Water Supply and Depuration

Tunisian scale

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Co-Evolve4BG

Analysis of Threats and Enabling Factors for Sustainable Tourism at Pilot Scale

Water supply and depuration

Tunisian scale

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OVERVIEW

The present document was produced in the framework of **Co-Evolve4BG** project "*Co-evolution of coastal human activities & Med natural systems for sustainable tourism & Blue Growth in the Mediterranean*" in relation to Threats and Enabling Factors for maritime and coastal tourism development on a national scale" Co-funded by ENI CBC Med Program (Grant Agreement A_B.4.4_0075).

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REVIEW

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SONEDE	Société Nationale d'Exploitation et de Distribution des Eaux
DGRE	Direction Générale des Ressources en Eau

Abstract

This report presents an overview of the different threats of the natural resources in Tunisia linked to the Tourism industry especially in coastal zones. It is developed through the review of existing data at national and regional scale. A literature review was conducted to identify the impact of over tourism on residents' economic and social life and biocapacity. The document is structured as follows; Section 1 provides a presentation of geographical framework linked to the impact of Climate change on climatic parameters evolution and Sea Level Rise. Section 2highlights the influence of Human Geographyon natural resources as well as an analysis of ecological footprint was established. Section 3 focuses on primary and industrial activitieson Tunisian coast.

Section 4 focuses on water and its uses. It gives both a general overview of water resources (conventional and non-conventional water mobilization) and a detailed state of water demand and consumption per sector. This section also describes sources of water losses and discusses strategies to mitigate the water scarcity impacts. A global water balance was established for evaluating the current situation of water resources. Section 5 is dedicated to the impacts of the tourism sector on the environment and water resources. It reports field studies to assess the actual water consumption in touristic units and describes the recommended approach to reduce this consumption. Future trends of water and tourism are also discussed.

I. Geographical framework

Tunisia is a country in Northern Africa (Fig.1). It is located on the southern coast of the Mediterranean Sea. Tunisia is rich in history with many Roman sites and World Heritage sites which contribute to the development of the tourism industry.

The climate in Tunisia is characterized by a hot and dry summer. Two thirds of Tunisian territory is arid. The annual average rainfall varies from less than 100mm in the extreme South to over 1200mm in the extreme North (Kayouli, 2006). The northern mountainous region has a Mediterranean climate with mild, rainy winters and hot, dry summers.

Tunisia is vulnerable to climate variability presented by a rising temperature and varied precipitation. An increase in the frequency of extreme events, such as floods and droughts, has been boosted. These conditions could threaten agriculture, economic development, and variability of water resources.

Climate change threatens the nearly 1150km of Tunisia coast by Sea Level Rise (SLR). Anincrease of evapotranspiration due to rinsing temperature and reduction of runoff and infiltration due to climate change (USAID, 2018).

An analysis of historical climate of Tunisia during the last 30 years show an increase of temperature by an average of 0.4 °C per decade and a decrease of annual average precipitation by 3% (USAID, 2018).The projected climate change for Tunisia shows an increase of annual maximum temperature by 1.5°C to 2.5°C by 2030 and 1.9°C to 3.8°C by 2050 (USAID, 2018).

In the framework of the project about the coastal resilience entitled, addressing climate change vulnerabilities and risks in vulnerable coastal areas of Tunisia, led by the APAL authority, and supported by the PNUD, the projection of salinization at the coastal aquifers (Djerba, Ghar El Melh, Utique and Kalaat El Andalous) has been established. The project shows an evolution of salinity of groundwater resources by 2100. In 2100, the salinity of Ghar El Melh, Utique and Kalaat El Andalous aquifers exceeds 20 g/l (MARHP, 2018).

