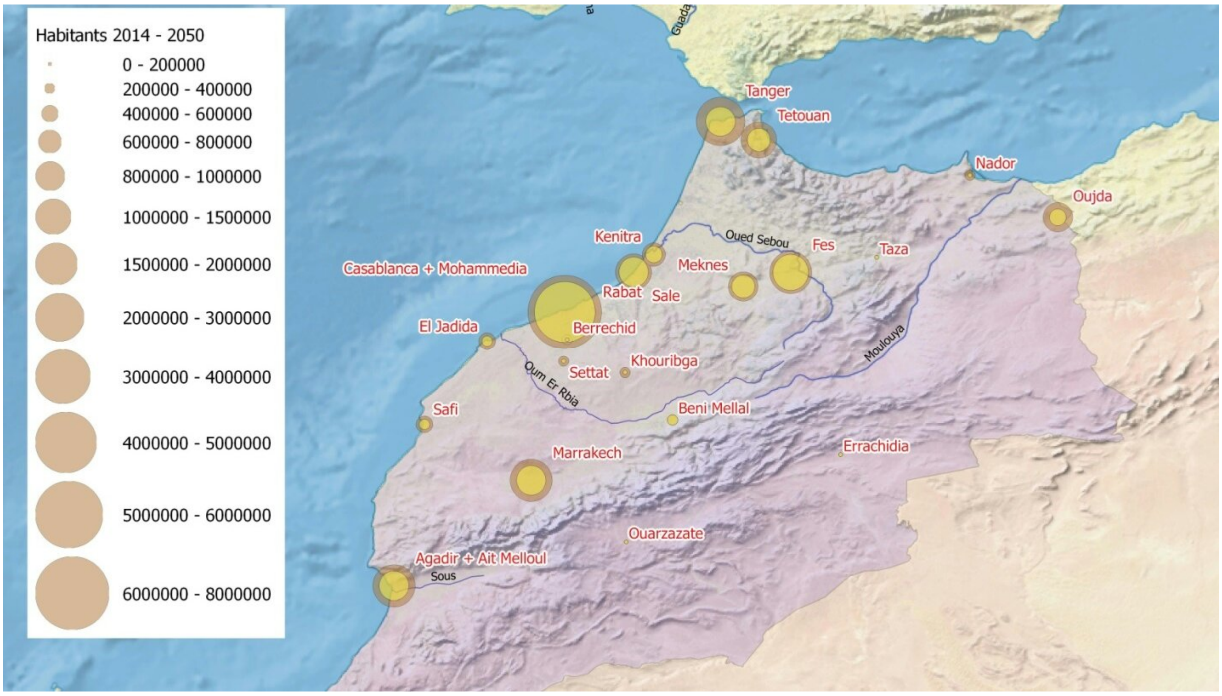


Figure III-3: Projected urban population growth between 2014 and 2050

Urban water demands may increase due to a rapid change of the number of persons per household. According to the 2014 population census[8], the national average number of persons per urban household was 4.25, against 5.35 in rural households. In the Marrakech – Safi region, subject of the case study, the number of persons per urban household was 4.36, close to the national average. In Grand Marrakech (subject of our case study), with a population of 928,850 persons in 2014, the average number of persons per household was 4.28, down from 4.81 in 2004 and 5.38 in 1994. Thus, the number of persons per household is decreasing rapidly, and this may put an upward pressure on urban water demands. At this rate of change, the number of persons per urban household could by 2030 well be around 3.5 to 3.75, and 3.0 to 3.25 by 2050.

Sr. #	Region	# of urban households	Urban population	Persons/ household	# of rural households	Rural population	Persons/ household
1	Tanger - Tetouan - Al Hoceima	525,168	2,131,725	4.06	273,956	1,425,004	5.20
2	Oriental	338,419	1,513,911	4.47	156,111	800,435	5.13
3	Fès-Mèknes	600,113	2,564,220	4.27	319,384	1,672,672	5.24
4	Rabat - Salé -Kénitra	766,852	3,198,712	4.17	248,255	1,382,154	5.57
5	Béni Mellal - Khénifra	287,268	1,238,739	4.31	232,906	1,282,037	5.50
6	Grand Cassablanca - Settat	1,214,427	5,050,749	4.16	344,977	1,810,990	5.25
7	Marrakech - Safi	444,856	1,938,016	4.36	483,264	2,582,553	5.34
8	Draa - Tafilalet	114,631	560,738	4.89	163,367	1,074,270	6.58
9	Sous - Massa	353,802	1,505,896	4.26	247,709	1,170,951	4.73
10	Guelmim - Oued Noun	60,873	280,094	4.60	29,329	153,663	5.24
11	Laayoune - Sakia El Hamra	75,865	343,362	4.53	2,889	24,396	8.44
12	Eddakhla - Oued Eddahab	25,469	106,277	4.17	3,916	36,678	9.37
	Total	4,807,743	20,432,439	4.25	2,506,063	13,415,803	5.35

Table III-3: Regional distribution of the number of urban and rural households – 2014 census

2. Characteristics of urban water supply for main cities in Morocco

Domestic water demands

ONEE assessed the total demand for potable water supply (AEP) in 2015 for the entire country at 1,210 Mm^3/year, and projects a demand of 1,585 Mm^3/year for 2030, which is much less than de demands for municipal and industrial water demands projected in the PNE (2015), i.e. 1,437 Mm^3/year for 2010 and 2,368 Mm^3/year for 2030. The figure below shows the total water consumption in Mm3 / year for the 20 major cities of Morocco. Not surprisingly, the economic center and the largest city of Morocco, Casablanca, in addition to the city of Mohammedia, has the largest water consumption, followed by the agglomeration of Rabat and Salé, Tangiers, Fez and Marrakesh. It is fortunate that most of the urban centers with ample water consumption are located at the coast, which facilitates the desalination of seawater for AEP in the future.

Domestic water consumption per inhabitant varies between 67 l / day (Errachidia) and 123 l / day (Rabat), and 100 l / day for Marrakech. Total per capita consumption varies between 76 l / day (Errachidia) and 163 l / day (Rabat), and 130 l / day for Marrakech.

[8] http://www.hcp.ma/file/167575; http://rgph2014.hcp.ma/downloads/Publications-RGPH-2014_t18649.html

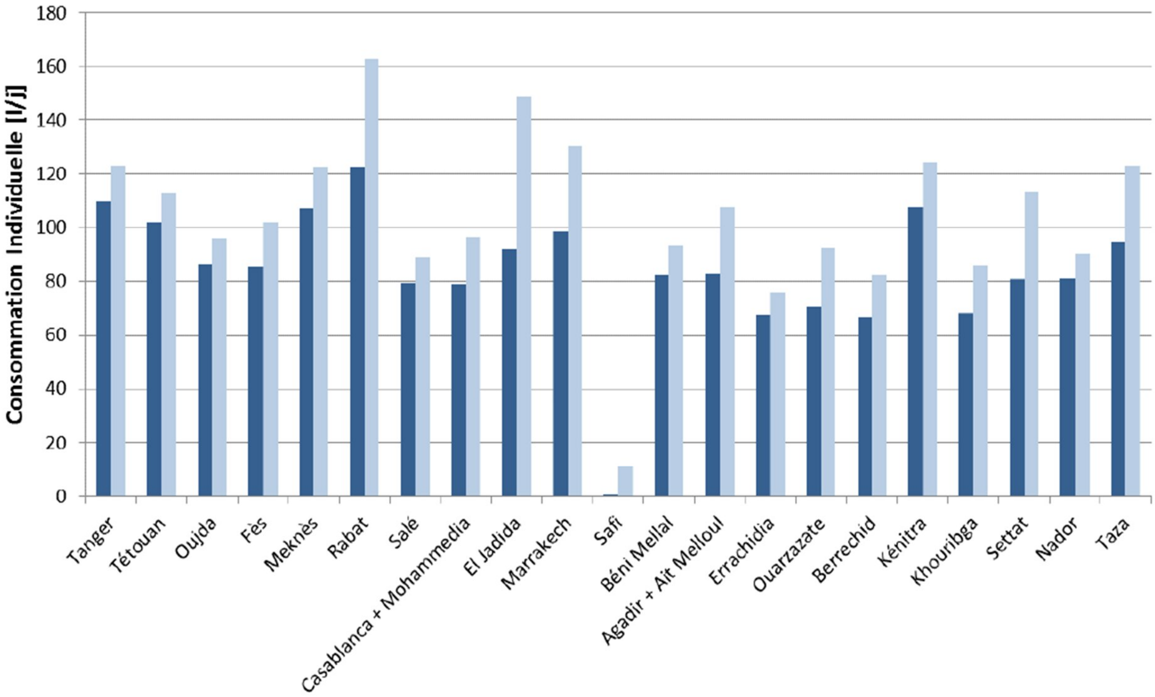


Figure III-4: Domestic and total drinking water consumption in 2014, in liters per capita per day

Comparing domestic consumption per capita in the twenty Moroccan cities with that of 57 cities in middle-income countries (Brazil Nordeste region, Egypt, Jordan, Mexico, Pakistan, Tunisia) shows that most values for Moroccan cities are consistent with the average of these other water scarce areas. Compared to international standards, the total specific consumption of water in the twenty cities is rather low on average and in no excessive case. In OECD countries, the average domestic consumption per inhabitant is approximately 180 l / day. In the United States and Canada, the average consumption per capita is around 300 l / day, while in many towns in Africa, the average is lower than 30 l / day.

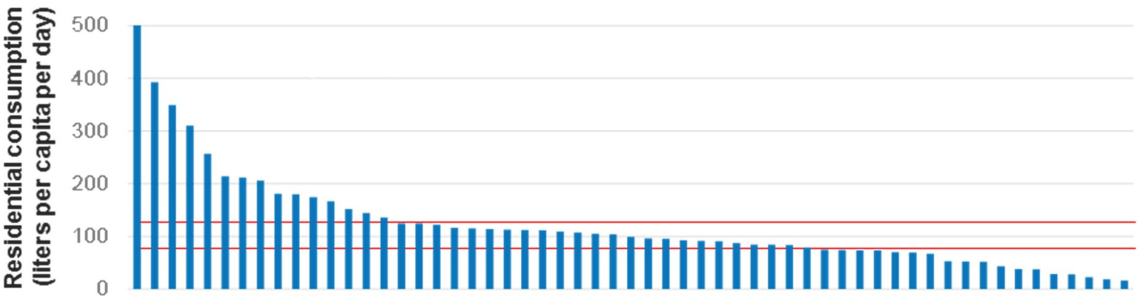


Figure III-5: Domestic drinking water consumption in 57 water scarce cities of other middle-income countries: Brazil (Nordeste region), Egypt, Jordan, Mexico, Pakistan, Tunisia

Urban water demands may further increase due to rapid socio-economic changes. In Marrakech of example, the average number of persons per household was 4.3 in 2014, down from 5.4 in 1994. The rapid decrease in households size may put an upward pressure on urban water demands, similar to the overall increase in purchasing power and changes in lifestyle of the modern urban population. Demand projections show a rapid growth in urban water demands: the Plan National de l'Eau (PNE, 2015) assessed Morocco's demands for domestic and industrial water supply at 1,437 Mm^3/year in 2010 and 2,368 Mm^3/year by 2030, which represents a 65% growth. Certain cities, such as Tanger and Tetouan could even experience a doubling of their urban water demand, as illustrated on the figure below.

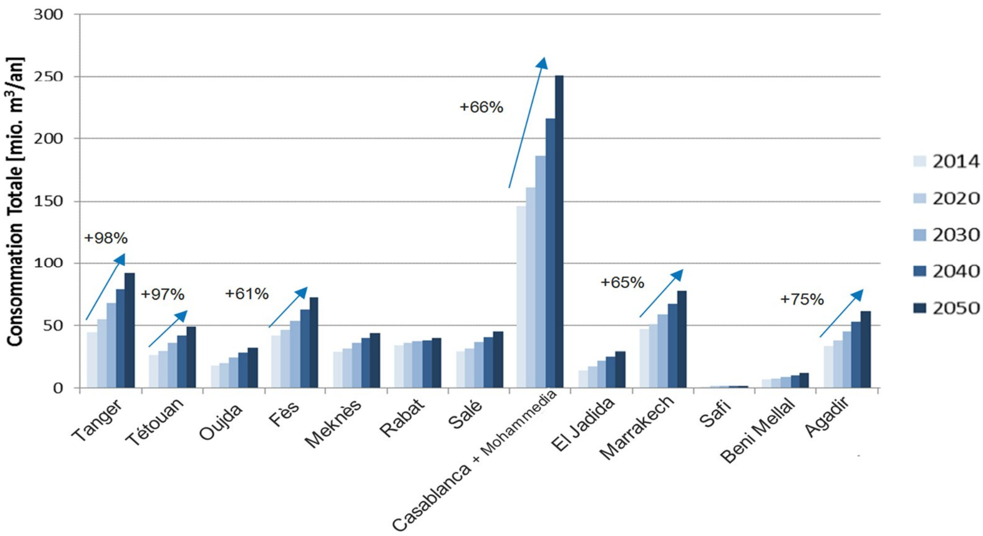


Figure III-6: Projections of total drinking water consumption in the major cities of Morocco (source: ONEE)

Physical water losses

Water losses in the urban network vary between 17% (Salt) and 45% (Fez); the average value in Morocco is 27% (Kurtze et al., 2015), which is still a great value in terms of international standards, but represents a reasonable value for an emerging country like Morocco. The water losses in the distribution system of Marrakech were reported to be about 25% in 2016, equal to the national average. The latter losses for Marrakech do not include commercial losses due to metering errors and lack of complete metering.

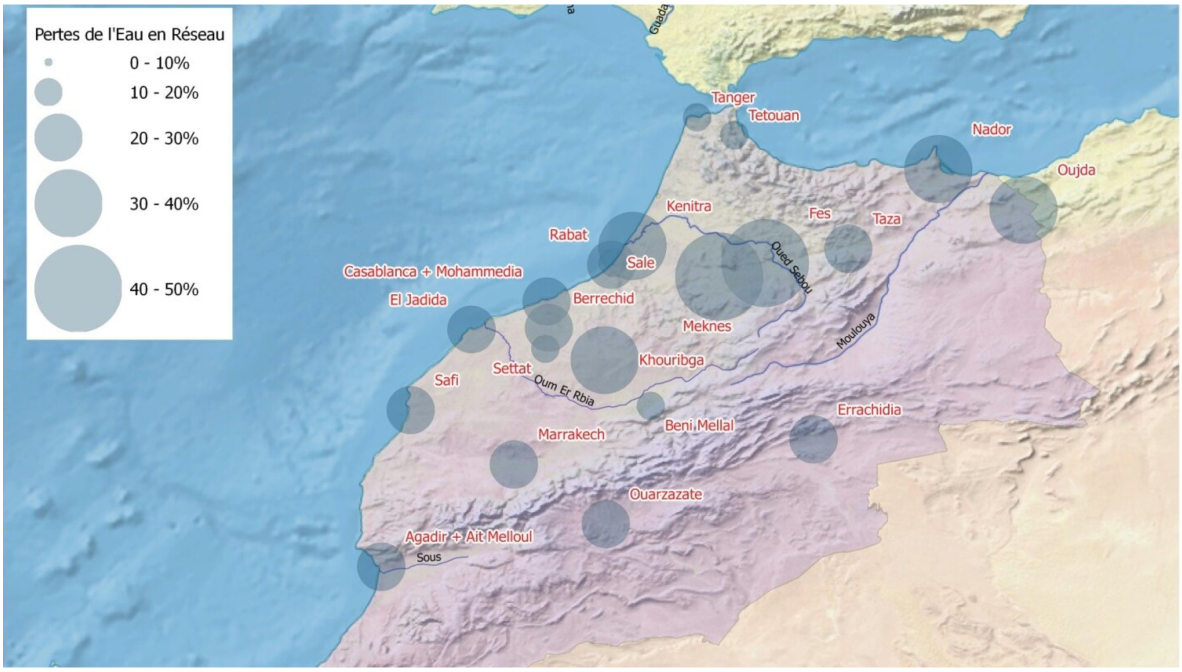
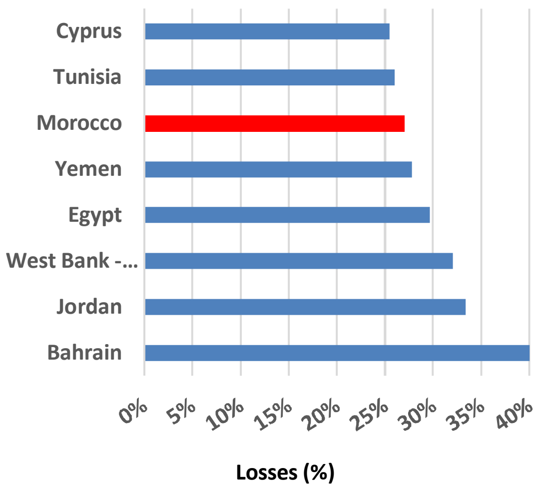


Figure III-7: Water losses in distribution networks in 2014 in Morocco, in percent and Mm3 / year (source: ONEE), and in the MENA region

These values compare to 20% to 60% in the MENA region as shown on the figure below. The Economic Level of Leakages (ELL) is the one below which the marginal cost of reducing leakages outweigh associated economic benefits. This value is highly context dependent. However, based on levels achieved in many countries (16% in the USA in 2008, 14% in Windhoek and one-digit losses in many western European, US and Australian cities and in Singapore), water utilities in Morocco are likely to have significant room for improvement. The PNE (2015) targets a non-revenue water level of 20% till 2030 nation-wide.

Figure III-8 - Average physical losses in urban areas of the MENA region



Reuse of treated waste water

Treated waste water provides an important potential source of water, for closing the widening gap between water demands and supplies. While recently there have been substantial improvements in access to water supply – with near-full access in urban areas and 94%[9] access in rural areas in 2014 - and to a lesser extent in access to sanitation[10], remaining challenges include *inter alia* a low level of wastewater treatment and reuse (now centralized under ONEE). Since launching its National Wastewater Treatment plan (PNA) the percentage of wastewater treated has risen from just 7% in 2005 to 41% in 2015, and it is anticipated to rise to 60% by 2020. While the reuse of wastewater (particularly in agriculture) is now seen and recognized by the Government in the new Water Law 36-15 (August 2016) as a viable resource and necessity for meeting the country's water requirements (EU-2013), it is still presenting significant shortcomings (GWI, 2016) due to: i) lack of an adequate institutional and regulatory framework; ii) insufficient technical expertise; iii) low levels of wastewater treatment; iv) financial constraints when operators unable to recover all cost of providing water for reuse through adequate tariffs; and v) effluent quality issues due to a mixture of domestic sewage and effluent from small-scale industrial activities such as textile dyeing and tanneries. In order to be developed, this sub-sector would also need to address the problem of additional costs incurred by the further processing, transport and storage of treated waste water.

To address the waste water challenges in the country, the National Sanitation Program (NSP) was launched in 2005 with the objectives to increase the rate of sanitation access to 80% of urban households by 2020 (90% by 2030), and to develop and improve wastewater treatment and reuse on the long-term to 100% of the collected waste water.

Based on a domestic and industrial waste water generation of 100 lpcd and a net restitution rate of 80%, urban wastewater would increase from about 600 Mm^3/year in 2015 to about 750 Mm^3/year in 2030 and 900 Mm^3/year in 2050. In drought periods this could in due time constitute between 5% and 10% of the total water resources of the country. Treated waste water thus constitutes an important potential source of water for closing the widening gap between water demands and supplies. It is noted though that part of this volume cannot be mobilized due to the absence of irrigable sites downstream of treatment plants, especially in coastal cities, and the high cost of water conveyance systems when reuse sites require additional costs for pumping and channeling.

Salama et al. (2014) reviewed wastewater treatment and reuse in Morocco. In 2000 about 60% of the waste water was discharged directly into the sea, while the balance 40% was discharged in rivers and streams, and as such remained part of the water balance. In larger cities the restitution rate was found to be 80% @ 80 lpcd. According to Kurtze et al (2015), Morocco had in 2015 a total of 62 wastewater treatment plants, 6 plants with primary level sanitation (capacity 100,000 m^3/day), 40 plants with secondary level sanitation (capacity 240,000 m^3/day), and 16 plants with tertiary level sanitation (capacity 161,000 m^3/day), equivalent to a capacity of about 150 Mm^3/year with at least secondary level sanitation, or only about 20% of all urban waste water produced in 2015. Morocco thus still has a long way to go to achieve its long-term objective of developing and improving wastewater treatment to 90% and reuse to 100% of the collected waste water.