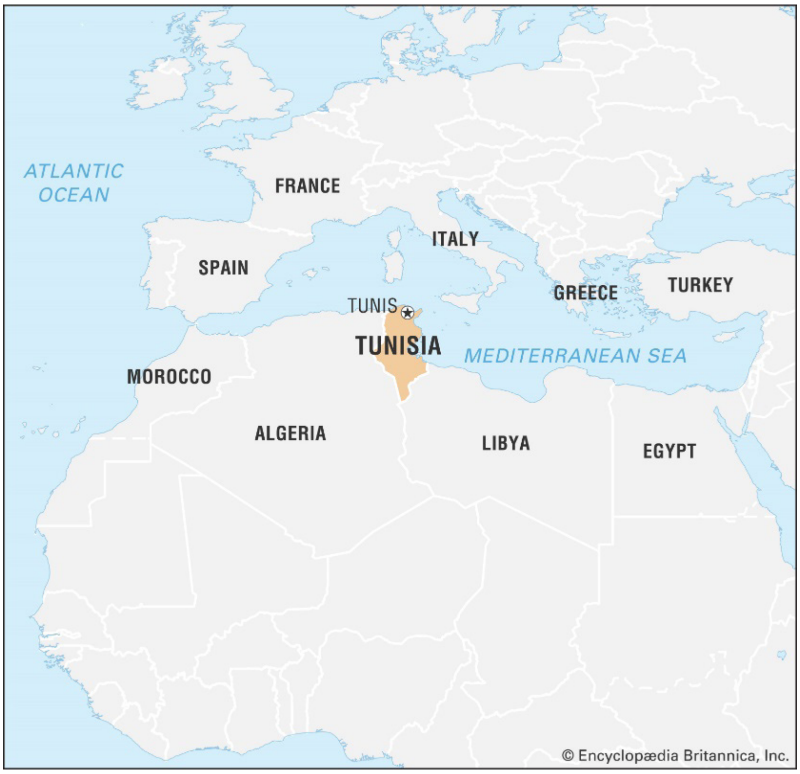

Figure 1. Tunisia geographical location

II. The influence of human geography

Tunisia has an area of 163610 km^{2}. The climate is temperate in the north, with rainy winters and hot summers.

II.1. Population

Population of Tunisia has risen sharply the last 50 years from 5 million people in 1970 to 11.7 million people in 2020 (an increasing of around 100%; Table 1).

Coastal regions in Tunisia harbor 80% of the country's economic activity.

Increasing urbanization has been observed in coastal areas. Tunisia has a coastline of 1400 km. In Tunisia 64% of population live in coastal towns. The urban expansion in the coastal regions with uncontrolled urban development has an impact on water resources quantity and quality, coastal erosion, and environmental ecosystems. The Tunisian coastal and lagoon have been affected by human activities resulting from the industrial and urban development of the coastline (Afliet *al.* 2008).

Coastal urban evolution and the development of coastal tourism produce large amounts of pollution from diffuse and point sources.

The evolution of Tourism industry is accompanied by an increase in water and food demand. The Economic growth in Tunisia is supported by agricultural and tourism industry. However, the agricultural activity in Tunisia accounts for 10-14% of gross domestic product (GDP) and employs 16% of the workforce, while tourism industry accounts 6.5% of GDP and employs 6% of the workforce (USAID, 2018).

Table 1. Population census on the rise in Tunisia (1970 – 2019)[1]

Indicator	Unit	1970	2016	2017	2018	2019
Population	Number	5,080,000	11,304,483	11,434,994	11,551,448	11,722,038

1 Retrievedfrom: Institut National de la Statistique

II.2. Environmental footprint

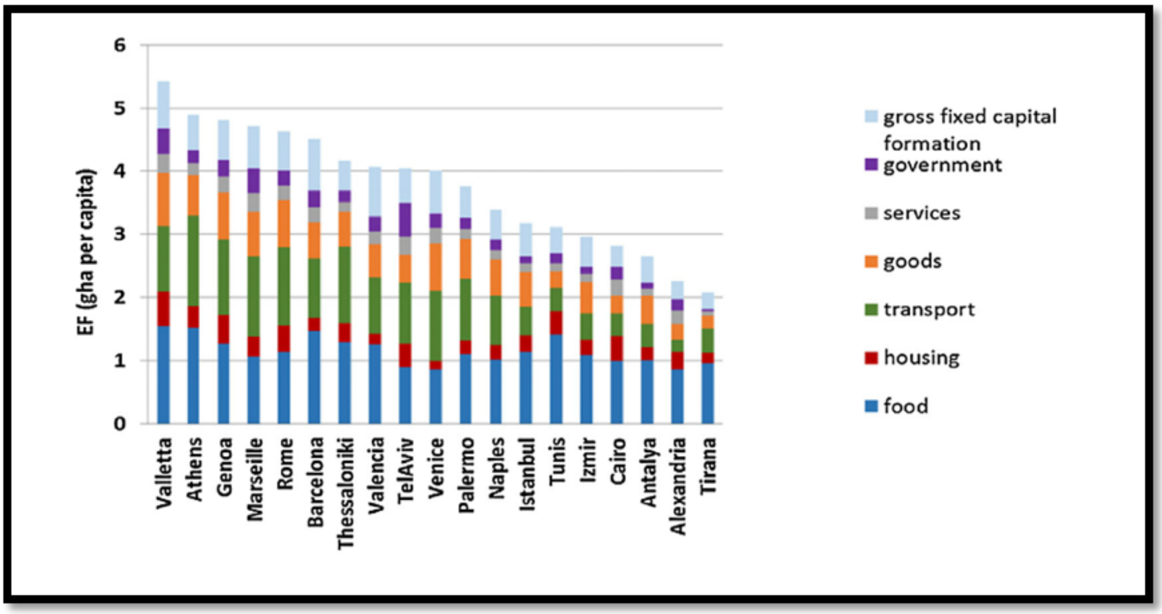

Figure 2. Rank of per capita EF of cities by consumption category in 2015 (Baabou*et al.* 2017)

Environmental footprint: measures the quantity of organic matter (land or water) that an individual, population or activity requires to produce the resources it consumes and to absorb the carbon dioxide emissions that it generates, using current technologies and resource management methods.Ecological Footprint accounting tracks demand for biologically productive land and water areas to produce the natural resources and ecological services that humans consume and compares this demand with the biosphere supply of such resources and services (Fig.2).

An ecological deficit occurs when the Ecological Footprint of a population exceeds the biocapacity of the area available to that population. A national ecological deficit means that the nation is importing bio capacity through trade, liquidating national ecological assets, or emitting carbon dioxide waste into the atmosphere. An ecological reserve exists when the biocapacity of a region exceeds its population's Ecological Footprint, which is the case of Tunisia as shown in Fig. 3.

Economic growth in Tunisia needs an increasing of energy consumption especially for domestic sectors, thus the economic development has an impact on natural resources and environmental pollution.

In 2008, Tunisia had a Footprint of less than the global average available per capita biocapacity of 1.8 global hectares.

Soils resources in Tunisia are threatened by water erosion, poor cover, cultural practices, and rugged topography. These factors have an impact on crop production and dam siltation.

The application of fertilizers to soils,to ensure crop production for food security, has effects on the quality and functionality of soils.

Meat production in Tunisia requires a great demand of natural resources water and land; it has a consequence on a larger greenhouse gas emission (Ibidhiet al. 2017).

Ibidhiet *al.* (2017) show that chicken meat has a water footprint (6,030L/kg), land footprint (9 m²/kg) and carbon footprint (3 CO2-eq/kg) smaller than sheep meat (with an average water footprint of 18900 L/kg, land footprint of 57 m²/kg and carbon footprint of 28 CO2-eq/kg).