Presently only 12% of the treated waste water (treated to tertiary level) is being reused (Salama, 2014), most significantly being the WWTP (STEP) plant of Marrakech, which is equipped for the treatment of 33 Mm^3/year of wastewater, of which presently only 7 Mm^3/year is being reused for the irrigation of golf

[9] http://www.water.gov.ma/ressources-en-eau/politique-de-leau

[10] In 2012 connections for sanitation reached 72% in urban areas (Kurtze et al, 2015), while the rural sanitation sector has been suffering delays due to the absence of ONEE interventions in small towns, and the lack of human, technical and financial resources and the lack of information at rural municipalities.

courses and green spaces. The expansion of the Marrakech WWTP recently commissioned by RADEEMA includes a 10-year O&M component awarded to a private company. The plant will also be fitted with an anaerobic digester to generate biogas from sludge and a solar sludge drying facility. The city of Salé is reported to reuse 1.4 Mm^3/year of treated wastewater. Five large-scale treatment plants are being improved elsewhere to reuse wastewater for golf course irrigation and landscaping. In Fes, it is understood that the city is undertaking a feasibility study to build a reuse facility at its 57 Mm^3/year WWTP.

Au niveau du Bassin de l'Oum Er Rbia, l'OCP procède actuellement à la réallocation géographique des prélèvements d'eau vers l'amont du bassin de l'Oum Er-Rbia et l'abandon total des prélèvements à partir des eaux souterraines au niveau du Tadla et de Bahira avec le recours à la réutilisation, dans le traitement des phosphates et pour l'irrigation des espaces verts, des eaux usées traitées de 10 Mm^3/an répartis comme suit : i) 5 Mm^3/an au niveau de ville de Khouribga et ii) 5 Mm^3/an au niveau des villes de Benguérir et de Youssoufia. These plants feature microfiltration and disinfection for tertiary treatment and are powered by biogas generated from sludge. While the wastewater discharge activities of large multinational companies like OCP are monitored for their wastewater quality, smaller scale individually owned industrial operations in the fisheries, olive oil refining, textiles and leather tanning sectors do not have onsite (pre-) treatment facilities, discharging their waste directly to municipal WWTPs.

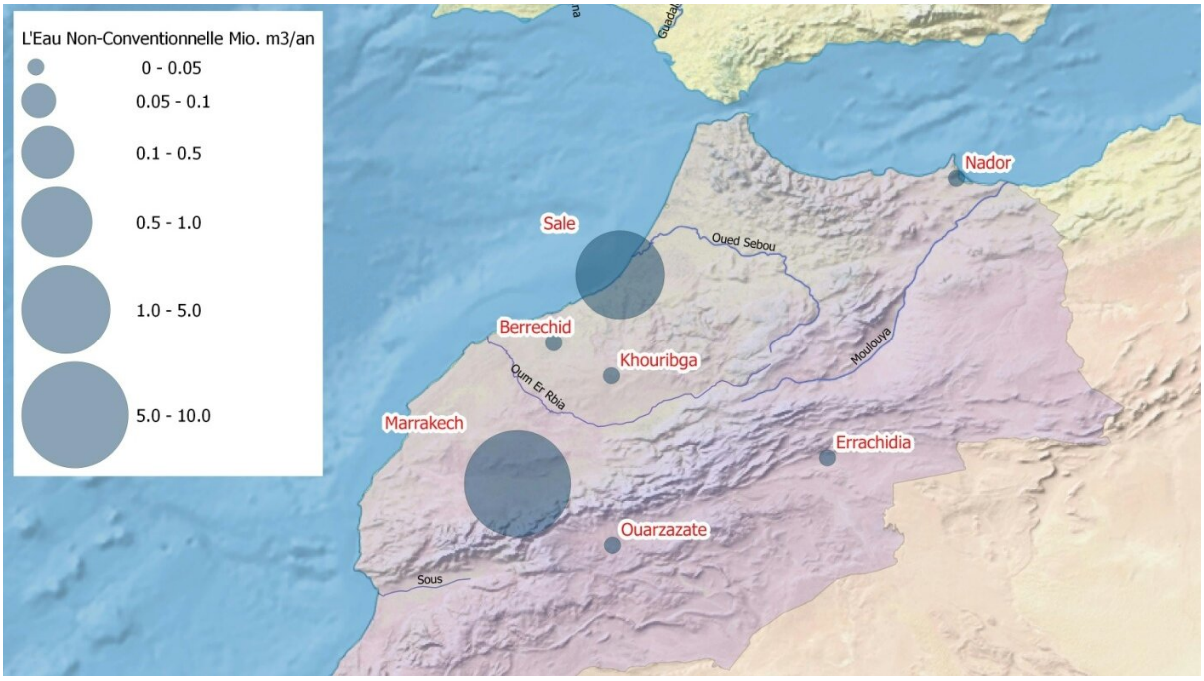


Figure III-9: Réutilisation des eaux usées en 2014, en millions m^3/an

ANNEX IV - Alternative supply and demand reduction measures aimed at achieving urban water security

1. Desalination of sea water and brackish water

Decreasing technological costs, its drought-proof nature and the production of superior water quality are among the reasons why desalination is becoming the water treatment technology of choice around the world. The perception that seawater desalination can be a drought-proof alternative to other water supplies has enabled water utilities around the world to effectively incorporate seawater desalination as a promising alternative to dwindling water supplies. In 2016 the total world-wide desalination capacity of seawater and brackish water stood at about 22 billion m^3/year. Also in Morocco desalination of sea water is now considered as a promising option; the National Water Plan (NCP) foresees the construction of seawater desalination plants to produce nearly 515 million cubic meters per year in 2030. Desalination is now a well-established technology, particularly in the MENA region, but it is still relatively expensive and energy-intensive, even though declining solar and wind energy cost move the gate posts in its favor. Morocco started to build small-scale desalination plants since 1995 and had completed 15 (mostly relatively small) installations by 2016, reaching a desalination capacity of 132 Mm^3/year (GWI, 2016), i.e. capacity installed and under construction. Morocco has planned to increase its desalination capacity to over 500 Mm^3/year under the PNE.

One of the plants under construction is the Agadir Desalination Plant, using Reverse Osmosis (RO) technology to produce 36 Mm^3/year at a construction cost of about 112 MUS$, to daily serve the drinking water needs of 800,000 people (123 lpcd). At a 10% discount rate, the construction cost alone amount to 0.31 US$/$m^3$, equivalent to 3 MAD/$m^3$. O&M could cost an additional 0.50 US$/$m^3$ (5 MAD/m^3). A Spanish firm will build, operate and maintain the plant under a 20-year PPP contract. The studies for the preparation of the latest PDAIRE for the Oum Er Rbia basin have evaluated the construction in 3 phases of a desalination plant with a capacity of 430 Mm^3/year between Rabat and Casablanca, at a total investment cost of 1,150 MUS$, or 0.27 US$/m^3 at a discount rate of 10%. Annual O&M and energy cost were estimated at 167 MUS$ or 0.39 US$/$m^3$, yielding a total cost of 6.6 MAD/m^3.

The phosphate company OCP is also in the process of constructing desalination plants at Jorf Lasfar – El Jadida (75 Mm^3/year) and Safi (25 Mm^3/year) for the purpose of providing 100 Mm^3/year by 2025 as drinking water for these cities and industrial water for OCP's phosphate production. There is also a plan to desalinate 17 Mm^3/year for the complexes touristiques prévus dans la zone côtière d'El Jadida-Safi pour la satisfaction de leurs propres besoins. Finally, it has been reported that a large desalination plant is under preparation for Casablanca (about 100 Mm^3/year by 2025 to 2030; the SNE (2009) mentions a capacity of 250 Mm^3/an). For the first phase of 100 Mm3 / year, the cost of water leaving the desalination plant is now estimated at 9 MAD / m3, which is slightly higher than common desalination costs for the MENA region. It should be noted that the total cost can vary from 10 to 15 MAD / m3 depending on the line of the water supply, the number of pumping stations, the cost of land, etc .; these costs are not included in the present calculation.

Almost all desalination plants (96%) in Morocco operate with reverse osmosis (RO) systems, with less than a handful using multi-effect distillation (MED) technology. The current capacity is relatively evenly split between medium, large and extra-large scale plants. As Morocco imports 95% of its energy needs, RO will likely remain the preferred technology going forward, given that it is the least energy-intensive of the desalination technologies. However, future projects in desalination may be combined with renewable energy generation to address the problem of high energy costs.

Desalination plants are generally financed by ONEE, which bases its investment decisions on (i) the costs of developing desalination infrastructure per m^3 generated, (ii) environmental impacts of releasing the remaining brine into the ocean, and (iii) the tariff that it is allowed to sell water at. Constraints include (i) the lack of formal financial mechanisms for cost-sharing, and (ii) the lack of formal mechanisms for inter-sectoral coordination. The Ministry of Agriculture is considering the Chtouka plant (81 Mm^3/year) for irrigation purposes (tomatoes) only. Future projects in desalination are likely to involve private sector investment in the form of build-operate-transfer (BOT) or build-own-operate-transfer (BOOT) contracts.

Financial aspects

The MENA desalination market is mature and yielded some of the lowest desalination cost projects in the world. The desalination technologies most commonly used in the MENA region at present are multi-stage flash distillation (MSF), multi-effect distillation with thermal vacuum compression (MED-TVC), seawater reverse osmosis (SWRO) and hybrid (thermal/SWRO) systems. While at present thermal desalination (MSF&MED) and RO are comparable in terms of total installed production capacity in the region, the long-term trend is that RO desalination is gaining wider application and a higher growth rate than thermal desalination in the region and worldwide (World Bank, 2016b). Some examples of the actual construction and O&M cost of desalination plants in the MENA region are listed in Table 4.1 and plotted in Figure 4.1, including the O&M cost and the total cost per m^3 water produced on the right axis of Figure 4.1, and the investment cost per unit capacity (m^3/year) on the left axis (source: WB, 2016b).

Plant name	Country	Year in operation	Capacity (Mm^3/yr)	Capital Cost (MUS$)		Capital cost (US$/$m^3$/yr)	O&M Cost (MUS$/yr)		O&M (US$/$m^3$)	Cost water (US$/$m^3$)	
				Actual	2016	2016	Actual	2016	2016	Actual	2016
Moni	Cyprus	2009	7.3	30.8	35.4	4.85	5.1	5.4	0.74	1.53	1.62
Larnaca	Cyprus	2009	22.6	70	80	3.54	13.2	13.9	0.61	1.19	1.26
Jorf Lasfar	Morocco	2013	27.7	160	168	6.08	13.6	14.3	0.52	0.96	1.10
Cap Djinet	Algeria	2007	36.5	133	148	4.04	16.2	17.9	0.49	0.82	0.91
Fouka	Algeria	2008	43.8	185	196	4.47	18	19.8	0.45	0.81	0.90
Hamma	Algeria	2008	73.0	250	272	3.73	29.8	32.3	0.44	0.82	0.91
Ashdod	Israel	2011	116.8	423	444	3.80	42.9	44.6	0.38	0.70	0.78
Magtaa	Algeria	2009	182.5	492	512	2.81	50.8	55.4	0.30	0.56	0.68
Sorek	Israel	2013	227.8	400	480	2.11	48.5	58.2	0.26	0.59	0.64

Table IV-1: Cost of SWRO desalination plants on the Mediterranean Sea (Source: World Bank, 2016b)

The capital costs include all direct and indirect expenditures associated with the planning, design, construction and commissioning of desalination projects. Direct costs are these associated with the physical construction of the desalination plant. Indirect costs incorporate expenditures for project development, planning, engineering, insurance, funding and legal and administrative costs. The annual O&M costs are the all-inclusive expenditures for energy and chemicals, membrane and cartridge filter replacement, staffing, equipment maintenance and replacement, operational insurance, staff training, and plant operations management and administration. The cost of water production encompasses all expenditures for amortization of the capital costs (repayment of debt and equity) and for annual O&M. Subsidies are not reflected in the costs, which in the MENA region are typically directly transferred to the final water users via their water tariff.

The economies of scale are obvious from the next figure. Overall, for plants with an installed capacity above 20 Mm^3/yr unit cost rates per m^3 installed capacity and per m^3 produced water are nearly twice as high for small plants (order of 20 Mm^3/yr) compared to large plants (order of 200 Mm^3/yr). In these examples 10% to 15% of the initial investment costs were charged to the annual cost of water production.

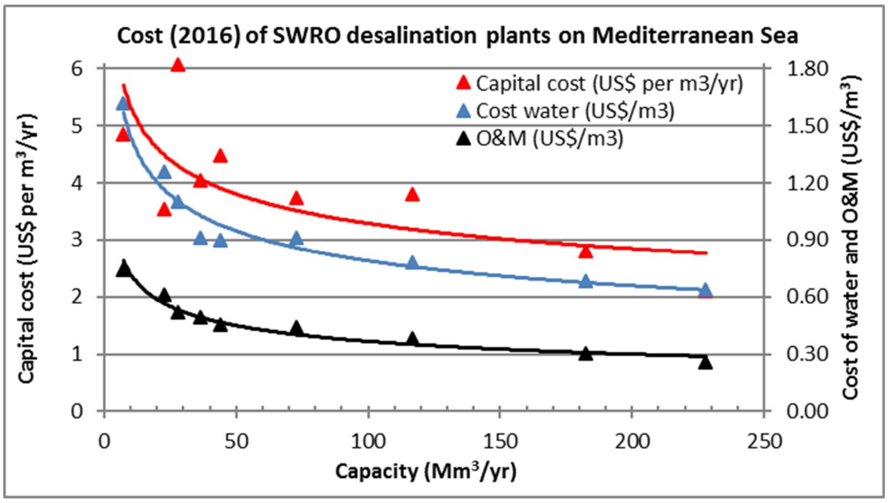


Figure IV-1: Unit cost rates of SWRO desalination plants on the Mediterranean Sea (World Bank, 2016b)

In Israel – the world leader in desalination - desalination plants will provide 650 million m^3 of water per year by 2020. Desalination used to be expensive in terms of energy use, but the kind of advanced technologies being employed now in Israel at e.g. the Sorek[11] SWRO desalination plant (228 Mm^3/year, built at a cost of 400 million US$ in 2013) have been a game changer. Water produced by desalination costs just a third of what it did in the 1990s and the Sorek plant produced drinking water at its factory outlet for US$ 0.64/m^3 in 2016. A desalination plant for 120 Mm^3/year in Ashkelon on the Mediterranean Sea, just north of Gaza, is reported to deliver fresh water at 0.50 US$/$m^3$.The Magtaa plant in Algeria (180 Mm^3/year) produced water at US$ 0.68/m^3 in 2016. This was achieved by an improved SWRO system requiring less energy to drive seawater through the desalination unit. In Algeria medium size SWRO plants (35 to 70 Mm^3/year) produce water at 0.90 US$/$m^3$. Larger SWRO desalination units (above 75 Mm^3/year or 200 million l/day) on the Atlantic coast of Morocco can benefit from substantial economies of scale in terms of investment per Mm^3/year production capacity, O&M cost and a lower salinity of the Atlantic Ocean compared to the Mediterranean; the latter may reduce energy demands for SWRO with 2kWh/m^3, equivalent to 0.20 US$/$m^3$.

As conventional supplies are dwindling, farmers may, like cities, have to seek alternative resources such as desalination and wastewater reuse solutions. Both seawater and brackish water desalination can act as viable solutions. Spain has implemented seawater desalination for irrigation along the Mediterranean coastline since 2008 to address the country's water stress. Despite its relative success, the higher price of desalinated water has allegedly been a cause of dispute. In Egypt, farmers have also started on a small scale to turn towards brackish water desalination for their irrigation water supply, providing farmers with adequate water and helping them to improve crop productivity. In Israel, desalinated water is mixed with water from other sources for irrigation purposes and maintaining minimum flows in rivers.

In the long run, it is expected that the use of renewable water resources and especially solar and wind power will increase and secure sustainable long-term drinking water supply in the MENA region. The steady trends of reduction of desalinated water production energy demands and cost, coupled with increased reliance on renewable power supply sources, are expected to accelerate the current trend of implementation of environmentally safe and sustainable desalination projects for the region. Significant progress has been made in advancing the development of new emerging technologies, such as membrane

[11] https://www.technologyreview.com/s/534996/megascale-desalination

distillation, dewvaporation and adsorption desalination, which could significantly lower specific energy consumption and be directly coupled with renewable power sources. As such emerging technologies evolve into reliable full-scale desalination systems over the next 10 to 15 years, desalination is expected to experience a quantum leap into sustainability and affordability. The World Bank White Paper (2016b) projects that technological advances will ascertain the position of SWRO treatment as a viable and cost-competitive process for potable water production, and reduce the cost of desalinated water by 20% in the next 5 years and by up to 60% in the next 20 years, suggesting that within 20 years cost should reduce to US$ 0.30 to 0.50 per m^3, or 3 to 5[12] MAD per m^3. However, it has also been noted that the potential desalination cost savings associated with the use of new and advanced desalination technologies in the MENA region could be partially negated by the adoption of very stringent environmental and renewable energy policies, such as recently introduced in for example Australia and the State of California, yielding projects with very high cost per m^3 of water produced.

Environmental and social impacts

UNEP / UNEP (2001) and the World Bank (2004) presented qualitative analyzes on the potential impacts of desalination plants. Their main recommendation concerns the evaluation of the impacts of these types of projects both during the construction and operation phases but also by analyzing the impact of the treatment unit in its interference with the physical environment that supports it. The sensitivity of this environment and the occurrence of archaeological remains justify this recommendation. The choice of the location of pumping points for seawater and the discharge of brines and the option to be chosen for their driving (direct intake, pumping in sands, drains or outfall) must be done in considering the sensitivity of the medium and the probable impacts of these two organs of the desalination unit.

The most important impacts are due to the brine (or concentrate) generated by all desalination processes. The most widely used technology in Morocco is reverse osmosis (RO), so we will limit ourselves to the impacts of desalination plants by OI. The good behavior of desalination plants must prevent overdoses in the raw water pretreatment stages. Indeed, the advantage of having acid solutions (5 to 7 pH) is justified by the operators to avoid clogging the filters of the OI. It is also justified by the fact that Bromine (Br) can only be eliminated at acidic pHs. Moreover, a pipe in the pH range close to neutrality makes it possible to avoid the production of acid concentrates which enrich themselves during the process of desalination by heavy metals. The concentrate is denser and therefore tends to flow close to the substrate, from which it prevents penetration of the sun's rays and can clog its porosity. The increase in concentrate levels of chemicals (mainly sodium bisulfate) results in a decrease in the oxygen concentration of seawater.

Density and concentrations of salt and chemicals have a negative impact on marine fauna and flora. The United States Environmental Protection Agency (USEPA) recommends that salinity changes should not exceed 4 units in areas naturally occupied by fauna and flora (UNEP, 2008). All the desalination techniques have in common the generation of brine. Management of this effluent makes it possible to mitigate the irreversible impact of its lethality on benthic fauna and flora, and desalination projects are classified in category A of the World Bank and require the implementation of the ecological management of the brine.

In addition, desalination projects allow the production of unconventional water whose quality meets the standards required for drinking water supply. Desalination of seawater or continental brackish water for public drinking water supply is increasingly adopted in areas where demand is increasing beyond available resources due to demographic, industrial or of climate change. Desalination thus helps to meet development needs and participates in the establishment of populations in the areas concerned.

[12] RADEEMA in Marrakech is now charging 6.5 Dh/m^3, including the cost of distribution, treatment and ONEE

Regulatory aspects applicable to desalination (and reuse) projects in Morocco

- Law No. 36-15 (2016): Reforms previous water law 10-95 to enable increased access to drinking water, and recognizes non-conventional sources as a key resource to meeting long-term sustainability.
- Law No 86-12 on PPP contracts (2014): Law outlining the conditions for resorting to, and procuring, public private partnership (PPP) contracts.
- Ordinance No 2685.14, setting drinking water and wastewater tariffs (2014): Sets out a new tariff structure for drinking water and wastewater tariffs, including an annual adjustment on 1 January until 2017.
- Moroccan standard 03.7.002 regarding the monitoring of drinking water quality in distribution networks (2011): Sets out the frequency and conditions for drinking water quality controls.
- Moroccan standard 03.7.001 for drinking water uality (2007): Sets out drinking water quality standards.
- Law No 54-05 on public service concessions 2006): Law outlining the conditions for outsourcing public services (including water and wastewater) to concessions.
- Ordinance No 1607.06 on domestic wastewater discharge (2006): Sets out domestic wastewater discharge standards.
- Ordinance No 1216.01, regulating the quality of water used for irrigation (2002): Sets out water standards for water used in irrigation, whether the source be surface water, groundwater or treated wastewater.
- Decree No 2-97-875 on reuse (1998): Sets out the general conditions for reuse, but does not include standards; to be revised based on the new water law

2. Reutilization of waste water for irrigation

Municipal wastewater contains valuable resources such as water, organic matter, energy, and nutrients (e.g. nitrogen and phosphorus) which can be recovered for many and diverse economic, social and environmental purposes. There are several technologies used to treat wastewater for reuse. A combination of these technologies can meet strict treatment standards and make sure that the processed water is hygienically safe, meaning free from bacteria and viruses. Some of the typical technologies used are ozonation, ultra-filtration, aerobic treatment (membrane bio-reactor), forward osmosis, reverse osmosis and advanced oxidation. Treated wastewater can be reused in industry (for example in cooling towers), in artificial recharge of aquifers, in agriculture and in the rehabilitation of natural ecosystems. In rare cases it is also used to augment drinking water supplies, like in Windhoek (Namibia) and during droughts in Singapore. Some water demanding activities do not require high grade water, for example in the domestic environment where toilets can be flushed using grey water from baths and showers with little or no treatment. Wastewater use can thus range from the formal use of ultrapure recycled water for advanced industrial purposes to the informal use of untreated and raw wastewater for vegetable production in a peri-urban area. The diversity of cases is as large as the diversity of types of wastewater and sludge, types of reuse and types of users.

Wastewater reuse for irrigation has been identified as a way to alleviate water scarcity, improve crop productivity and reduce the need for fertilizers (such as nitrogen, phosphorus and potassium), and improve environmental sustainability. Most importantly, it is consistently available regardless of season, climatic conditions and associated water restrictions. Therefore, Morocco's National Strategy for the Development of the Water Sector (2009) and the National Reuse Plan (Plan National de Réutilisation des Eaux Usées, PNREU; December 2015) aim to increase reuse of treated wastewater by 2030 to 325 Mm^3/year. The PNREU has identified 28 priority reuse projects for development, including the rehabilitation and upgrading of existing WWTPs to include reuse, as well as WWTPs under construction or planned where reuse has been identified as a key component. Most of the planned reuse infrastructure will serve agricultural needs (45%) and green spaces and golf courses (43%), with another portion designated for aquifer recharge (6%). A total of about 8 billion MAD (US$ 800 million) in investment is required to increase the water reuse capacity from 38 Mm^3/year to 325 Mm^3/year by 2030. Industrial and commercial end-users are expected to cover 20% of the capital expenditure and 100% of operating expenditure through tariffs.

Total urban waste water produced in Morocco would be 950 Mm^3/year, on average only about 5% of the total water resources of the country, but in drought periods up to 10%. However, part of this volume cannot be mobilized due to the absence of irrigable sites downstream of treatment plants, especially in coastal cities, and the high cost of water conveyance systems when reuse sites require additional costs for pumping and channeling. Presently only 12% of the treated waste water is being reused (Salama, 2014), most significantly being the STEP plant of Marrakech, equipped for the treatment of 33 Mm^3/year of wastewater, of which presently only 7 Mm^3/year is being reused for the irrigation of golf courses and green spaces. The slow progress with reuse of wastewater in agriculture can be attributed to several factors, including the difficulty of establishing institutional and legal instruments accepted by all stakeholders, as well as rules for sharing the costs of wastewater treatment between municipalities (producers) and users (farmers).

Financial aspects

Treating and using locally available waste water can be an economic solution to water scarcity, which contributes at the same time to environmental sustainability. The costs of primary and secondary treatment for the STEP at Marrakech are reported to be 2.2 MAD/m^3, while the cost of the tertiary treatment and the cost of pumping and transport to the customers (golf courses) for reuse of this water (including capital and O&M cost) are reportedly 3.6 MAD/m^3; 20% of this latter amount is for the tertiary treatment proper and 80% is for the capital and O&M of the transport system. In this example, the cost of treatment (2.2 MAD/m^3 up to tertiary level) is less than the cost of transport of the treated water to the customers (2.9 MAD/m^3). Water is sold to golf courses in Marrakech for 2.5 MAD/m^3. In Benslimane, treated wastewater is sold to a golf course for 2 MAD/m^3. It is reported (Salama, 2014) that due to the scarcity of resources and repetitive droughts, more and more farmers accept the principle of a more rational resource management, especially through an adequate price setting policy. In the regions with more severe water scarcity, farmers are ready to pay the cost of water, provided they have a perennial source. It is noted that the cost of stage 3 treatment and transport to the golf courses (3.6 MAD/m^3) is much less than the cost of desalination or the cost of inter-basin transfer of water, and equivalent to the cost of treated water paid by RADEEMA to ONEE, i.e. 3.4 MAD/m^3 excluding taxes and comprising capital and operating costs of ONEE and the water royalty paid to ABHT.

Thanks to technological advances in wastewater treatment and disposal, as well as improved sanitation management practices, communities are recognizing that water, once used, can still be put to productive use — making wastewater a largely untapped renewable freshwater source for increasing food production and facilitating economic development in water-stressed areas. If properly utilized, wastewater holds great potential for sustainable development as a source of energy, water, agricultural nutrients, and other resources. Wastewater treatment and reuse, supported by relevant research and pertinent policy-level interventions, can transform this untapped resource from an environmental burden and health constraint into an economic asset that contributes to achieving water security while maintaining the health of people and the environment. Appropriate policies can guide the use of non-conventional water sources, including sufficient financial commitment for policy implementation and education of stakeholders, supported by increased collaboration between researchers, international organizations, governments, and water users (Qadir et al., 2006).

Creation of an enabling environment and supporting policies and regulations for the use of unconventional water sources, such as wastewater management, for the redeployment, recovery and reuse of water for human and other competing uses, is needed. There is significant potential for wastewater to contribute to achieving water security, particularly in areas with acute levels of freshwater scarcity and increasing problems of water quality deterioration. Future projects in desalination and reuse are likely to involve private sector investment in the form of build-operate-transfer (BOT) or build-own-operate-transfer (BOOT) contracts for the provision of drinking water and agricultural irrigation. The new Water Law 36-15 (2016) recognizes desalination and water reuse as key resources for securing the country's water future, and signals that Morocco is preparing for a new phase of greater private sector investment in the water sector. The law provides for concessions as an option for private sector involvement in desalination projects and specifies crucial features including the rights and obligations of the concession holder that must be addressed in a concession agreement. This is viewed as a move to mitigate operational uncertainties throughout the period of a concession, thereby improving the risk profile of the BOT/BOOT projects.

Measures aimed at saving water at the local level do not necessarily save the same amount of water at basin level, and a comprehensive water balance needs to be prepared before embarking on local water saving measures. Unless waste water is discharged directly to the sea, the reuse of treated waste water – otherwise discharged treated or untreated in a river - may deprive downstream riverine users from its use on their fields. An example of this can be seen on the next figure, displaying a satellite image of the Tensift river valley downstream from the water treatment plant operated by RADEEMA in Azzouzia, just North of Marrakech, near the intersection of the N7 and the Tensift River (lower right corner of the picture). The water treatment plant for Marrakech treats about 33Mm^3 waste water per year; 7 Mm^3 is treated to stage 3 and provided to golf courses and other green spaces, and about 25 Mm^3/yr of stage 2 treated water is discharged into the river. Clearly, part of this water is used for the irrigation of olive trees near the river (over an area of about 15 km by 1.5 km), and part of this water may be recharging the already over-exploited Haouz aquifer, or flow further downstream where it may be captured for further usage. No olive trees can be observed near the river further upstream and downstream of the river reach shown in the next figure. The same observation is true for a reduction of the leakages in the water distribution system for the city of Marrakech, which is presently likely recharging the Haouz aquifer. A third example is rainwater harvesting; while potentially extremely useful and beneficial at the local level, it will affect river flows and reservoir inflows downstream when applied at a large scale in upstream parts of a river basin. Therefore, it is prudent to conduct a detailed water audit and prepare a comprehensive water balance at sub-basin and aquifer levels before embarking on large scale investments in water saving measures.

Figure IV-2: Tensift River valley downstream from the water treatment plant of RADEEMA in Azzouzia near the intersection of the N7 and the Tensift River (lower right corner of the picture)

Regulations: The Water Law 36-15 states that utilities are to treat the water to comply with the applicable standards that correspond with its use, and the cost of the treatment is to be borne by end-users. Decrees that elaborate on this article of the new law are expected to be issued in the future, including for industrial reuse, groundwater recharge and for extending agricultural reuse standards. Some large reuse plants may treat the wastewater to a standard agreed upon with the client and off-taker; for example, the Marrakech WWTP adheres to WHO guidelines.

Environmental and social impacts. In areas where water is a scarce resource, the reuse of treated wastewater can help alleviate stress on freshwater resources, serve as a source of groundwater recharge and as a tool to mitigate drought. Wastewater can be used for ecosystem services such as ecosystem protection, wetland improvement, wildlife management and biodiversity conservation. They can also generate savings on the use of energy through biogas recovery and thus contribute to reducing greenhouse gas emissions. Wastewater is a rich source of nutrients for plants. Thus, irrigation with these waters can eliminate the need for fertilizer use, which reduces input costs for farmers.

Risks regarding agriculture and health: Around 90% of wastewater produced globally remains untreated, causing widespread water pollution, especially in low-income countries. Increasingly, agriculture is using untreated wastewater for irrigation. Cities provide lucrative markets for fresh produce, so are attractive to farmers. However, because agriculture has to compete for increasingly scarce water resources with industry and municipal users, there is often no alternative for farmers but to use water polluted with urban waste directly to water their crops. There can be significant health hazards related to using untreated wastewater in agriculture. Wastewater from cities can contain a mixture of chemical and biological pollutants. In low-income countries, there are often high levels of pathogens, while in emerging nations where industrial development is outpacing environmental regulation, there are increasing risks from inorganic and organic chemicals. The WHO (2006) - in collaboration with the FAO and UNE - developed guidelines for the safe use of wastewater in 2006. These guidelines advocate a 'multiple-barrier' approach to wastewater use, for example by encouraging farmers to adopt various risk-reducing behaviors. These include ceasing irrigation a few days before harvesting to allow pathogens to die off in the sunlight, applying water carefully so it does not contaminate leaves likely to be eaten raw, and cleaning vegetables with disinfectant.

Some nutrients, such as nitrogen and phosphorus, are present beyond the normal nutrient requirements of ecosystems and crops. As a result, wastewater application can lead to nutrient accumulation and possible long-term negative effects: for example, the inorganic fraction of nitrogen (requires mineralization before it can be used by plants) is leached towards groundwater and surface water, which results in pollution by nitrates with adverse impacts on health (eg digestive disorders) and the environment (eutrophication).

A high content of salts and heavy metals in wastewater poses a risk of salinization / sodisation and contamination of soil and crops, especially after prolonged use. Heavy metals accumulated in the soil can be transferred to the human food chain with possible health effects. Nevertheless, a significant amount of health risk arises from pathogenic organisms, including helminth eggs and coliforms in wastewater. The potential risk associated with pathogenic infections is the main reason for reluctance to use wastewater for agriculture.

Social aspects such as concerns about the sustainability of wastewater reuse practices (soil losses due to salinization / sodisation and accumulation of heavy metals), nuisances presented by the development of water-borne disease vectors, poor hygiene, odor, noise, aesthetics, low visibility and impact on land values and essential groundwater resources are additional barriers to the implementation of wastewater irrigation and as many arguments to make the social acceptability of such projects very difficult. Nevertheless, there are several examples of countries with severe water shortages where the reuse of treated water, mainly for agriculture but even for the EAF, has been successfully adopted.

Reuse of wastewater, when properly controlled, can be an important asset in local government planning policy (Lazarova and Brissaud, 2007). According to these authors, the advantages of reusing wastewater include:

1. Alternative resource

- Increase water supply and supply flexibility while decreasing aggregate demand.
- Define the need to mobilize other water resources.
- Ensure a reliable, available and drought-free resource.
- In some cases, quicker and easier execution than the mobilization of new first-hand water resources.

2. Conservation and conservation of resources

- Saving drinking water for domestic use.
- Control overexploitation of underground resources.

3. Added economic value

- Avoid the costs of developing, transferring and pumping fresh freshwater resources.
- Reduce or eliminate the use of chemical fertilizers in irrigation.
- Provide additional revenue through the sale of recycled water and by-products.
- Provide economic benefits to users through the availability of recycled water in the event of drought.
- Promote tourism in arid regions.
- Increase the land value of irrigated land.

4. Environmental Value

- Reduce nutrient discharges
- Reduce releases of nutrients and pollutants into the receiving environment.
- Improve and maintain water bodies in the event of drought.
- Avoid the negative impacts associated with the construction of new dams, reservoirs.
- Improve the living environment and the environment.
- Propose a reliable alternative to wastewater discharges in sensitive environments.
- Take advantage of the nutrients provided by irrigation water to increase the productivity of agricultural crops and the quality of green spaces.

5. Sustainable development

- Reduce energy and environmental costs in relation to deep aquifers, long-distance water transport, desalination, etc.
- Ensure a low-cost alternative resource for drylands, protecting sensitive areas and restoring wetlands.
- Increase food production in the event of irrigation

Blumenthal and Peasey (2002) have shown that the use of untreated sewage to irrigate vegetables has resulted in increased helminth infection (mainly Ascaris lumbricoides infection), bacterial infections (typhoid , cholera, Helicobacter pylori) and symptomatic diarrheal diseases in consumers. When the wastewater was partially treated, there was evidence that the risk of enteric infections (bacterial and viral) was still significant when consumers ate certain types of uncooked vegetables irrigated with water that exceeded the WHO guideline of 1000 CF / 100 ml by a factor of ten.

Wastewater treatment has considerably reduced the risk of helminthic infections (especially Ascaris infection). Studies of the risk of enteric viral and bacterial infections associated with the use of treated wastewater suggest that when sprinkler irrigation is used and the population is exposed to treated wastewater aerosols, infection is present when the treated wastewater concentration was 106 CT / 100 ml but no increased risk of infection when this concentration was 103 to 10 CF / 100 ml.

Risk regarding groundwater recharge: the use of wastewater as a wastewater resource for the aquifer recharge supplies. The treated wastewater (TWW) constitutes an alternative resource available throughout the year and more particularly during low water periods, at a time when conventional resources are strongly requested or even unavailable. The recharge of aquifers with recycled wastewater can, however, pose risks to the quality of groundwater and to health due to the presence of heavy metals, nutrients and microorganisms in the TWWs or in water pumped from the recharged aquifer. Their origin is multiple, they come from products consumed by the population, corrosion of materials in water and sanitation networks, service activities (health, automobile) and industrial discharges (Cauchi et al., 1996 - in ONEMA & BRGM, 2012).

If the aquifer is captive, the recharge technique retained is direct injection by drilling into the saturated zone. On the other hand, if the water table is free, the treated waste water can be injected into the saturated zone and / or into the unsaturated zone, or it may be infiltrated by ponds. These recharge modes combined with the hydrogeological characteristics of the aquifer (presence or absence of clays, permeability, transmissivity, etc.) make it possible to continue the decontamination of the TMEs thanks to the anaerobic conditions prevailing and the sorption / desorption characteristics of the aquifer. rock matrix.

The quality of the TWWs depends on the quality of the raw sewage and the treatments put in place. According to ANSES (2016), about half of the substances present in raw treated wastewater are disposed of more than 70% in a conventional biological process. However, a number of contaminants are eliminated to less than 30%: for example, pesticides or their polar transformation products (glyphosate, aminomethylphosphonic acid, diuron), certain drug residues (carbamazepine, diclofenac, propranolol, sotalol) and carboxylate. The use of advanced treatments (including oxidation, adsorption or membrane processes) can reduce the concentrations of microbiological and chemical contaminants in treated wastewater.

The quality of groundwater recharged by TWWs is not always strictly correlated with the water quality of the infiltrated or pumped TWWs water in the aquifer. The results of the mixture of EUT and water already present in the aquifer can be modified by several physical, chemical and biological interactions between water and subsoil: Such interactions are often unpredictable. This spatial problem is further aggravated by the very slow and variable residence times (tens to hundreds of years) characteristic of many aquifers.

The risk of waterborne exposure to pathogenic microorganisms is dependent on a range of factors that include concentration, dispersal in water, ability to survive in the environment, and quality of water treatment. Three main groups of micro-organisms must be considered when using water collected after artificial recharge of aquifers: viruses, bacteria and protozoa (WHO, 2003).

These technical considerations led to the inclusion of the TWW groundwater recharge in the list of activities subject to an environmental assessment or prior authorization in international regulations (USA, France, UK). Sewage treatment plants and ancillary works are listed in the positive list of activities subject to Law 12-03 on EIA in Morocco. The aim of these regulations is to introduce a case-by-case analysis that takes account of the variability of the parameters and the control of their impacts according to the end-uses (irrigation, drinking water, etc.). Most guidelines or regulations on artificial aquifer recharge for drinking water require that the recharge water comply with guideline values for drinking water (WHO, 2003).

3. Reduction of physical and commercial water losses

Much of the drinking water infrastructure in Morocco has been in service for decades and can be a significant source of physical and commercial water losses through leaks, unauthorized consumption (theft), administrative errors, data handling errors, and metering inaccuracies or failure. Physical water losses in urban systems vary between 17% (in the town of Sale) and 45% (in Fez), and the average value is 27%. For comparison, it has been estimated that the average water loss in urban water supply systems across the USA was 16% in 2008 (EPA, 2013), of which up to 3/4th (12%) was considered to be recoverable, while water losses in London stood in 2015 at 26%. Unaccounted-for water in Arab countries is estimated to vary between 15% and 60%, whereas the best practice rate ranges from less than 10% for new systems to 25% for older systems. WHO-UNICEF (2000) report 39% as total losses (physical and commercial) as an average for large cities in Africa, 42% for Asia and 42% for Latin America and the Caribbean. Instead, many western cities operate at one digit NRW or UFW-loss levels (as defined below), such as Amsterdam at 3%, Berlin at 4%, Denver and Singapore at 5%, Copenhagen at 7%, Toronto at 9% and Vancouver at 11% (Brears, 2017); see also https://en.wikipedia.org/wiki/Non-revenue_water. Windhoek, Namibia, operates at 11% loss only.

For Morocco, the action plan for managing the demand for drinking water, industrial and tourism proposed by the PNE (2015) foresees improvements in the yields of the drinking water distribution networks to reach almost 80% on the national average in 2020 and maintain this level until 2030. It is not clear why the PNE does not foresee a more ambitious plan to increase the efficiency of distribution systems beyond 2020, for example to reach 85% by 2030.

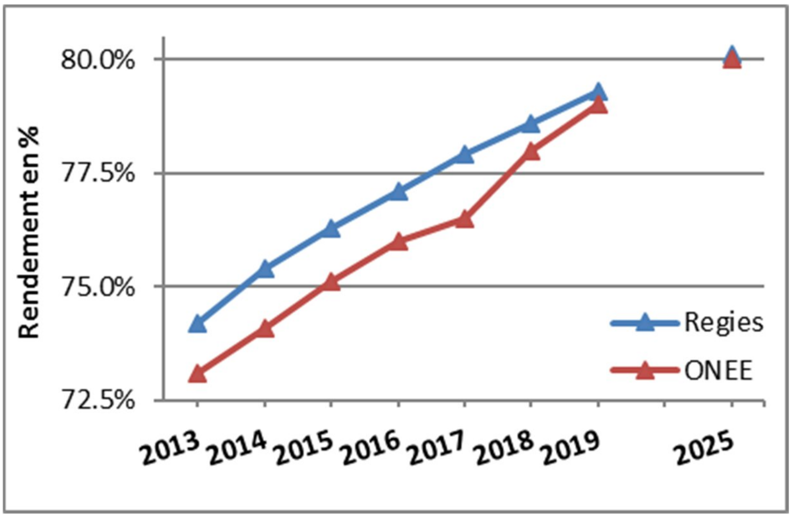


Figure IV-3 : Évolution prévisible du rendement global des réseaux de distribution des Régies Autonomes et de l'ONEE-Branche Eau (source : PNE, 2015)

The standard terminology for losses (EPA, 2013) includes:

Authorized consumption is water that is used by known customers of the water system.
Real or physical losses are actual losses of water from the system and consist of leakage from transmission and distribution mains, leakage and overflows from the water system’s storage tanks and leakage from service connections.
Apparent or commercial losses occur when water that should be included as revenue generating water appears as a loss due to unauthorized actions or calculation error (unauthorized consumption or theft, customer metering inaccuracies, and systematic billing anomalies or data handling errors).