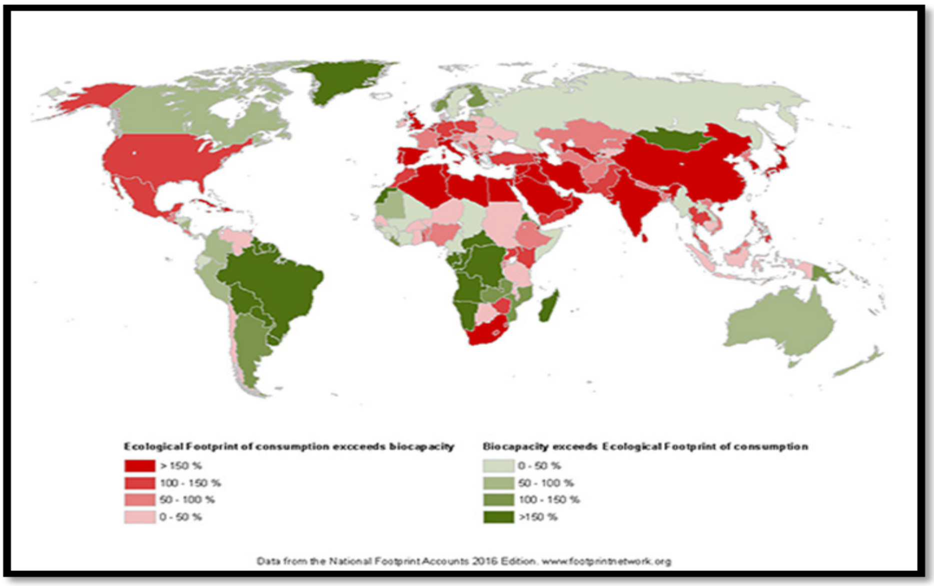

Figure 3. Global Ecological Deficit[2]

II.3. The environmental pressure caused by tourism

The Mediterranean region presents an attractive tourism destination; in 2016, this region has received more than 330 million tourists (Sánchez *et al.* 2019). Tunisia is considered as one of the most popular destinations due to its diverse tourist offering (Widzet *al.* 2020). It is receiving 5.7 million tourists in 2016 (UNWTO Tourism Highlights, 2017 Edition| Tourism Market Trends UNWTO). In 2018 and 2019, Tunisia received 8.3 million tourists and 9.4 million tourists, respectively.

Widzet *al.* (2020) show that the evolution of Tourism industry in Tunisia passed by three phases: exploration, involvement, and development (Fig.4).These phases influence the economic and social life of residents through over tourism.

2 Retrieved from https://www.footprintnetwork.org/resources/data/

Over tourism describes the situation in which the impact of tourism exceeds physical, ecological, social, economic, psychological, and/or political capacity thresholds.

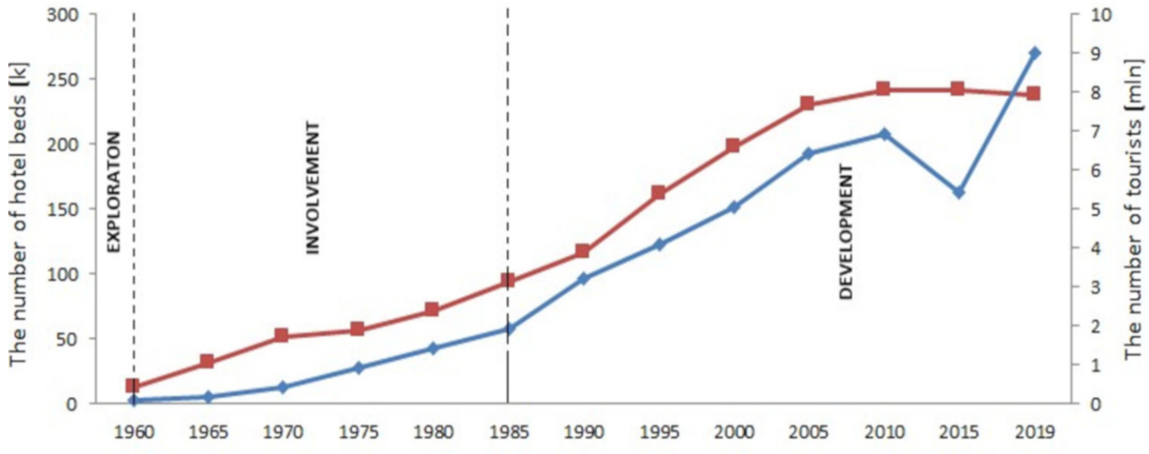

Figure 4. Tunisian evolution phases as a tourist reception area in 1960–2019 (Widz*et al.* 2020)

The analysis of the over tourism risk phenomenon in Tunisia by Widz*et al.* (2020) demonstrated that Tunis, Sousse, and Monastir governorates present the highest risks. Nabeul and Medenine governorates were assigned a high and a medium risk respectively (Fig.5).

The tourism industry has an impact on social and naturalresources (water, soil, and coast).