Non-Revenue Water (NRW) is water that is not billed and paid for. It can be either unbilled authorized consumption (e.g. for firefighting), or result from apparent and real losses. Unaccounted-for-water (UFW) represents the difference between the volume of water delivered into a network and the volume of water that can be accounted for by legitimate consumption, whether metered or not. UFW thus equals the sum of physical and commercial losses; the difference with NRW is unbilled authorized consumption.

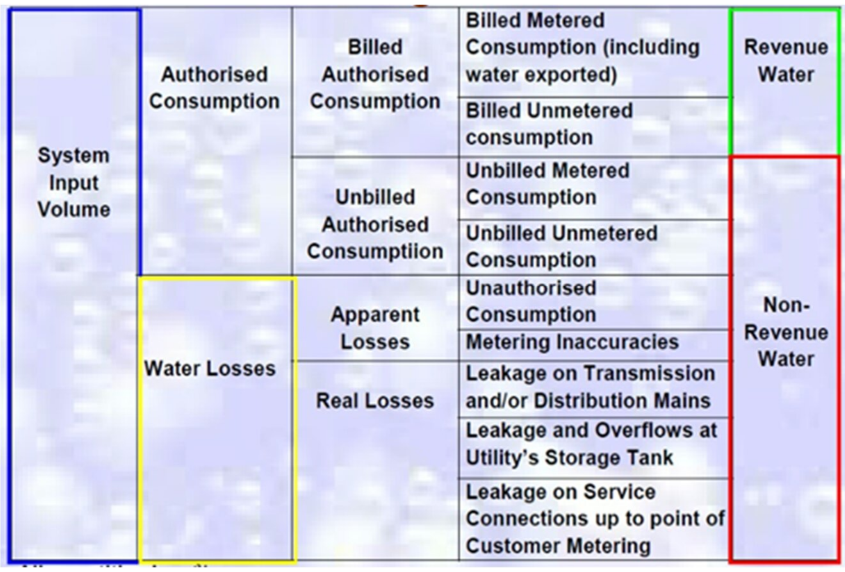


Figure IV-4: Standard terminologies for water losses and consumption

From the perspective of water balances under stress one would be mainly concerned with physical or real losses. From the perspective of economic and financial viability of the water utility, both commercial and physical losses (UFW) are important. Physical losses represent costs to a water system through the additional energy and chemical usage required to treat the lost water and the cost of the lost raw water. Commercial losses represent a loss of revenue because the water is consumed but not accounted for and thus not billed.

A water loss control program can help to identify physical losses of water from the water system and commercial losses. Implementing controls to reduce the losses can reduce the need for costly upgrades and expansions due to population growth and increased demand. The critical first step of such program is a water audit to identify and quantify the water uses and losses from a water system, followed by the implementation of control measures and the evaluation of performance indicators to determine the success of the chosen control actions. Utilities should thus first determine their baseline water use and losses (water audits for sub-systems), prioritize and implement water efficiency projects and operational changes, and then evaluate and continuously improve their water loss management. Specific interventions exist to combat apparent and real losses. It is important that the water utility determine the cost impact to the water utility from its apparent and real losses, and design an intervention strategy that takes into account the water resources and economic benefits of containing these losses.

Universal metering is key to water conservation. Water meters, both at the source and the service connection, are very important for all aspects of the water supply operations and make accurate water auditing possible. Universal metering ensures that customers pay for the exact amount of water consumed, and assists utilities to promote water conservation by making customers aware of their usage and to detect leakages in the system. It allows water utilities to detect automatically abnormally high water consumption, as well as to communicate directly with all users on the need to use water wisely. Meter records provide historic demand and customer use data that is used for planning purposes to determine future needs. Utilities are nowadays also exploring the use of smart meters in a drive to reduce water consumption, enable accurate leak detection and achieve reduced leakage in the water distribution system.

Data collection for a water audit may include i) locating leaks and losses through an examination of billing records, flow monitoring, visual inspection or leak detection equipment (e.g., acoustic, thermal, electromagnetic, tracer), ii) condition assessments using traditional external visual inspections (e.g., periodic walk-over and opportunistic inspections of exposed mains), internal visual inspection technologies (e.g., closed circuit television camera inspections), pit depth measurements, destructive testing (e.g., test coupons) and non-destructive testing (e.g., ultrasonic testing), and iii) hydraulic modeling to predict locations of leaks in a water system based on physical and operating data of the water system.

To reduce apparent losses and combat unauthorized consumption, water utilities should have clearly defined regulations for water service provision, and means to detect common breaches in the supply, metering and billing processes[13]. Adequate revenue capture relies upon accurate water meters, theft reduction, efficient systems of customer metering, meter reading and billing, detecting and resolving systematic data handling errors, and enforcement that prevent consumption data error – and revenue loss – from occurring. For most water utilities the customer billing system also becomes the de facto customer consumption database, and many functions rely upon the integrity of the customer consumption data that is included. When consumption data integrity is corrupted by such errors, the effects of water conservation programs might not be accurately assessed. Similarly, demand data for water distribution system hydraulic modeling or planning studies may be corrupted. Therefore, it is crucial to rehabilitate water meters and strive to obtain universal metering, which will be key to water conservation, detection of leaks and full cost recovery of services provided.

Continued investment in the water distribution system is key to lowering NRW/UFW: Lost water from aging infrastructure is costing local governments and utilities lost revenue or unrecovered costs of production. Tools and free Water Audit Software are available for determining the economic level of loss for an individual water supply system – the level at which the cost of investing in water loss management is less than the value of the lost water. Utilities with low NRW/UFW rates and minimal system leakages tend to proactively upgrade or replace their distribution infrastructure, survey their system regularly for leak detection, use computerized main replacement systems, and operate 24/7 service centers where the public can report leaks. Controlling leakage effectively relies upon a proactive leakage management program that includes a means to identify hidden leaks, optimize repair functions and upgrade piping infrastructure as its useful life ends. The science of leakage management is moving from a singular “find and fix” approach to a more comprehensive “predict and prevent” strategy. The current approaches include:

Active Leakage Control – Utilities should establish a leakage detection program, seeking hidden or unreported leaks, by sonically canvassing the water distribution system (leak detection survey) or using automated leak noise monitoring or minimum hour flow analysis to detect emerging leaks; http://www.water.ca.gov/wateruseefficiency/publications/ doc/1992_DWR_Leak_Detection_Guidebook.pdf

Speedy, quality repairs – Utilities should establish a Call Centre and website for reporting leaks and create a rapid response unit for attending to leakages, such that utilities will be able to respond quickly and perform quality, lasting repairs.

Pressure Management - Pressure management is a highly effective means to control excessive leakage losses. It is particularly effective for systems that suffer high levels of background leakage, which is the collective leakage from many weeps and seeps at pipe joints and fittings. Reducing pressures at low demand hours has been found to be cost-effective in reducing background leakage. Pressures into discrete pressure zones can be controlled by pressure reducing valves.

[13] http://www.allianceforwaterefficiency.org/Water_Loss_Control_-_What_Can_Be_Done.aspx

Water Main Rehabilitation and Replacement – Water Utilities need to conceive a proactive investment plan for renewal of their water distribution system, aimed at lowering the NRW/UFW ratio (incl. development of computerized planning for asset management and system rehabilitation). Utilities should have in place funding and programs to identify expiring assets and ensure that they are reconditioned to continue to provide reliable services.

Leakage Component Analysis - By using data collected by a water utility on the number and types of leaks found and repaired in their water distribution system, a Leakage Component Analysis can be conducted to help utilities determine the extent of leakage control activities that are economic to undertake. A free tool exists for water utilities to conduct a leakage component analysis. The Water Research Foundation and the US - EPA sponsored the research project *Real Loss Component Analysis: a Tool for Economic Water Loss Control*[14]. The project produced a spreadsheet software tool that provides users with an easy format to enter data on the leakage events that occur in a water utility over the course of a year. Utilizing various data from the standard water audit, the tool calculates the economically optimum leakage levels and relates the appropriate leakage control activities such as acoustic leak detection and pressure management to reduce leakage in the water distribution system. The tool may be downloaded for free from: http://www.waterrf.org/Pages/Projects.aspx?PID=4372.

Part of the solution for high NRW problems is based on good governance and in regulatory terms, this action should be accompanied by a legal obligation, to be borne by the authorities, concessionaires and large consumers of resources, to make public and to report to the ABH concerned all water losses in feeding systems and distribution networks, ie doing a Water Audit. An example of a water loss or non-revenue water policy that can be voluntarily adopted as a municipal ordinance is provided by the AWWA (Water loss or NRW policy). Such an obligation has been made compulsory in some countries for its obvious benefits, in particular to encourage these authorities, concessionaires and large consumers of resources to conduct regular audits of their respective water supply and distribution systems and to alert the public and the real-time regulator. For example, the State of California (Senate Bill 555, 2015); requires any water authority with more than 3,000 connections or treating more than 3.7 Mm3 / year of water to annually audit the losses of the past year from October 2017, to establish where the water goes and if the loss results from meter (count), water theft or physical loss ("leaks") error in the system, in order to use this information to reduce operation costs, detect losses real-time resources or repair infrastructure before losses increase; http://www.water.ca.gov/urbanwatermanagement).

Environmental and social impacts

The main objective of a water service is to satisfy the demands of customers. High physical losses often result in intermittent feeding, either because of the limited availability of raw water (to compensate for losses due to losses) or because of the rationing of distributed water, which may be necessary to to reduce the hours of supply (and thus the hours of water leakage) per day. Large leaks can result in high pressure losses that affect customers because they often cause supply disruptions during peak hours. In addition to inferior service, intermittent supply poses a significant health risk, as contaminated groundwater, and even sewage, can enter leaky pipes during outages, supply and periods of low pressure.

In the long term, losses can lead to unnecessarily high rates to cover the manager's financial losses. On the other hand, if the rates are not adjusted, the manager's financial capacities are weakened and the manager will not be able to provide an appropriate service to his clients. Customer dissatisfaction is an important consequence of intermittent supply. It leads to a loss of confidence in service providers (public and / or private) and a weak willingness of consumers to pay for an improved service. This

[14] http://www.waterrf.org/PublicReportLibrary/4372a.pdf

discourages public policy from introducing tariff increases that could help improve the situation and the cycle of vicious loss management is strengthened.

Finally, unsatisfied customers can turn to other sources of supply that are more expensive and of lower quality, which increases their incomes and entails a significant health risk.

The national average of losses on urban distribution networks in Morocco is 27%, applied to the 814 Mm3 sold by the ONEE - Water Branch in 2012, a volume of 220 Mm3 / year would be lost but would participate in the recharge of groundwater when they exist. This is the case, for example, for the city of Marrakech where losses on the network are estimated at 25%, or 17 Mm3 / year.

4. Demand management

Reportedly, public awareness of the decrease in water availability is not high in Morocco. Citizens in areas of Morocco with plenty of water do not seem to be concerned about the availability of water. While the valuation of water by the public is insufficient, the Ministry of Water is working to improve the conservation of water in the agricultural sector through subsidies for the conversion to drip irrigation and a program to reduce water use by tourists and the industry. The reason for this lack of valuation of water by the public is that the public does not yet have a full understanding of the prevailing and looming water scarcity. There are not yet many programs aimed at reducing the water consumption by individual citizens. There is simply a lack of education of the citizens about the value of water. The education of Moroccan citizens is key to conserving water. Implementing an education program that teaches children about environmentalism would help with the conservation of water. Educating children has a two-fold benefit, as children will bring what they learn at school home to their parents. Creating Face-book pages regarding climate change and environmental issues would also help to raise public awareness. Almost 20 million of Morocco's 33 million inhabitants use the internet, up from ten million in 2011 (African Internet Users, 2015). Both the government and NGOs can use this growing internet presence to their advantage in their objectives communicating to the citizens. The creation of websites and social media pages that educate and engage the technologically active community could tremendously increase awareness of issues such as environmentalism and the importance of water conservation.

Practices that reduce the demand for water should be strongly encouraged in policies and plans, such as water saving home appliances. Legislation or regulations could be adopted to aid in water conservation efforts by mandating that in new or rehabilitated buildings all new toilets are less than 6 liter flushing, clothes washers are highly water efficiency, and faucets are either automatic or use leak proof fixtures. There is a wide array of demand management tools and strategies that can be applied by water utilities in a drive to reduce domestic and industrial water consumption, including *inter alia* (Brears, 2017):

i. Water should be priced to promote conservation while ensuring revenue stability: Introduce or strengthen variable (volumetric) and fixed pricing for water supply and waste water treatment in order to promote urban water conservation and ensure revenue stability for the water utility. Tariffs should include fixed and variable components in order to ensure revenue stability during times of reduced water consumption. The price of water should reflect ideally, and as much as politically possible, the actual nation-wide cost of providing water, water-related services and sewage treatment, in order to meet operating and maintenance cost and to promote conservation of water through demand reduction. Water should not be seen as being "cheap". Setting the fees to match the real cost of water, reduced water demands in Israel with at least 25%, but this may not always be politically feasible. Certain consumer categories can be subsidized from other government budgets, if the need arises, rather than from the budget of the water utilities.
ii. Universal metering is key to water conservation: It is essential that utilities rehabilitate water meters and strive to obtain universal metering, which will be key to water conservation, detecting leaks and full cost recovery of services. Universal metering ensures that customers pay for the

exact amount of water consumed, and assists utilities to promote water conservation and reduce leakages in the system. It allows water utilities to detect automatically abnormally high water consumption, as well as to communicate directly with all users on the need to use water wisely. Utilities elsewhere are also exploring the use of smart meters in a drive to reduce water consumption, enable accurate leak detection and achieve reduced leakage in the water distribution system.

iii. Water conservation yields energy savings and reduced carbon emissions from treating less wastewater: Renewable energy solutions, including the recovery of heat and energy at treatment plants, help to further reduce energy cost and carbon emissions. Investing in separate storm sewer and sanitary sewer systems helps to reduce system overflows during heavy storms, and reduces volumes of waste water to be treated.

iv. Utilities employ incentive programs, labeling schemes and ordinances to encourage/impose water efficiency: Targeted subsidies and rebates on water saving devices and technologies as well as free water audits are offered to domestic and industrial consumers to promote water efficiency. Utilities elsewhere distribute water-saving kits and water audit checklists to the public and schools. Promoting water-efficient devices and appliances based on a water-efficiency labeling scheme and providing subsidies for purchasing water-efficiency labeled devices, helps consumers make informed sustainable choices. Ordinances can be used for imposing water efficiency in new developments, to develop alternative sources of water, introduce universal metering and water labeling schemes.

v. Promote water conservation as a way of life: Water conservation requires behavioral changes, culturally ingrained in consumers, and promoted through awareness and educational programs on environmental impacts of overconsumption, the dangers of over-exploitation of aquifers, outreach programs on water conservation, etc. Options are to distribute water saving kits to schools and homes, and organize various PR events; school children must be educated in the value of water conservation. Demographic-target messaging and use of internet based communication tools may be effective and useful, to encourage water conservation as a way of life

vi. Recognizing water savings helps: Providing recognition and annual awards for outstanding contributions towards water conservation is seen as an important tool for raising public awareness, while showing non-domestic customers real-life examples of how businesses can save water and lower their operational costs.

vii. Water audits help non-domestic consumers to implement water efficiency plans: Free water audits can be effective in helping non-domestic users in identifying areas where businesses can increase efficiency, reduce water (and energy) consumption, and reduce operational cost. It may be considered to introduce (mandatory) Water Efficiency Management Plans (WEMP) for large-scale non-domestic users, with subsidies for retrofitting to ensure short pay-back periods.

viii. Regulatory hurdles often tend to hamper the development of alternative water supplies: Alternative water supplies, such as grey water, rainwater harvesting and reuse of treated waste water, reduce the need to increase supply to meet rising demand, but utilities often face regulatory hurdles in developing these systems. Chapters IV and V of Morocco's water law 36-15 address the harvesting and use of rainwater and the reuse of wastewater; reuse for human consumption and the preparation of food is prohibited and reuse is subject to regulations and approval by the ABH.

ix. Discourage landscaping of parks and homes that consume much fresh water, and work with golf courses and tourist facilities to reduce the consumption of potable water and increase the use of grey water for landscaping; promote the use of drought resistant plants in public areas.

Environmental and social impacts: The concept of sustainable water demand management is recent (Arfanuzzaman et al, 2017). It integrates the concepts of optimal price, regulation of surface water and groundwater, water conservation and sustainable water consumption. In order to achieve sustainability in water demand management, it is recommended to evaluate certain criteria in the economic, social and environmental sectors in order to manage the increasing demand for water for building socio-ecological resilience, such as follows:

Economic Sustainability of Water Demand Management: Price regulation can control water demand even if the level of income is higher. The economic sustainability of WDM requires the availability of technical expertise in the manager to ensure cost-effective service, loss control, and control over water pricing. If water is available at a low price, consumers tend to consume more water and the risk of waste and excessive use of water are increased. Only an optimal water price can ensure the sustainable consumption, production and conservation of water. Given that people of all social classes have the same right of access to water, the minimum amount of water required to meet the needs of everyday life should be the lowest. Some studies (García-Valiñas, 2005, Statzu and Strazzera, 2009, Martins and Fortunato, 2007) conclude that there is an inverse relationship between water prices and demand and that price regulation can control demand even if the income level is already higher.

Social sustainability of WDM management: Equity is an essential element of the social sustainability of WDM. Generally, equity issues arise when the poorest groups pay more per unit of water than other social groups. They also occur when low-income groups (shanty towns, and other poor communities) are not covered by the distribution service and also when the rich and the poor pay the same price for water.

Environmental sustainability of WDM: In terms of environmental sustainability, the production, distribution and consumption of water must produce positive environmental effects. Demographic and economic developments are accompanied by increased pressure on water resources to meet water needs. This pressure leads in some cases to irrational exploitation of groundwater resources (for example, in Dhaka - Bangladesh, the piezometric level has risen from 28m in 1997 to 75m in 2012) with the major risk of soil collapse in the parts removed. The environmental sustainability of WDM is also compromised in the event that all wastewater is discharged into the natural environment without prior treatment. The pollution of the surface water resource in this case, prevents its use and / or significantly increases the costs of its drinking water. This situation reinforces the use of groundwater and the vicious circle of their excessive exploitation is consolidated.

Groundwater conservation can be managed by imposing excessive pumping taxes, levy quotas, and prices based on the volume drawn (meter for each work). Without any taxes or pricing, the viability of policies and programs for conserving groundwater resources is greatly compromised. The figure below shows that if there are no taxes, the extraction of water increases considerably by residents or businesses and vice versa in the case of taxation.

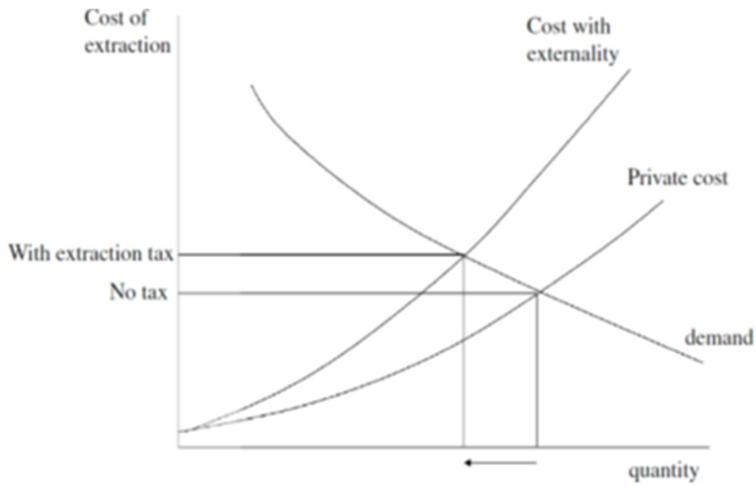


Figure IV-5: Impact des taxes sur les prélèvements des eaux souterraines (source : Arfanuzzaman and Rahman, 2017)

Water Pricing Policies: Water pricing and consumption are inherently related, which can be quantified by price elasticity, defined by the percentage change in the quantity demanded by the percentage change in price. Obviously, policy improvements can have a significant impact. In addition, at least 20-30% of the water used by households and industry can be saved by implementing appropriate intervention tools. Experience shows that rising water prices and pollution taxes promote water conservation and pollution reduction. An example in Global Water Partnership (2000) illustrates this trend. In 1990, in Bogor, Indonesia, following a 200-300% increase in tariffs for different consumer groups, households with a monthly consumption of more than 30 m3 had to pay the equivalent of US $ 0.42 / m3 (excess consumption of 20 m3) instead of 0.15 US $ / m3. This resulted in a significant decrease in water consumption (approximately 30%) in the target groups. Nicosia, Cyprus, based on statistics of IWA.

The document provides an overview of prices of water in various developed and less developed countries and presents an analysis on residential price elasticity of demand for water because of price increases for 8 different towns and regions. The price elasticity was found to vary as an average over a period of 10 years between -0.1 and -0.5, on average -0.3 across 8 countries. This implies that on average a doubling of the price of water would yield a 30% reduction in water demands (varying between 10% and 50% reduction in the countries considered in the analysis). The analysis concluded that the price elasticity of the residential water demands was in general inelastic because there is no easy availability of substitutes for residential water supply, and the degree of water necessity is high. It also concluded that the higher the water consumption is, the greater the sensitivity to price increases is.

Due to the price inelasticity of domestic water, utilities generally do not have to fear financial constraints as a result of price increases, since percentage wise price increases will exceed volume decreases. However, only a levy will not be an optimal solution unless an alternative mechanism is developed. For example, local authorities can promote the development of rainwater harvesting systems in residential areas, administrative buildings and hotel operations.

5. Dams and storage reservoirs

In the past, the "policy of large dams" has enabled the water sector to support the development of Morocco. At the present time, over a continent-wide workforce of 1,300, and 45,000 worldwide (Skinner, 2009) with a surface area of total reservoir of about 500 000 km ^{2}. In Morocco the total storage capacity reached about 18.5 Bm^3 by 2014; 14 dams are currently under construction or have been recently constructed, adding a storage capacity of 510 Mm^3 , at an average investment cost of 19 MAD / m^3 , including:

3 dams in the Loukkos, Tangérois, Mediterranean Coasts (100 Mm ^{3})
3 dams in the Moulouya (121 Mm ^{3})
2 dams in the Sebou (185 Mm ^{3})
2 dams in the Tensift (42 Mm ^{3})
1 dam in the Souss-Massa (8 Mm ^{3})
3 dams in the South Atlasic (54 Mm ^{3})

Storage capacity per capita grew faster than the population (from 160 m ^{3} / capita in 1960 to 500 m ^{3} / capita in 2015), and the regularized volume increased over the same period of 120 m ^{3} per person to 340 m ^{3} per person (SNE, 2009).At the same time, the irrigated perimeters have been massively extended, while guaranteeing a regularized quantity of water per hectare at the same level.In addition, the country has been successful in improving access to drinking water. The SNE (2009) to invest 21 billion MAD over the period 2010 - 2030 in new dams and reservoirs, to mobilize an additional 1.7 Bm ^{3} , at an average cost of 12 MAD / m ^{3} .

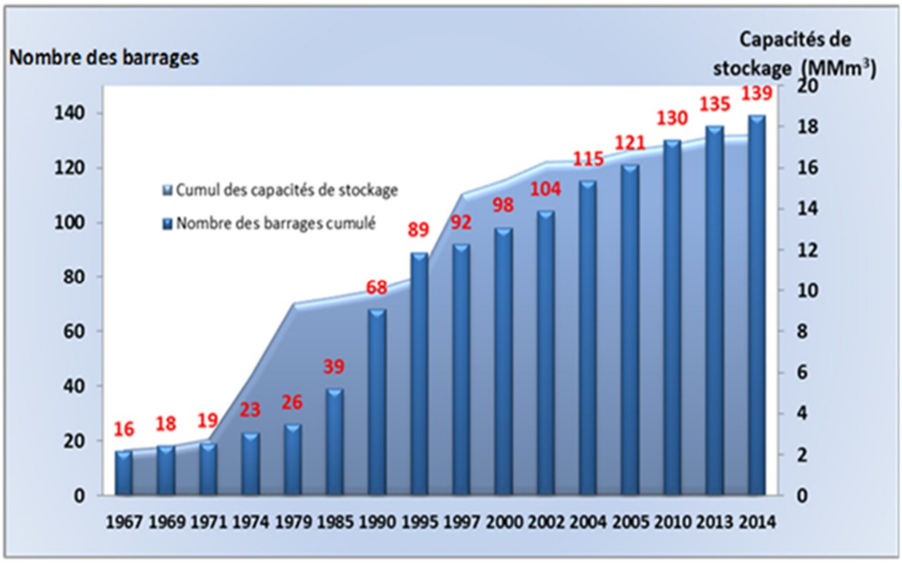


Figure IV-6: Evolution of the number of large dams carried out and their total storage capacity (source: PNE, 2015)

In addition, the Government is pursuing a program of small and medium-sized dams. The local role of small and medium dams is important for irrigation, livestock watering and flood protection. The goal of the SNE is to realize one thousand small dams by 2030.

Dams are planned, built and operated to meet human needs, but the history of dams over the past 100 years has shown that their many benefits to society combine with a range of environmental and social costs. The World Commission on Dams - WCD (Berkamp et al., 2000) recommends that the decision to construct a dam and its design and operation should be based on a rigorous analysis of costs and benefits. The main positive impacts on dams are (Schultz, 2002):

- Mitigate and eliminate the effects of floods;
- Improve downstream soil quality (decreased impact of drainage)
- Electricity production
- Participate in the improvement of river transport
- Improve resource availability for drinking water supply
- Improve the availability of the resource for irrigation
- Development of recreational and tourist areas

The negative impacts of dams can be grouped into ten categories including environmental and social impacts (Berkamp et al., 2000). The list below is general, each dam site to its specificities ; and is presented here to show the types of impacts a dam project could generate. More details are available in the WCD report cited above:

- Construction work (clearing, clearing, noise, dust, etc.)
- Limitation of movement of aquatic fauna;
- Flooded fauna and flora at site level;
- Disruption of watercourse regimes;
- Stopping the flow of nutrients downstream;
- Loss of aquatic ecosystems downstream;

- Artificial lakes created by dams may in some cases be significant producers of GHGs in the atmosphere (Falter, 2017) because organic matter decomposes into CO_2, CH_4 and N_2O;
- Marine intrusion in estuaries;
- Loss of economic enjoyment;
- Loss of cultural values;
- Loss of social cohesion in displaced groups

6. Storm water collection and rainwater harvesting

Storm water collection and rainwater harvesting in general is the accumulation and deposition of rainwater for reuse on-site, rather than allowing it to run off. Rainwater can be obtained from impervious areas, roofs etc, and in many places the water collected is redirected to a deep pit (well, shaft, or borehole), or a reservoir with percolation. Its uses include water for gardens, livestock, irrigation, domestic use with proper treatment, etc. The harvested water can also be used as drinking water, as well as for other purposes such as groundwater recharge. Rainwater harvesting provides an independent supply of water and water. It provides water when there is a drought, can help mitigate flooding of low-lying areas, and reduces demands on wells which may enable groundwater levels to be sustained. It also helps in the availability of potable water as rainwater is of salinity and other salts. Application of rainwater harvesting in a water supply system for a water supply system in a water supply system in a water supply system. Rainwater harvesting can also provide benefits to Agriculture. Countries with an arid or semi-arid environment use rainwater harvesting as well as reliable source of clean water. To enhance irrigation in arid environments, ridges of soil are constructed in order to trap and prevent rainwater from running down hills and slopes. Even in periods of low rainfall, enough water may be collected in order for crops to grow.

Rainwater harvesting is an ancestral practice in the region, carried out for example by cisterns (metfias), and has been reinvented and modernized. It is a small-scale and inexpensive local solution to create additional storage capacities, in addition to large-scale storage methods. For this reason, the SNE and PNE recommended as follows:

- Assess the potential for rainwater harvesting in rural and urban areas
- Launch a pilot program to assess feasibility in the Moroccan context and select appropriate techniques from a wide range of available resources, such as storage in low-capacity tanks, hill dams and groundwater storage (for artificial groundwater recharge)
- Assessment and management of water resources
- Develop a regulatory framework for the management of water resources and the use of rainwater harvesting.

The pilot projects focus on the most deficient basins (OER, Bouregreg, Tensift and Souss). The target in the SNE is to capture 5 - 15 Mm3 / year at a cost of 110 to 340 million .

Internationally, there is much experience with rainwater harvesting in countries like India, China, Brazil, Sri Lanka, South Africa, Israel, USA and many other countries. In China and Brazil rooftop rainwater harvesting is being practiced for providing drinking water, domestic water, water for livestock, water for small irrigation and a way to replenish groundwater levels. Gansu province in China and the semi-arid North East of Brazil both has reportedly the largest rooftop rainwater harvesting projects ongoing. In India rainwater harvesting is sometimes compulsory or has already been practiced for centuries in several of its States. Sri Lanka enacted legislation to promote rainwater harvesting through the Urban Development Authority in 2007, and also has a long history in storing rainwater water. In Israel rainwater harvesting systems are being installed in local schools for the purpose of educating schoolchildren about water conservation principles. Until 2009 in Colorado, water rights laws a property owner who captured rainwater was deemed to be stealing it from those who have rights to take water from the watershed. Now, residential property owners can obtain a permit to install a rooftop precipitation collection system. Douglas County, in the Southern Suburbs of Denver, never reached a stream; instead it was used by plants or evaporated on the ground.

However, this lack of impact on downstream flows may not always be valid. The next figure shows the example of the relationship between annual precipitation and runoff since 1960 for the Chambal river basin in Madhya Pradesh, India, upstream of the Gandhi Sagar dam. The data show that prior to the 1990s the basin runoff was larger than afterwards for the same amount of basin rainfall. Gandhi Sagar reserves the right to modify the Gandhi Sagar reserves for a period of three years. It is perceived that numerous scattered small-scale water resources development works at village level, such as the construction of small village tanks, check dams, bunds on farm lands and other rainwater harvesting initiatives, have over time rainfall and a gradual decline in the inflow into Gandh i Sagar reservoir. Whereas such small scale works provide much benefit to the local villages and farmers, the impact on downstream water can be negative, and therefore needs to be assessed prior to embarking on large scale rainwater harvesting investments. Such evaluations need to be included in the pilot project planned under the SNE (2009). Experiences in other countries also need to be evaluated.

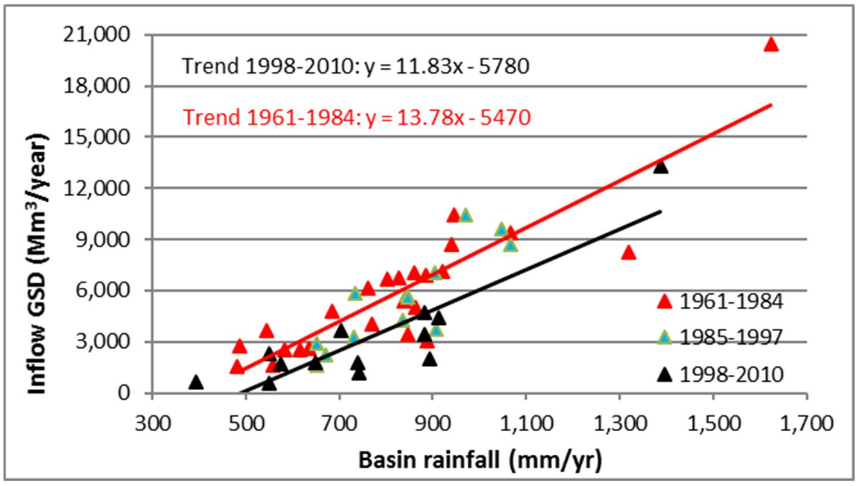


Figure IV-7: Inflow Gandhi Sagar reservoir in Madhya Pradesh (India) versus upstream basin rainfall

Environmental and Social Impacts: Rainwater harvesting (RW). Angrill et al. (2011) carried out the environmental impact analysis of RW and RW systems in a water supply substitution. In urban areas, the irrigation of gardens, the flushing of toilets, laundry, and other activities related to potential non-potable uses. These techniques have been widely developed in China, Brazil, Australia, Germany, India, and Japan.

These authors, citing several research papers, conclude that '' Rainwater harvesting (RWH) provides access to a non-potable water use, mitigates the pressure on aquifers and surface courses, reduces water stress and pollution to surface waters, by soil sealing resulting from urbanization and reduces loads on sewers. Additionally, the use of rainwater on a wide scale is perceived as an adaptive strategy to climate change.

7. Groundwater recharge by infiltration

Unlike the large increase in dams' capacity over the past 50 years, there has been no significant increase in controlled use of aquifers for groundwater storage. However, a debate on the limits of large dams (environmental and social impacts as well as growing concerns about dam safety issues and the impact of siltation) would make more sense if there is a serious alternative to in view of the increase in storage capacity needed in the coming decades.

Groundwater is a valuable strategic resource for development, particularly in arid and semi-arid regions. Their characteristics (volume, permanence and wide spatial distribution) compensate for the scarcity and temporal variations of rainfall runoff and natural recharge of aquifers. This gives greater flexibility to integrated water management. Controlled overexploitation is possible and even recommended, only when it is limited in time and affordable in terms of costs and benefits. It is imperative to implement management strategies that include artificial recharge, to preserve groundwater. In economic terms, the general purpose of water storage can be expressed as "capture water where and when the value is low and re-allocate water where and when its marginal value is high".

Currently used groundwater resources are estimated at 4.3 billion m ^{3} at the national level , while groundwater resources that can be used in a sustainable manner do not exceed 3.4 billion m ^{3} .Overexploitation of groundwater at the national level is therefore estimated on average at nearly one billion m ^{3} per year.

The overexploitation of groundwater causes several challenges, for example:

- Use of strategic reserves to ensure the supply of drinking water during droughts
- Increased pumping costs due to lower piezometric levels
- Degradation of water quality (increased mineralization, marine intrusion for coastal aquifers), and
- Soil subsidence

Artificial recharge is therefore necessary to restore overexploited aquifers and can be considered as an alternative to storage in dams (reasonable cost, no loss by evaporation, possibility of using treated wastewater, no eutrophication problems).

Given the impact of climate change and the growing demand for water, the authorities have developed a program to safeguard groundwater. This program, developed as part of the Strategy national water, aims to ensure the sustainable management of groundwater. This program involves the implementation of the irrigation water saving program, the use of surface and sea water resources, the artificial recharge of groundwater, and a strengthening of the control and penalties in the event of overexploitation. It is within this framework that the Government launched the initiative to establish and sign groundwater contracts with the following main objectives:

- Analyze the current state of groundwater resource utilization with assessment of socio-economic impacts and future challenges, including protection of groundwater and preservation of existing water investments;
- Define a plan of action based on the best scenario for the improvement of the groundwater situation, specifying its cost, its duration and the responsibilities of each stakeholder in the implementation of the program;
- Develop and implement monitoring and sanctioning mechanisms to achieve the objectives and ensure sustainable and integrated management of underground water resources.

Consequently, the SNE has planned multiple actions for the conservation and replenishment of groundwater, as follows:

- Strengthening of the control system and penalties in case of overexploitation
- Limitation of pumping in groundwater (revision of tariffs, elimination of subsidies,
- Strengthening of the responsibility of the ABH in the management of the aquifers and generalization of the contracts of ground water
- Systematic use of conventional and unconventional alternative water resources to relieve pressure on groundwater

Programs of artificial recharge of the aquifers (storage of 180 Mm^3 / year). For groundwater recharge, feasibility studies are already under way to launch recharge projects. The storage cost of 180 Mm^3 / year will be 1 billion MAD.

Re-injection of wastewater after treatment for coastal water tables used for irrigation (100 Mm^3 by 2030)

Substitution of volumes taken by ONEP and governed by surface water from surface water (90 Mm^3 / year by 2020)

In addition, the SNE recommended:

Evaluate the feasibility of groundwater recharge in detail;

Combine groundwater recharge with non-conventional methods of mobilization (treated wastewater and catchment of rain and flood water);

Take stock of the pilot operation carried out (Aoulouz dam or a series of thresholds have been set up to use the flood water to recharge the Souss water table), and launch pilot projects in priority on groundwater the most overexploited;

Evaluate potential for additional mobilization and storage and include groundwater recharge in planning and management and resources;

Immediate action on the following aquifers: Souss, Haouz-Mejjate, Berrechid, and the Tadla aquifer system

Worldwide, the World Water Vision presented at the 2nd WWF in The Hague (2000) estimated that additional storage of 150 km^3 would be required for irrigation by 2025 and an additional 200 km^3 to replace the current over-consumption of groundwater. In addition, the Declaration of the African Ministerial Conference on Water at the World Summit on Sustainable Development in Johannesburg in August 2002 recognized that per capita water storage in Africa accounts for about 1% of water storage capacity per capita in Europe.

Artificial recharge of aquifers involves high costs resulting from preliminary studies, design, construction, operation, maintenance and monitoring of systems. Small-scale applications of industrial and municipal users can be realized if they are encouraged and supported financially. In general, small farmers cannot bear the costs of artificial recharge. However, they are numerous and their consumption of water is high. Medium- and large-scale recharging projects to increase available water storage are possible only if government users support them. This approach is currently being addressed in Mexico by the local groundwater technical committees (Técnico de Aguas Subterráneas - Cotas Committee) for overexploited aquifers, as a sustainable management strategy.

8. Inter-basin Water Transfer

The Transfer Project: The National Water Plan and the PDAIREs envisage a project of interbasin water transfer from north to south of Morocco. This major project involves transferring water southward from the three watersheds , including the Loukkos, Laou and Sebou basins to the Bouregreg and Oum Er Rbia basins and to the Al Massira dam , located in the north of Marrakech. Whereas 50% of the available water originates from the Sebou and Loukkos basins in the North, the other basins of the country represent 92% of the water demands.

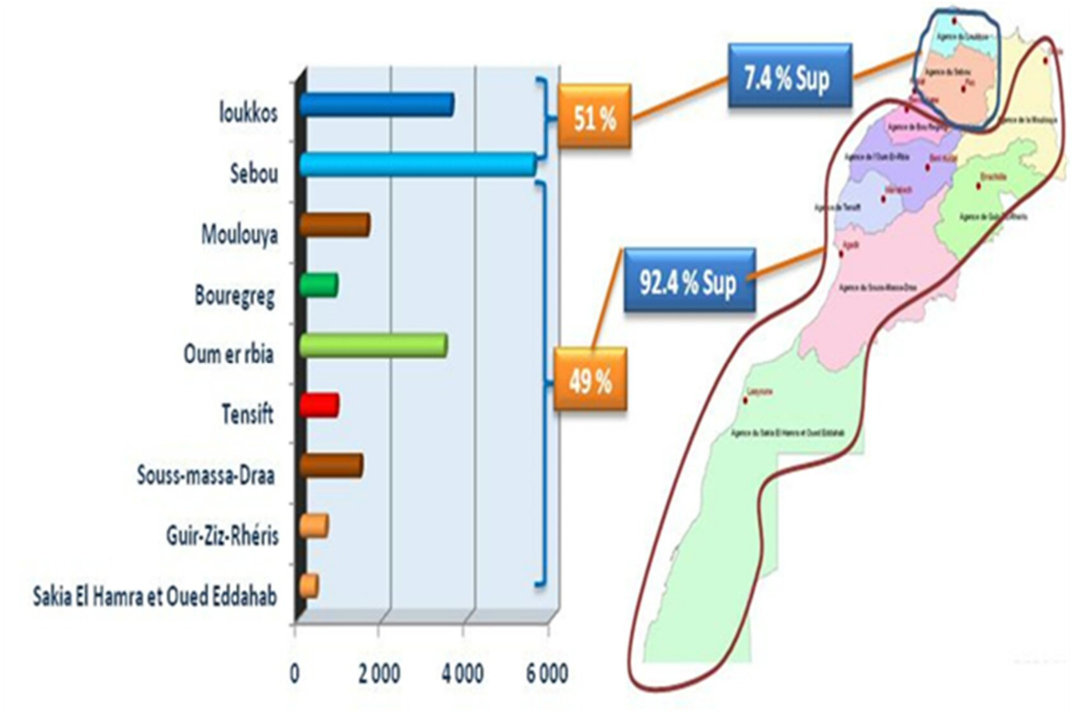


Figure IV-8: Distribution of surface water by hydraulic basin (source: PNE, 2015)

The idea for this water transfer project stems from the following main considerations:

the pooling of available or projected storage capacities in the Laou, Loukkos, Sebou and Oum Er Rbia basins, notably in Al Massira, which has an important storage capacity not always met, can mobilize additional water resources now lost at sea;

the Bouregreg, Oum Er Rbia and Tensift basins have structural water deficits that will be aggravated by the decline in water supplies in these basins and the increase in demand for drinking water, Marrakesh.

In this context, the objective of the transfer project is to pool the storage capacity at the level of the basins in question in order to reduce losses at sea and without impact on the resources usable in the donor basins. The project - which provides (in two phases) a water transfer of 845 m^3 / year to the south - will allow the extension of irrigation on an area of about 70 000 ha, building of irrigation on an area of about 125 000 ha and the satisfaction and security of the drinking water needs of the city of Marrakech.The allocation of transfer water (total of 845 Mm^3 / year) will be as follows:

Perimeter oued Cherrât: 25 Mm^3 / year

Backup of the Berrechid aquifer: 95 Mm^3 / year

Chaouia irrigation extension: 163 Mm^3 / year

Holding of the Al Massira Dam: 562 Mm^3 / year (of which 95 Mm^3 / year for AEP of Marrakech)

The location of these perimeters is given in the figure below. The water transferred by the Project from the north to the Al Massira dam will be divided between the Doukkala (extension and reinforcement) irrigation systems, Bouchane, Bahira and Haouz Central, and AEP for the city of Marrakech (95 Mm^3 / year). The project is a 5,000- kilometer traverse , which crosses situations of relief and geology different imposing tunnel passages.Four tunnels are planned, ranging in length from 7 to 63 km, or 164 km in total, and nine pumping stations.

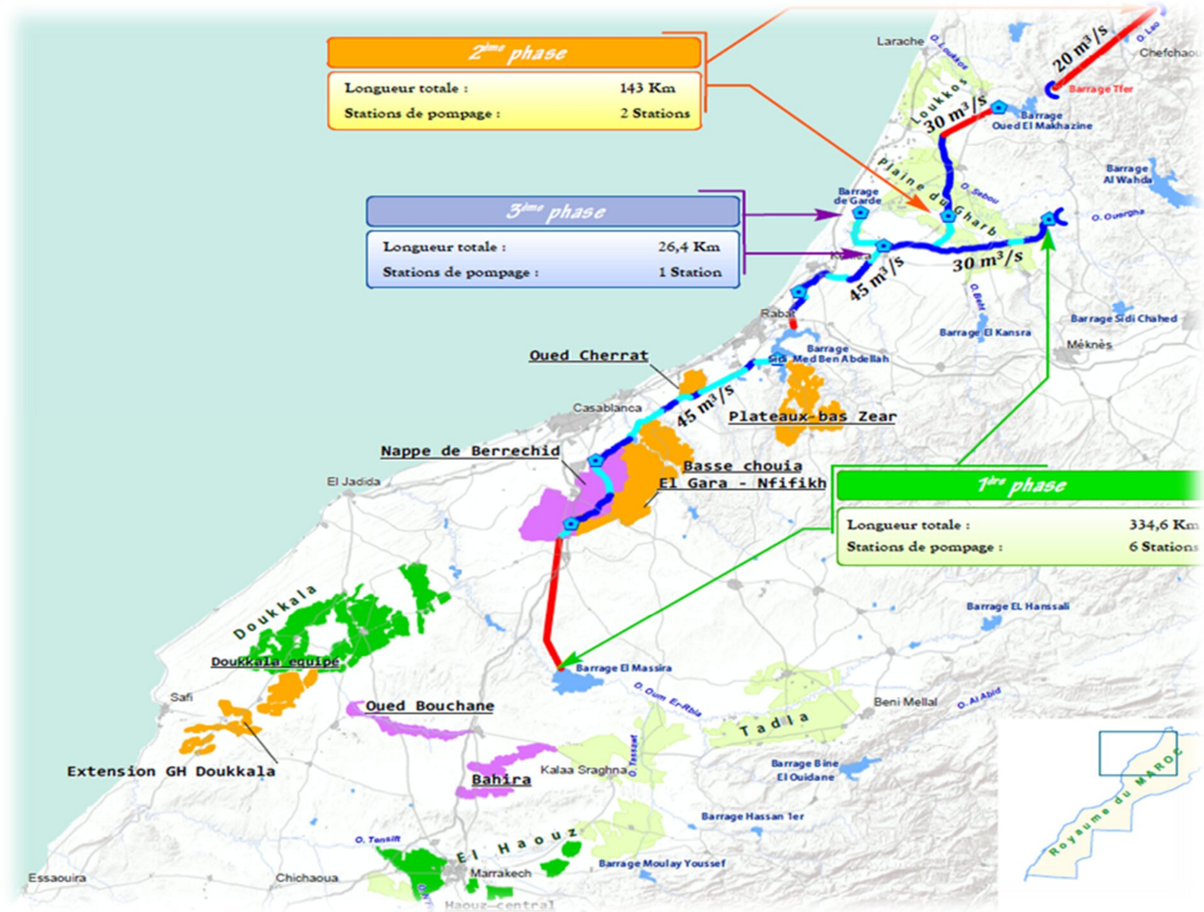


Figure IV-9: Map of the North - South Transfer Canal [1]

Project Costs: The cost of hydraulic infrastructure of the Northern Transfer Project (excluding investments associated with hydro-irrigation and drinking water) was estimated to be approximately MAD 31 billion as part of the feasibility study of the hydro-agricultural development under the Northern Transfer Project. The maintenance and maintenance costs are estimated at MAD 185 million / year, the annual depreciation allowance is MAD 628 million / year (2% of the initial investment), and the pumping costs (energy cost) are estimated at 1.78 MAD / m ^{3} .Given the location of the perimeters (Cherrât, Berrechid, Chaouia and Al Massira dam reservoirs), and the water allocations allocated to these perimeters and the reservoir of the Al Massira dam, water delivered to these perimeters and to the reservoir of the Al Massira dam is different.It is the highest for the water that arrives at the dam reservoir Al Massira.The assumptions taken into account in calculating the cost of water can be summarized as follows:

the costs of investment, depreciation and maintenance and maintenance are proportional to the length of the sections;

the energy costs necessary for the pumping station correspond to the energy costs of the downstream section;

the costs per section add up to give the actual cost of the m ^{3} transit in the section concerned.

Thus, in sections, the results were obtained as shown in the next figure and table. The m ^{3} that will pass through the transfer lines will cost more and more expensive over the kilometers traveled.The total specific cost of water delivered to the Al Massira dam is estimated at 7.4 MAD / m ^{3} (updated to 5%), almost the same cost estimated in the present report for desalination of seawater (updated to 10%) .However, the Al Masira reservoir still needs to be treated for domestic use.

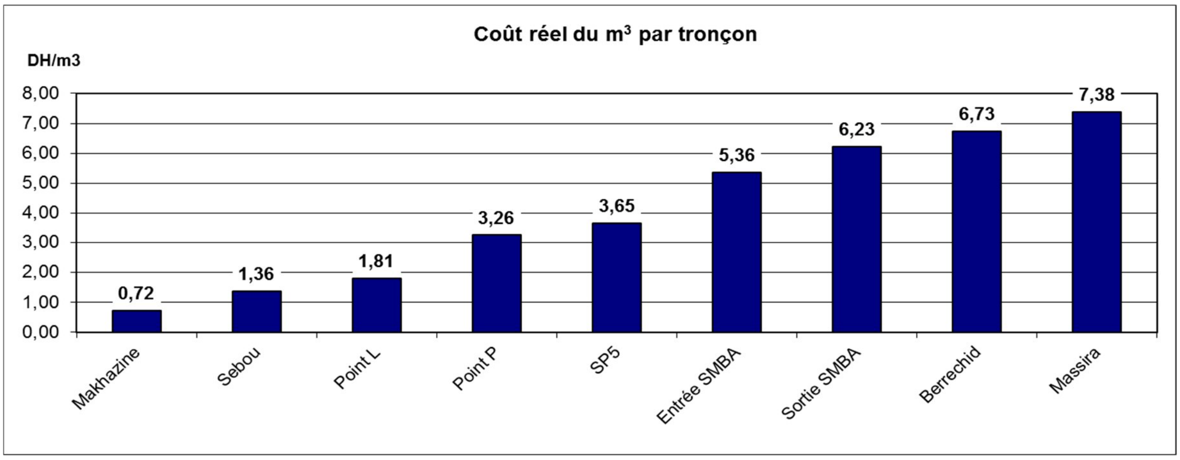


Figure IV-10: Summary of costs of water transferred from north to south [2]

Perimeter:	Extension Cherrat	Chaouia		Doukkala		Rhamna		Enhancement GH Haouz central
		Backup. IP tablecloth Berrechid	Extension Gara Nfifikh	Enhancement BS and HS	Extension HS	Backup. Bahira tablecloth	Extension Bouchane	
Transfer (MAD / m3)	**6.2**	**6.8**	**6.2**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**
Investment (MAD / m3)	5.0	5.2	5.0	5.6	5.6	5.6	5.6	5.6
Energy (MAD / m3)	1.2	1.6	1.2	1.8	1.8	1.8	1.8	1.8
AHA (MAD / m3)	**0.4**	**0.6**	**0.7**	**0.2**	**0.9**	**1.9**	**1.7**	**1.5**
Investment (MAD / m3)	0.4	0.4	0.4	0	0.7	0.7	0.6	0.25
Energy (MAD / m3)	0	0.2	0.3	0.2	0.2	1.2	1.1	1.25
Global cost Investment transfer) [MAD / m3]	**6.6**	**7.4**	**6.9**	**7.6**	**8.3**	**9.3**	**9.1**	**8.9**

Table IV-2: Summary of Project Costs Transfer from North to South

Environmental and social impacts: A study was conducted by the DRPE. The main findings of his critical analysis (as part of the ODA study of the transfer project) are:

For linear works (in general the channels), the identification and the evaluation of the impacts were carried out, taking into account a band of 10 km on both sides of the route. This strip is wide enough to allow for alignment adjustments based on land use or socio-environmental constraints.

The total length of the route is 504 km, the area considered is therefore 10,080 km ^{2} .A first comparison of this route with the map of sites of biological and ecological interest (SIBE sites) below makes it possible to conclude that several SIBE will be crossed and thus the impacts of the project on wildlife and flora of these particular ecosystems could be significant if the appropriate mitigation measures are not identified and their budget estimate is integrated into the overall investment of the selected variant.

The human environment is rich and dense. The total number of houses directly affected by the transfer of water supply is 210 houses of which 126 houses will be affected by the passage in the gallery. The population to be moved is about 1,100 people.

The rate of urbanization is constantly increasing.

For the Béni Mansour dam, the future reservoir of the Beni Mansour dam on the Oued Laou will partially mitigate the lands of the rural communes of Bni Said, Tassift d'Oulad Ali Mansour and Al Oued. The total area embedded at the Normal Holding Coast (110 NGM) is 897 ha. The agroforestry area occupies a total area of about 484 ha, or 54% of the total area of the Béni Mansour dam.

The future reservoir will create scattered dwellings on both sides along the Oued Laou. The number of homes affected is approximately 230 homes. The population to be moved is about 1,200 people.

The flooding of the future dam reservoir Tfer will partially flood the lands of the rural communes of Brikcha, Ain Beida, Souk L'Qolla, Bou-Jedyane, Tatoft and Laghdir. The total flooded area is 35.6 km^2. The agroforestry area occupies a total area of about 27.6 km^2, or 77.5% of the total area covered by the Tfer dam.

The future restraint will lead to scattered dwellings on both sides along the Loukkos wadi. The number of homes affected is about 180 dwellings. The population to be moved is about 900 people.

A total of 3,200 people will be displaced and another group (not yet assessed) will be affected by the loss of enjoyment of flooded land. Social impacts can be seen as important, long-lasting and extensive. The mitigation measures to be implemented must take account of the compensations of these populations.

The impacts of climate change [3] **:** The impact of climate change is analyzed with reference to different IPCC hypotheses and models that attempt to translate these assumptions. The " Horizon 2050" series generated in the pre-feasibility study corresponds to decreases in basin-scale inputs as follows, corresponding to a moderate climate change scenario:

Loukkos and Laou: -20%

Sebou: -25%

Bouregreg: -22%

Oum Er Rbia: -22%

Tensift: -20%

The pre-feasibility study analyzed the impact of such a scenario on the availability of the resource in the northern basins (surplus basins) for the transfer. This test showed that taking into account this hypothesis has no significant impact on the long-term average transfer volume (1939-2003), whereas this volume decreases only 3% from 921 to 890 Mm^3 / year on the short series (1981-2003).

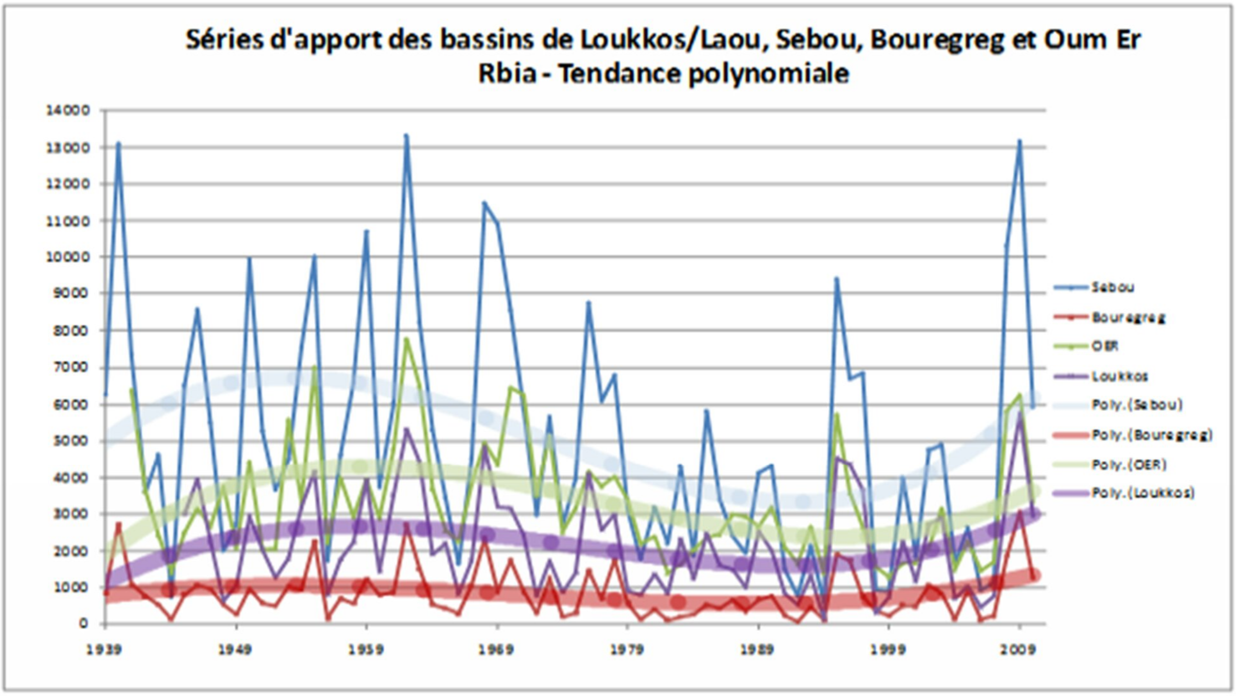


Figure IV-11: Lakkos / Lao, Sebou, Bouregreg and Oum Er Rbia basin supply series

Indeed, as it has been translated in the development of input series influenced by climate change, it leads to lower average inputs but does not eliminate surplus years (even if it diminishes in importance). The reservoirs are still filled during the wet years, the water supply is balanced between the multiple reservoirs with a multi-year regulation horizon and the volume transferred is less affected (the climatic elasticity is well below 1). On the other hand, the demand for catchment basins is increasing, given the decrease in their own resources, which increases the use of transfer water. It reduces average supplies at all basins.

Basin	**Decrease in supplies under CC assumption tested without transfer (Mm ^{3} / year)**	**Decrease in supplies according to the hypothesis of CC tested with transfer (Mm ^{3} / year)**	**Impact of the north-south transfer project on supplies (Mm ^{3} / year)**
There where	-2	0	2
Loukkos	-16	-8	8
Top / Middle Sebou	-12	-14	-2
Netherlands Sebou	-111	-163	-52

Table IV-3: Impacts of transfer on supplies to water users in donor basins taking into account climate change (indicated above)

It is possible to judge the effectiveness of the transfer by analyzing its impact on the volume of fresh water returned to the sea, simulated with a model of water resources system for the three donor basins .This volume is equal to 3 622 Mm ^{3} / year for the three basins without transfer and 2 753 Mm ^{3} / year with transfer, a difference of 869 Mm ^{3} / year, compared with the volume transferred at the end of the project, equal to 860 Mm ^{3} / year:

Wadi	At sea without transfer (Mm^3 / year)	At sea with transfer (Mm^3 / year)
Lau / Loukkos	1 116	737
Sebou	2 506	2 016
Total	**3 622**	**2 753**

Table IV-4: Impact of transfer on discards at sea for the four northern donor basins

Conclusions of the DRPE study on climate change: The above table summarizes the variation in performance indicators according to the climate change scenarios analyzed. The displayed colors (according to the caption indicated below) allow to qualify the level of risk reached. The analysis shows the sensitivity of the system's performance to variations in the mean input and demand.

The impact on PMH (water-borne specimens), with respect to average supplies, is low; there is only a moderate risk of a decrease in the guarantee if there is a significant decrease in contributions (-40%);

The satisfaction of demand for GH (located downstream) presents a moderate risk for a 40% decrease in inputs; on the other hand there is a considerable risk of a reduction in the guarantee (from 34% without the transfer and 50% with the transfer) for the same level of decrease in contributions (40%): There is a significant increase in the number of deficit year;

The impact on the satisfaction of municipal and industrial water demands is low (this request being given priority No. 1);

Energy production poses a low risk for reductions of up to 20% in inputs and an increase in agricultural demand of 5%.This risk becomes moderate for a 40% decrease in inputs.

The same observation is made for the low flow rate of the Sebou medium.

The transferred volume presents a moderate risk from the 20% decrease in inputs.

It is important to note that the conclusions on the volume of the transfer and its impact on the risk of satisfying demand for GH, taking into account climate change, should be taken with caution. These components should be analyzed globally, integrating the other donor and beneficiary basins.

The above table summarizes the impacts of climate change on the water surface of the Atlantic Ocean from the Sebou basin, modeled separately from the other basins, with and without a transfer of about 500 Mm^3 / yr.It can be seen that much of the impact of climate change and water transfer is compensated by the Atlantic Ocean, at least for runoff reductions up to 20%. The runoff elasticity of the ocean is about 1.8, indicating that the ocean is very sensitive to variations in the water supply.

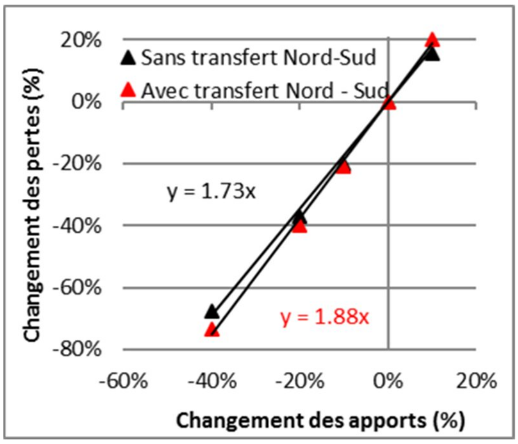


Figure IV-12: Changes in losses at sea due to changes in water supplies for the Sebou basin

Sebou Basin	CC	Q Losses at Sea	dQ / Q ₒ	Elasticity	Q Losses at Sea	dQ / Q ₒ	Elasticity	Difference of losses
		Without transfers			With transfers			Impact
Reference Scenario	0%	2,546	0%		2,043	0%		-504
Scenario 1	10%	2,939	15%	1.54	2,452	20%	2.01	-487
Scenario 2	-10%	2,031	-20%	2.02	1,619	-21%	2.07	-412
Scenario 3	-20%	1,601	-37%	1.86	1,224	-40%	2.00	-378
Scenario 4	-40%	828	-67%	1.69	547	-73%	1.83	-282

Table IV-5: Change in water losses to the sea in the Sebou river basin according to the climate change scenarios analyzed

[1] Feasibility study of hydro-agricultural development related to the transfer of water from North to South, 2016

[2] Feasibility study of the hydro-agricultural development related to the transfer of water from north to south, February 2016

[3] Feasibility study of hydro-agricultural development related to the transfer of water from North to South, 2016.

[4] CC = Reduction in inputs due to climate change

ANNEX V - Evaluation of the impacts of water reallocation from irrigation to potable water

The priority given by the Law on Water (Law 36-15) to water supply to cities on irrigation can lead to an increase in water shortages for irrigated agriculture. Important questions to consider include how farmers can respond to water shortages (crop changes, irrigation methods, etc.), the assessment of impacts on agricultural yields per m^3, and the analysis of impacts on the regional economy. The objective of this section is therefore to present an analysis of the economic impacts of water scarcity on agriculture in the region (Tensift basin), specifically: (i) a conceptual description of the impacts of water scarcity, (ii) adaptation measures by farmers, (iii) the consequences of these water stresses on agriculture on the region's economy (taking into account multiplier effects), and (iv) a brief analysis of the economic value of irrigation water (MAD / m^3) applicable to the economic cost of opportunity calculations in the case of allocation of resources to Marrakech supply at the expense of agriculture .This analysis would contribute to the reflection of water sector stakeholders on the value of water for irrigated agriculture and on the trade-offs between water supply for cities and irrigated agriculture.

Context

The development of the Tensift hydraulic basin is strongly influenced by limited water resources. Over the period 1945-2010, the annual average inputs, drained by the various wadis of the Tensift basins, are estimated at about 1,080 Mm^3 / year, to which is added water transfer from basin of the Oum Er Rbia, via the Rocade channel of about 200 Mm^3 / year in an average year, ie an overall potential of 1,280 Mm^3 per year in surface water resources (source : ABHT).This potential is also exposed to a succession of periods of drought with a decrease in the inputs from precipitation (rain and snow), and a drop in the flow of wadis.

Demand is growing due to the socio-economic development of the city of Marrakech and neighboring municipalities (mostly agricultural). It addresses the needs of drinking water, water for agriculture, tourism and industry. In spite of the efforts made with regard to localized irrigation conversion (irrigation with taste), agriculture is increasingly soliciting groundwater due to the irregularity of surface water supplies. In this context where surface water is fully mobilized, the deficit is filled by groundwater beyond its renewable potential.

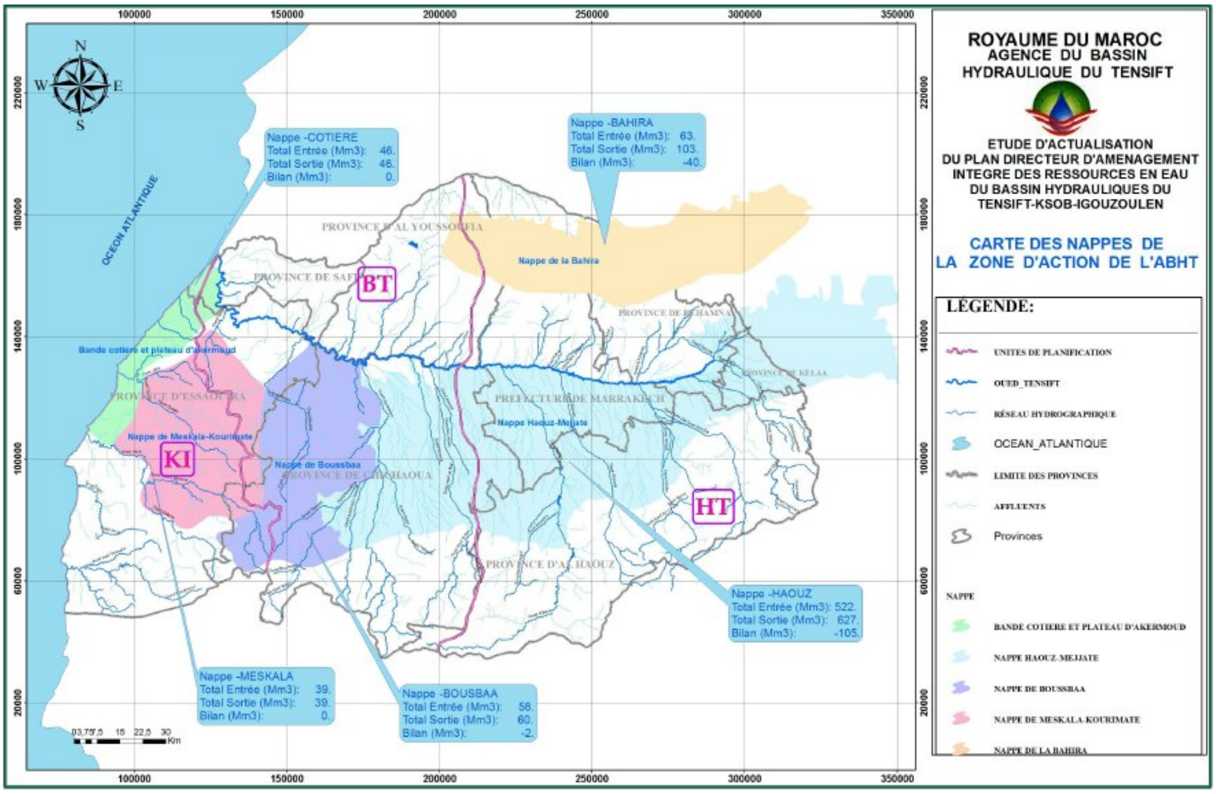


Figure V-1: Balance of underground resources exploited in Mm 3 / year (Source: PDAIRE, ABHT [1])

This section proposes a conceptual analysis of the economic impacts of water scarcity on agriculture in the region (Tensift basin), taking stock of the impacts of water scarcity on the activities agricultural responses in the region, adaptation measures by farmers and analysis of the consequences of these water stresses on agriculture on the region's economy.

1. Impact of water scarcity on agricultural activities in the Region

The agriculture of the Marrakech-Safi region is characterized by the predominance of cereals (78% of useful agricultural area - UAA) and arboriculture (9.5%) .While the agricultural sector is the main engine of the national economy, this is also true for this region. Indeed, this sector absorbs almost 53% of the active population of the region. The UAA of the region (1904 400 ha) represents 48.5% of the regional total area (39,300 km 2). The area under irrigation is about 301 000 ha, nearly 16% of the regional UAA and 24% of the UAA irrigated at national level, which shows its importance in the region. The share of fallow land is relatively high (8.8% of the UAA), reflecting the unavailability of water resources for agricultural intensification.

Irrigated perimeters in the ABHT area are characterized by the importance of irrigation in TDC (small and medium hydraulic) and private irrigation with more than 250 000 hectares cultivated, which is the largest area of the Moroccan Basin Agencies. The perimeters of the large hydroelectric (GH) of the Haouz, which currently cover nearly 41,000 hectares, depend on more than 70% of the water transferred from the Oum Er Rbia basin.

In general, the performance of agricultural production remains highly dependent on weather conditions, in particular because of the importance of rainfed agriculture in the area; the fluctuations in rainfall result in a significant change in yields and agricultural value added. The variations in the figures below are explained by the interannual variations in rainfall affecting cereal and agricultural GDP yields. The 2009 peak in cereal yields is explained by the doubling of precipitation in the year from normal. The return to normal precipitation explains the negative growth in later years before the 2009 recovery, which also corresponds to a good rainfall year.

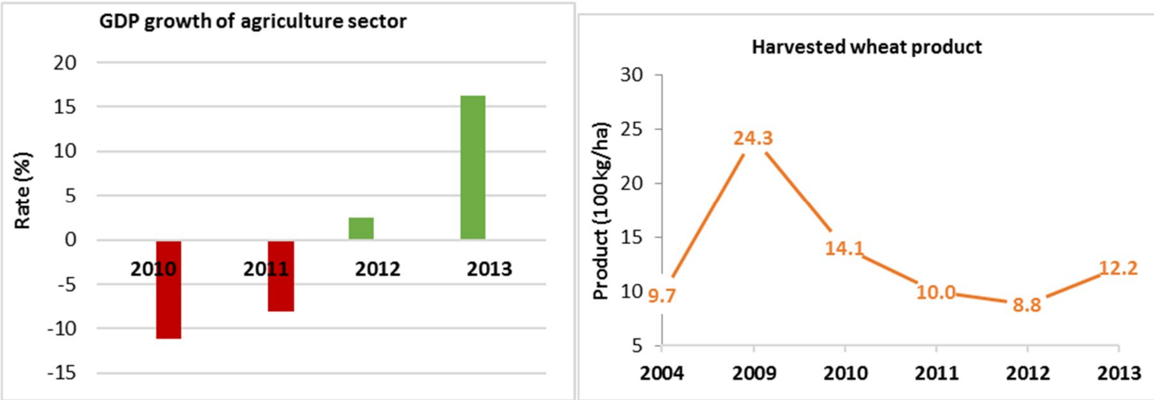


Figure V-2: Primary sector GDP growth rate and average yield evolution of soft wheat in the Marrakech - Tensift - Al Haouz region (Source : HCP, Regional Accounts, 2005 to 2014)

These figures show that the rate of growth of the regional economy reaches its maximum in 2013 following the good agricultural season.In contrast, regional economic growth is less dependent on the performance of the secondary sector, as shown by 2010 rates. In 2011, it is also clear that the effect of agricultural decline has resulted in the impact of the regional economy as a whole.

2. Adaptation measures by farmers

It is possible to distinguish between two groups of farming strategies in response to a decline in available water resources in terms of quality and / or quantity.

Adaptive strategies : The first group brings together strategies that can be described as "adaptive", that is, the farmer will try to adapt his farming system and crop the resource (Kuper et al , 2009).The change in crop rotation depends on the level of risk aversion (aversion to absolute risk, or risk-taking) linked to climatic conditions and the control of production technology for high value-added crops, irrigation water. Some farmers may prefer to reduce the area devoted to them to traditional crops (cereals in particular), given the significant risk associated with the introduction of new crops or the extension of high-value but high-risk crops. Thus, instead of expanding the market gardening area or introducing it, the farmer will produce more wheat, and sell it at the favorable price fixed by the authorities and for his consumption, purchased the subsidized wheat flour. In some cases, these coping strategies can be collective. In the Tadla as in the Basin Tensift, collective conversion projects for irrigation localized (water saving and better valuation of irrigation water as objectives) are set up by the government, with the support from donors. In Souss, groups of farmers collectively manage perimeters irrigated from groundwater (AFD, 2012). When water becomes too scarce, the ultimate choices are to return to rainfed crops, and often supplement agricultural incomes with non-farm labor, which may lead to emigration.

Alternative strategies: The second group brings together strategies that can be described as "hunting strategies" ; it is an increased substitution of surface water by groundwater. These strategies include investing to acquire sufficient freshwater to maintain the farm's production system.Farmers first try "vertical" strategies by drilling deeper. This strategy requires means to invest. It also often involves the circumvention of legal drilling control devices. Others mobilize "horizontal" strategies, fetching water farther (a few kilometers) and bringing it back to the farm through pipes. Finally, when it has become too costly to provide the water needed for the cropping system in place, the choice often (when the farmer has the means) is to move to other areas where water is still accessible, to continue with the same system of culture.

The extent of the substitution effect versus the adaptive strategy varies across the different areas of the basin. If the cost of energy is seen as one of the main constraints to pumping, effectively limiting the importance of the " hunting strategy", its subsidy in the current context, makes it ineffective as a regulating element.

The main criterion for choosing one or the other strategy then remains access to capital. The scarcity of water resources thus implies an increased differentiation between farms, with direct consequences on the territory and rural development.

3. Impact of agricultural stress on agricultural GDP and regional GDP

The difficulties faced by the primary sector in accessing water are not without repercussions on other sectors of the regional economy. Variations of harvested products and agricultural added value and present significant training effects upstream *"Backward linkages"* [2] and downstream " *Forward linkage* " [3] production systems.

By way of illustration, the decline in agricultural activity in the region in 2014 has led to a decline in the secondary sector's gross domestic product (GDP). Primary and secondary sectors recorded growth rates of -15.6% and -20.1%, respectively, leading to a 3.7% drop in regional GDP and an increase in unemployment. Meanwhile, the tertiary sector saw its share in the formation of regional GDP increased from 47% in 2013 to 51.2%, an increase of nearly 2 billion dirhams of the PIBT [4].

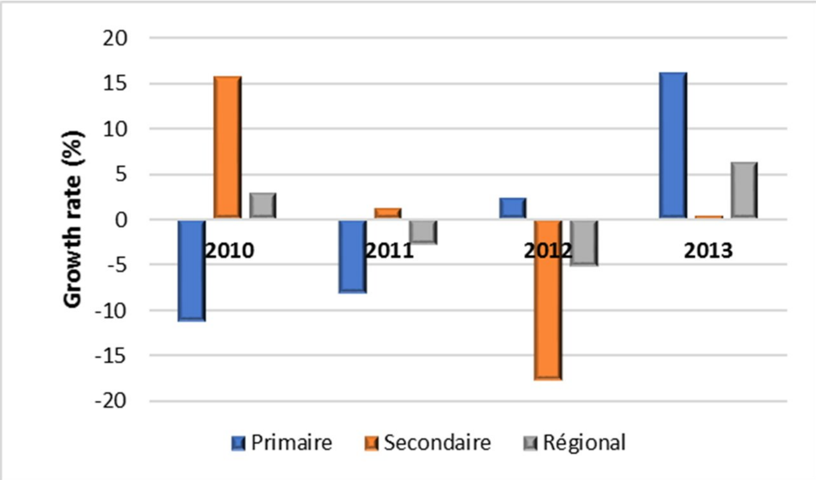


Figure V-3: GDP growth rate of the Marrakech - Tensift - Al Haouz region (Source: HCP, Regional Accounts 2005 to 2014) [5]

The economic effects of a decline in water resources, however, should vary from one production system to another, depending in particular on the level of utilization of the cubic meter of irrigation water ; much more important by rosaceae and vegetable crops. According to surveys carried out by Agro - Concept (2015, Rabat), in the context of studies relating to the transfer of water to the Tensift basin, the valuation level [6] irrigation water ranges from 0.5 MAD / m ^{3} for alfalfa to 17.4 MAD / m ^{3} for the fishery.

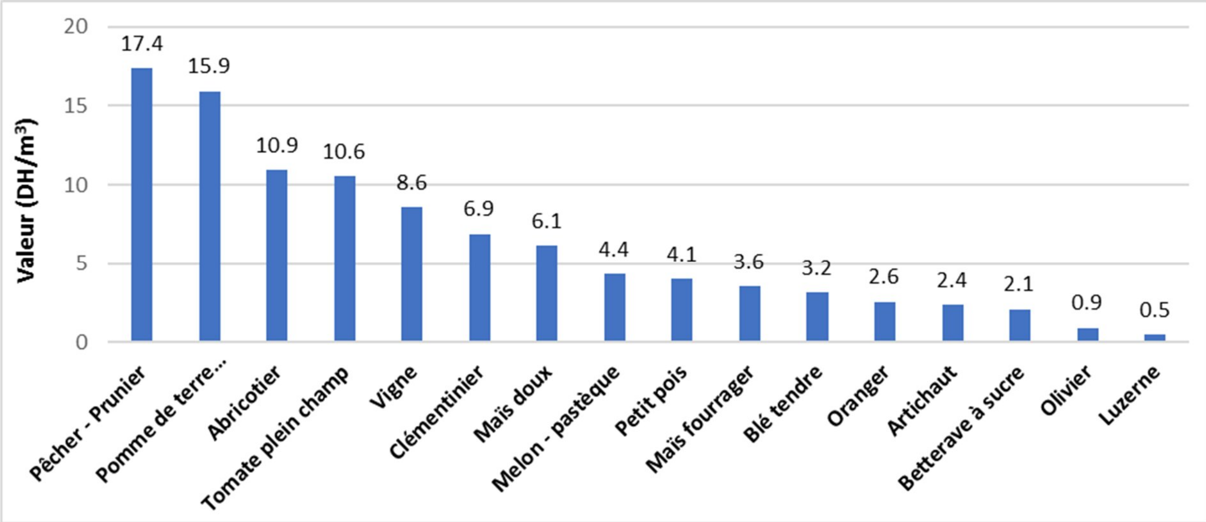


Figure V-4: Valorization of irrigation water by different crops in the Tensift basin [7]

In other words, all things being equal and ignoring the threshold effects [8] , a 10 000 m ^{3} reduction in the endowment , would mechanically lead to a net loss of 174 000 MAD in a plum plant, compared with only 9 000 MAD for an olive plantation.

The other impact is on agricultural land (Box 3.1) .It should be stressed that the price of agricultural land depends on the profitability of agricultural activity. This profitability, in turn, depends on the productive combinations that derive from the allocation of resources available to the farms.

4. Land Losses

Agricultural land makes it possible to generate operating income from production and income from capital in the form of rent corresponding to land rent, the level of which increases with the differential productivity between land (see Box below). Irrigation is an essential factor in this productivity and therefore in the rent and consequently in income from land. Thus, the value of land varies greatly with the ease of access to irrigation water. In this context, and in the context of the reallocation of available water, tenants of agricultural land will see the productivity of land capital decrease, and thus lead to revising lease contracts or, in the extreme case, relocating their production, to areas where the resource is available with lower access cost. For landowners, this decline in the productive value of land will result in a decrease in future earnings. However, since land is not required for the same use, its value for industrial or immovable production, depending on its proximity to urban centers or the dynamics in the industrial sector, could exceed that for agriculture. The income impact on landowners of so-called " agricultural " land, then depends on the possibilities of reallocation for other purposes.

In all cases, and depending on the variability of the situation in the whole of the basin, there will be an increase in the area of summerfallow and an extension of the fallow periods [9] , and a decrease in the UAS (extreme case).

In addition to the economic impacts and on agricultural land, the reallocation of agricultural water does not necessarily lead to social impacts, the extent of which is equally variable according to production systems. Indeed, the economic shortfalls resulting from the adjustment imposed by the reduction in water allocation should result in a fall in labor demand in the agricultural sector. The social impact of this decline in labor demand will depend on the capacity of the regional (and national) labor market to reallocate this labor force. This reallocation is not without cost. The mobility cost represents the expenditure that a worker should incur to move from one sector of activity to another (Hollweg et al., 2014).It depends on several factors including:

The adequacy between the current skills of the worker and those required in the sector envisaged;

The distance between the location of the new opportunity of employment and the current area of residence or work may have an effect on the size of the mobility cost. Workers who have lost their jobs in the agricultural sector in rural areas may find it too costly to migrate to industrial areas on the outskirts of urban centers;

Labor market policies, despite their noble intent and legitimacy for employee protection, may have severe dismissal and hiring costs, further increasing the cost of mobility (Bolaky and Freund, 2004).

Box 1: Economic Determinants of the Price of Land *(adapted from François Facchini (1997)*

There is *"the price of land a broad theoretical consensus: the price of land is the capitalization of income, rent or return value provided by a hectare of land"* (Boinon and Cavailhes 1988, p.215) .If r is the discount rate and R is the marginal productivity of the land, the current value of land (VA) is:

$$VA = \frac{R1}{(1+r)} + \frac{R2}{(1+r)^2} + \ldots + \frac{Rn}{(1+r)^n}$$

Assuming that the land gives an infinite duration of constant annual income, its value is expressed in a simple form. We thus find the capitalization formula of David Ricardo (1951) where $P = R / r$ is the price of land, R is the land rent and r is the interest rate used for capitalization.

According to the actors the land is not asked for the same use. To specify this demand, three types of value can be distinguished:

The productive value, first of all, is a function of the marginal productivity of the land. Land is an input needed for agricultural, industrial or real estate production. Any change in the price of land modifies the productive combination, the choice of the production technique being a function of the relative abundance of the factors. In this perspective, technology is an endogenous variable. The goal function here is maximizing profit.

The investment value, then, is a function of the observed or possible income of the land (Caziot, 1930 [10]) .The investor seeks to value his savings by buying land. He gets rents (rent) and a possibility of surplus value in the sale if he anticipates a rise in the price of the land. The objective function becomes the maximization of utility over time. In addition to the prices of agricultural commodities that determine the amount of landed property, the quality of the land will also play an important role in determining future land income. The investor (the lessor) may, for this reason, wish to improve the fund in order to increase expected future income.

Finally, consumption value depends on population density D, proximity to urban center P, aesthetic aspect H and recreation A, and other factors such as taste or availability of credit X Pope, 1985).The consumption value is then:

$$VC = VC (D, P, H, A, X)$$

Individual preferences in the workplace, job-search costs, and the psychological cost of changing jobs are all likely to have an impact on the cost of hand mobility labor. The presence of mobility costs implies losses at regional (and national) scale depending on the magnitude of the situation, as they prolong the period of reallocation of labor (increase in frictional unemployment) and thus of economic adjustment. When this reallocation of labor resulting from market processes is weak, then there is a high adjustment or social cost.

The other effect, which deserves to be cited, is that of pressure on the demand for public services. Migration phenomena, such as the rural-urban type, linked to the decline in agricultural activity, puts pressure on the demand for urban services (health and education services, housing, transport, water supply) and environmental degradation (Todaro, 1997, ILO, 1998).

5. Economic Impact Assessment of Irrigation Water Reallocation to Potable Water

The water of the Tensift basin is solicited by:

the drinking water sector, and the industries of Marrakech and the surrounding urban and rural centers;

irrigated agriculture, conventionally divided between large hydroelectric (GH), and small and medium hydraulic (TDC);

tourism, including the needs of hotels, golf courses and other recreational areas.

The available water resource is thus a key element in the development of the region's most important sectors (tourism, agriculture, urban expansion). These sectors are competing, and increasing their needs in the face of scarce resources inevitably results in reallocations between users and between sectors.

This section evaluates the impacts of the reallocation of irrigation water to the supply of drinking water to the city of Marrakech (Plaine du Haouz). These are impacts that have been assessed, and are therefore not the only impacts of reallocation; the conceptual sections above describe the broad spectrum of effects and possible impacts.

The costs of this reallocation have been "calibrated" on an assumption of 10 million m^3 per year reduction in surface water allocated to the agricultural sector, with a view to a strong increase in municipal and industrial water demands at the national level. For Marrakech region demand is projected to increase to 126 m^3 / year in 2015 to 160 mm^3 / year (+ 26%) in 2030 and 189 m^3 / year (+ 50%) in 2050.It should be noted that for the RADEEMA area of action in Marrakech, the municipal and industrial water demands is projected to increase from 66 million m^3 / year in 2015 to 79 million m^3 / year in 2030 (+ 20%) and 93 million m^3 / (+ 41%).

At the national level, municipal and industrial water demands is shown in the PNE (2015) at 1.437 Mm^3 / year in 2010 and 2.368 Mm^3 / year in 2030, an increase of 65% over 20 years 26% for the region of Marrakech mentioned above concerns a period of 15 years or 35% for 20 years). Therefore, it is quite possible that the PNE (2015) overestimated the municipal and industrial water demands. Based on the projection of the urban population, we have then extrapolated the PNE (2015) estimates to 2050 by 2050, resulting in an municipal and industrial water demands of almost 3,000 Mm^3 / year in 2050, doubling the 2010 demand (compared to about 55% for the Marrakech region for the same period 2010 to 2050). It appears that the gross municipal and industrial water demands rate calculated in the present report is perhaps too high, which explains the strong increase in municipal and industrial water demands in the PNE (2015). In other words, it is realistic that municipal and industrial water demands could increase with a volume of at least 1,000 Mm^3 / year by 2050 at the national level. This volume corresponds to a water demand for irrigation of about 200,000 hectares, because the increase in municipal and industrial water demands in parallel and aggravated by a decrease in water availability as a result of climate change can have a very significant impact on the level of agricultural production at the national level.

Year	Urban population (million)	**Municipal and industrial water demand (Mm^3 / year)**	m^3 / year per person	liter per day per person
2010	18.3	1,437	78.5	215
2030	26.7	2,368	88.7	243
2050	32.3	2,947	91.3	250

Table V-1: Municipal and industrial water demands Projections by the PNE (2015)

Approach adopted and assumptions: Our approach takes into account:

production losses induced by a reduction in agricultural

the losses incurred by the holders of unrealizable agricultural inputs are: (i) land (fixed factor), and (ii) the labor factor whose mobility is imperfect and costly for families and the economy in general.

We only consider current production factors such as inputs and equipment, can adjust to the least cost due to a decrease in water endowments and our approach does not include the losses induced by their reallocation. Similarly, we do not consider the downstream effects of reductions in agricultural production due to restrictions on access to water and assume that these effects are easily substitutable and low cost by supplying other suppliers . This assumption is only valid for relatively small reductions in allocations in relation to needs. Finally, the approach used here excludes the effects of reducing surface water supplies on the groundwater harvesting.

Table V-2: Impacts of Reduction in Irrigation Allocations

Impacts of the reduction in allocations	Taken into account	Approaches
Losses in agricultural production	Yes	Reduction of the value of the production approached by the indicators of valuation of the cubic meter
Land Revenue Losses	Yes	Decrease in land rent estimated by reduction in gross margins
Losses in jobs	Yes	Estimation of the social cost of labor reallocation
Impacts on underground resources	No	Difficult to estimate without modeling the effects of the groundwater contract
Impacts on upstream and downstream economic activities	Yes	Moderate impact due to opportunities for reallocation and substitution

Losses in agricultural production : Agriculture accounts for more than 80% of water withdrawals (superficial and underground), with in 2010 707 Mm^3 / year for TDC, 348 Mm^3 / year for large hydraulics and 271 Mm^3 / year for private drilling (ABHT, 2010), totaling 1 326 Mm^3 / year. The surface water allocations allocated to large-scale water supply only cover 51% of farmers' needs (ORMVAH, 2011).

Against this backdrop, a decline in agricultural sector allocations is expected to impact the overall valuation level. The economic effects of a decline in the resource, however, vary from one production system to another in terms of differentiated valuation levels of different crops. The table below shows the results according to different scenarios. Economic losses are greater in the event of a decrease in the apricot supply (MAD 109.2 million , compared to MAD 12.4 million for the olive tree), due in particular to the high level of water use, irrigation by this crop.The average loss on a pro rata basis is 2.3 MAD / m ^{3} .

Table V-3: Losses in agricultural production of a decrease in crop allocations [11] of 10 Mm ^{3}

Assumption Assumptions	Crop rotation (ha)	Overall valuation (Million MAD / year)	Economic loss (MAD / m ^{3} reallocated)	Economic loss (Million MAD / year)
Initial (T0)		1 660	--	--
Reduction of 10 M m ^{3} / year for olive trees	89 700	1 648	1,2	12,4
Reduction of 10 M m ^{3} / year for cereals	70 000	1 632	2,8	27,9
Reduction of 10 Mm ^{3} / year for apricot trees	5 500	1 551	10,9	109,2
Reduction of 10 Mm ^{3} / year for citrus fruit	5 100	1 613	4,7	47,4
Reduction of 10 M m ^{3} / year in proportion to the area		***1 637***	***2,3***	***22,9***

Effect on rural agricultural land : The price of agricultural land depends on the profitability of agricultural activity.This profitability, in turn, depends on the productive combinations that derive from the allocation of resources available to the farms. If the water available for irrigation falls, the yields of the different speculation will decrease, resulting in a contraction of the margins per hectare, and hence the "rent" that the farmers can get.

The effect of the decline in the profitability of production systems on land rent is here approached by the ability of farmers to pay rent.

The net effect on land revenues was calculated by reference to the association contracts in the Tensift area, which allocates a quarter of this gross margin to the land factor. The next figure shows the results of the ability to pay, equivalent to the different scenarios [12] .

The ability to pay farmers is greatly impacted by the decrease in the volume of water allocated, when it concerns citrus and apricot trees, largely because of the small size of these groups in the overall rotation of the region, resulting in large decreases in irrigation water volumes per hectare. Indeed, a decrease of 10 million m ^{3} / year, affecting apricot trees, corresponds to a contraction of the allocations per hectare compared to the water requirement of the crops of 33%, against only 5% in the cereals and 25% in the case of citrus fruits.

The distribution scenario of a drop of 10 m ^{3} / year, in proportion to the area, has less impact on the land rent but still higher than when the reduction affects only olive tree plantations. To the "surface effect" which attenuates the impact of the decrease in the per hectare allocation, we must add the resilience of the olive tree to a lack of water (here 2% of the needs).

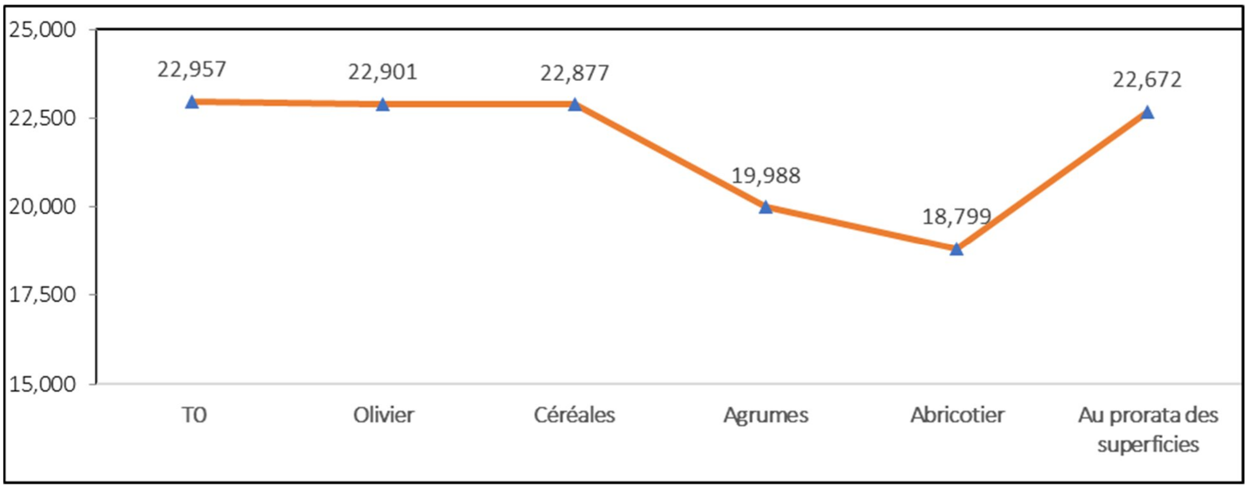


Figure V-5: CAP Average tenants in MAD / year due to a decrease of 10 Mm ^{3} / year of water

Impact on the workforce: Another level of impact is on the labor force employed in production activities.The economic shortfalls resulting from the adjustment imposed by the reduction in water supplies will result in a fall in demand for labor in the sectors concerned, the impact of which will depend on the capacity of the labor market to reallocate this workforce.

The decrease in olive tree allocations by 10 million m ^{3} / year results in a net loss of 29,000 working days (JT), compared to 92 thousand MT when the same volume is reallocated to the citrus. Assuming a working day valued at MAD 65 , and a mobility cost equivalent to 3% [13] of workers' average annual farm income [14] , we obtain an overall labor mobility cost of 180 000 MAD / year in the event of a decrease of 10 Mm ^{3} / year of water impacting citrus fruits and 83 000 MAD / year if this concerns cereals. In proportion to the areas, the losses are 85 000 MAD / year or less than 0.01 D / m ^{3} .

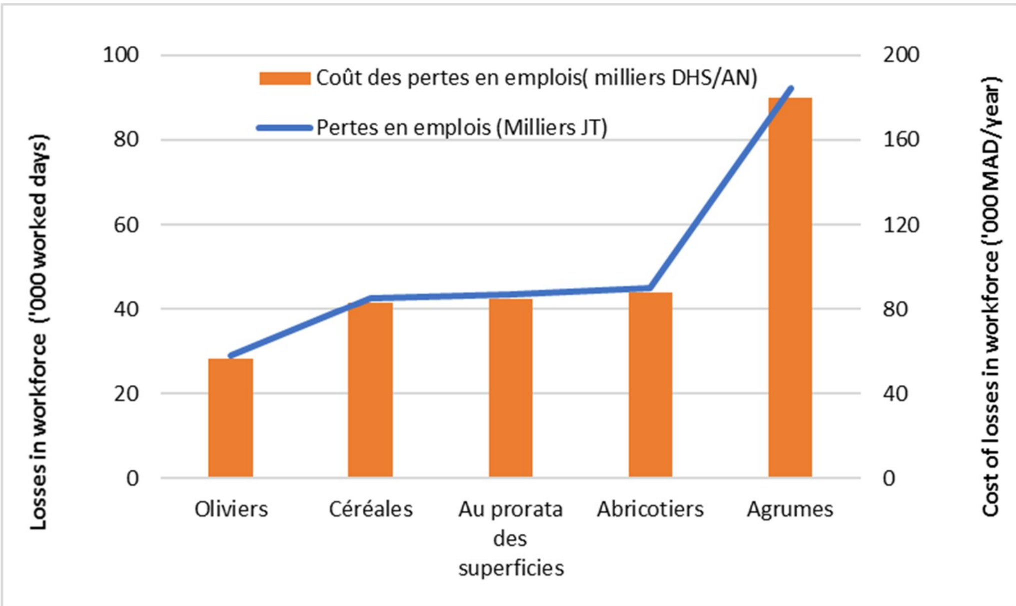


Figure V-6: Social costs due to the decrease of 10 Mm ^{3} / year of water

This mobility-related cost represents the minimum expenditure that workers will have to make to find a job in the agricultural sector. The presence of these mobility costs implies losses at the level of the regional economy because they prolong the period of reallocation of labor (increase in frictional unemployment) and hence of economic adjustment. The longer this period of reallocation, the greater the cost of global mobility. When this reallocation of the workforce resulting from market processes is weak, then there is a significant adjustment or social cost (rising unemployment and precariousness).

Impacts on upstream and downstream economic activities: The calculations would be incomplete if we do not take into account the multiplier effects of production on the development of the rest of the sectors of the economy. Indeed, the total multiplier effect of the production of irrigated agriculture in Morocco is estimated to be 130% (Doukkali and Lejars, 2015), ie each unit of production of irrigated agriculture induces an increase of production in the other sectors of the economy of 0.3 unit of production.

6. Conclusion

In summary, it is estimated that total losses for crop production, including multiplier effects, due to a moderate reduction in the amount of irrigation water amount to about 3 MAD / m ^{3} .

This water value of about 3 MAD / m ^{3} for the Tensift River basin is similar to what was derived by Doukkali and Grijsen (2015) in their study "Economic Contribution of Over-exploitation of Groundwater in Morocco" , which assessed the economic importance of over-exploitation of groundwater, considered equivalent to a form of mining. Their results are summarized below. The direct contribution of the groundwater factor alone to value added (excluding labor, land and other capital) is MAD 14.2 billion at the national level. This contribution is 2.9 billion dirhams in the Souss-Massa region and 1.7 billion in the Tensift region. In this contribution, over-exploitation of groundwater contributes 23% at the national level, 46% at the level of the Souss-Massa region and 33% at the level of the Tensift region, ie 3.25 billion dirhams 1.32 billion dirhams at the level of the Souss-Massa region and 0.58 billion dirhams at the level of the Tensift region. In terms of percentages, this corresponds to 0.4% of GDP at national level, 2.16% of total value added in the Souss-Massa region and 0.87% of total value added at national level. of the Tensift region.

Table V-4: Added value generated by overexploitation of groundwater

	Unités	Maroc	Souss-Massa	Tensift
Utilisation des eaux souterraine dans l'agriculture	Millions de m^3	3 766	606	708
Contribution de l'eau à la valeur ajoutée des cultures irriguées par les eaux souterraines	Milliards de Dh	14.2	2.9	1.7
Pourcentage de Surexploitation des eaux souterraines	%	23%	46%	33%
Valeur ajoutée directe générée par la sur-exploitation des eaux souterraines				
- Total	Milliards de Dh	3.25	1.32	0.58
- Par m3	Dh/m3	3.8	4.8	2.4
Facteur multiplicateur		1.3	1.3	1.3
Valeur ajoutée totale générée par la sur-exploitation des eaux souterraines				
- Total	Milliards de Dh	4.23	1.72	0.75
- Par m3	Dh/m3	4.9	6.2	3.1
Contribution au PIB national et à la valeur ajoutée totale régionale				
- Valeur ajoutée directe générée par la sur-exploitation des eaux souterraines	%	0.40%	2.16%	0.87%
- Valeur ajoutée totale générée par la sur-exploitation des eaux souterraines	%	0.53%	2.80%	1.13%

This calculation would be incomplete if we do not take into account the multiplier effects of production on the development of the rest of the sectors of the economy, indeed a multiplier effect of 130% (Doukkali and Lejars, 2015). The application of this coefficient gives the national level a total contribution of the overexploitation in the groundwater agriculture of 4.23 billion dirhams per year, or 0.53% of the total GDP of the country. At the level of the Tensift region, this total contribution would be 0.75 billion dirhams per year, ie 1.13% of the total regional added value. At the level of the Souss-Massa region, the contribution of groundwater overexploitation would be 1.71 billion dirhams per year, or 2.8% of the value added at the regional level. The value of each additional m ^{3} extracted by overexploitation was estimated at 4.9 MAD / m ^{3} at the national level, 6.2 MAD / m ^{3} at the level of the Souss-Massa region and 3.1 MAD / m ^{3} at the level of the Tensift region.The value of water for the Souss-Massa region is higher than for the Tensift region, as the Souss-Massa region produces much more valuable export crops, such as fruit and vegetables.

Because of its arid to semi-arid climate, characterized by limited and fluctuating rainfall, Morocco has made the mobilization of surface water an important component of its economic and social development strategy. Significant investment efforts in surface water storage and mobilization facilities, as well as significant availability of renewable groundwater, were expected to secure water resources that were large enough to meet the needs of its population, harmonious development of the different sectors of the economy and contribute significantly to its food security.

Beginning in the mid-1980s, with the liberalization of agriculture and the introduction of new, low-cost drilling technologies, unprecedented development of irrigation from groundwater has occurred. This has inevitably created an imbalance between water supply and demand and led to overexploitation of groundwater resources. At present, most of the country's groundwater is overexploited, and this exploitation has reached alarming levels, especially in the watersheds in the southern half of the country, such as the Tensift or Souss-Massa basins.

In a country often subject to prolonged droughts, the risks of over-exploitation are numerous, in particular in terms of the environment, the sustainability of the production systems in place and, above all, the security of supply of drinking water to droughts. In spite of these risks, government intervention to regulate and limit this overexploitation has remained timid and hesitant for fear of causing disruptions that may hamper the development momentum experienced by the regions concerned by this overexploitation of groundwater.

Doukkali and Grijsen (2015) have shown that the economic contribution of this overexploitation of groundwater remains relatively low in terms of value added created. It generates at most only about 0.5% of national GDP. Even in the regions that consume most of these groundwater, the consumption of non-renewable groundwater capitals remains relatively low. In the case of Tensift it does not exceed 1.1% of regional value added. Even in the case of Souss-Massa, which is most often referred to as an important pole of national agricultural production, it represents at most only 2.8% of the regional value added.

[1] It should be noted that the recent assessment by GIZ (2016) presented in this report shows an overexploitation of the Haouz aquifer of 176 Mm ^{3} / year compared to 105 Mm ^{3} / year.

[2] The *backward linkage effect* is used to indicate the link between a particular branch and the other upstream branches to which it purchases its inputs.

[3] The ripple effect downstream or *"Forward linkage"* is used to describe the relationship between a particular branch and branches below which it sells its output (eg Agribusiness).

[4] Gross domestic product of the tertiary sector.

[5] While the text refers to the new division, ie the Marrakech-Safi Region, this graph refers to the former administrative division of the regions for which data are relatively available.

[6] The value of the cubic meter of irrigation water represents the value added per hectare plus the cost of irrigation water, divided by the volume of water used for irrigation, hectare.A net valuation can be calculated, considering the net margin per hectare instead of value added.

[7] Source: Ministry of Agriculture Morocco, 2016, "Feasibility study of hydroagricultural development related to the transfer of waters from north to south", NOVEC / Agro Concept.

[8] All the cubic meters of water brought to the crop do not have the same objectives and impacts on growth and yields.

[9] The minimum level of rainfall for cereal production is 180 mm; in Marrakesh the average rainfall is close to 200 mm, classifying the area as unfavorable (HCP, 2011).While private pumping and public development have led to an increase in production, irrigation water is scarce due to an increase in the area under fallow and an increase in the length of time in some areas. The fallow-summer UAS is relatively high, reaching 8.8% of the regional agricultural UAA (Directorate-General for Local Authorities, 2015: The general monograph: The Marrakech-Safi Region).

[10] Investment value is charged by transfer, maintenance and tax expenses (Alston, 1986)

[11] Source: ORMVAH - Main actor for the implementation of the Regional Agricultural Plan Marrakech Tensift Al Haouz.

[12] The rate of profit considered here is 15% of sales revenue.

[13] For more details on estimating mobility costs: Hollweg et al, 2014

[14] The number of working days for the calculation of the average annual income is 200 days.