The governorates at the highest risk of over tourism are in the coastal zone. It has attracted the greatest density of tourists, creating many problems on the natural environment (preservation of biodiversity and the natural character of the coast, fresh water supplies for tourists, wastewater treatment and electricity consumption)

Figure 5. Overtourism risk in Tunisia based on the tourism intensity index (Widz*et al.* 2020)

III. Primary and industrial activities

III.1. Agriculture, fertilizers, and pesticides

Agricultural activities present a source of nutrients, sediments, pesticides on a large surface of water bodies. The Nitrate concentrations in some aquifers in Tunisia contributed to groundwater contamination.

Groundwater resources in Tunisia are threatened by an overexploitation for satisfying water demand for drinking, irrigation, and tourism.

The concentration of nitrates is a major challenge for the quality of groundwater in Tunisia.Re *et al.* (2017)show that agricultural practices have been identified as the main source of nitrate in groundwater from the Grombalia basin. Ameur *et al.* (2015) show that the maximum nitrate concentration at the Sminja aquifer, located in northeast of Tunisiais137 mg/l.The Korba aquifer of Cap-Bon (Northeast of Tunisia) is threatened by agricultural activities using great amounts of fertilizers and the seawater intrusion.

III.2. Aquaculture

Seawater, saltwater, and freshwater aquaculture are growing rapidly across the Mediterranean – at a rate of around 10% per year – in response to stagnating fisheries catches.Tunisia, occupying a central place in the Mediterranean, opens widely onto the sea, mainly on its eastern and southern shores. Fisheries and aquaculture play an important role in socio-economic terms and as a source of food. Annual per capita consumption followed the same trend (from 13.5 kg in 1988-it fell to 8.5 in 1990, rising again in recent years to 9.5 kg) with a much-skewed regional breakdown, because annual per capita consumption in the inland regions is below 1.5 kg. Aquaculture in Tunisia is not developing at the pace expected by the public authorities, despite the substantial potential that has been identified (20,000 tons/year). Current production levels are about 3700 tons, accounting for almost 3% of Tunisia's total fish production. The value of aquaculture exports was around 29 million Tunisian dinars (DT) in 2005 (equivalent to just under $22.3 million USD). Today, over 1000 people are directly and permanently employed in aquaculture.

III.3. Industry

The World Economic Forum declared Tunisia in 2011-2012 the most economically competitive country in Africa and number 40 globally. After economic growth recorded a slight recovery of about 2% in 2017, it accelerated to 2.5% in the first quarter of 2018, and 2.8% in the second quarter. The recovery was supported by agriculture, tourism, and the mechanical and electrical industries.

The World Bank predicted that the growth rate would reach 2.4% in 2018 before gradually approaching its potential of about 3.4% in the medium term for the same year as the business climate improves because of structural reforms and improved security and social stability. Growth will be supported by expansion in agriculture, the transformative industries, and tourism-related services.

The tourism industry in Tunisia is one of the most important industries, especially since Tunisia is poor in oil and natural resources. Tourism industry in Tunisia is greatly vulnerable to many factors; terrorism, political insecurity, and natural disasters.

Table 2. GDP rates in Tunisia[3]

Indicators	measuring unit	2016	2017	Change ±
GDP (at constant 2010)	Billion US$	48.682	49.634	0.952
GDP growth (annual)	%	1.1	2.0	0.9
GDP per capita (constant 2010)	US$	4,269	4,304	35
GDP (at current value)	Billion US$	41.808	39.952	-1.856

III.4. Shipping traffic

Since the ancient Carthage and the Roman Empire, North Africa and more specifically Tunisia, was an important trading area.

Even today, it conducts 96% of its foreign trade by sea. As a result, the country has a vast network of maritime-related infrastructure. It has two container ports in Tunis and Sfax and seven smaller, specialized commercial ports (Fig.6). More than 27m tons of goods transit through Tunisian ports annually, Rades Port Tunis is by far the country's largest port, handling approximately 80% of containerized traffic and movement of goods on rolling units, with traffic of over 300,000 twenty-foot equivalent units per year. Efforts to upgrade Tunisia's ports have, hence, centered on Rades, which in recent years has grappled with bottlenecks – and as a result costs the economy up to €271.9m annually.

3 Retrieved from: International Monetary Fund (IMF), World CIA Fact book, World Bank Data and World Trade Organization (WTO)

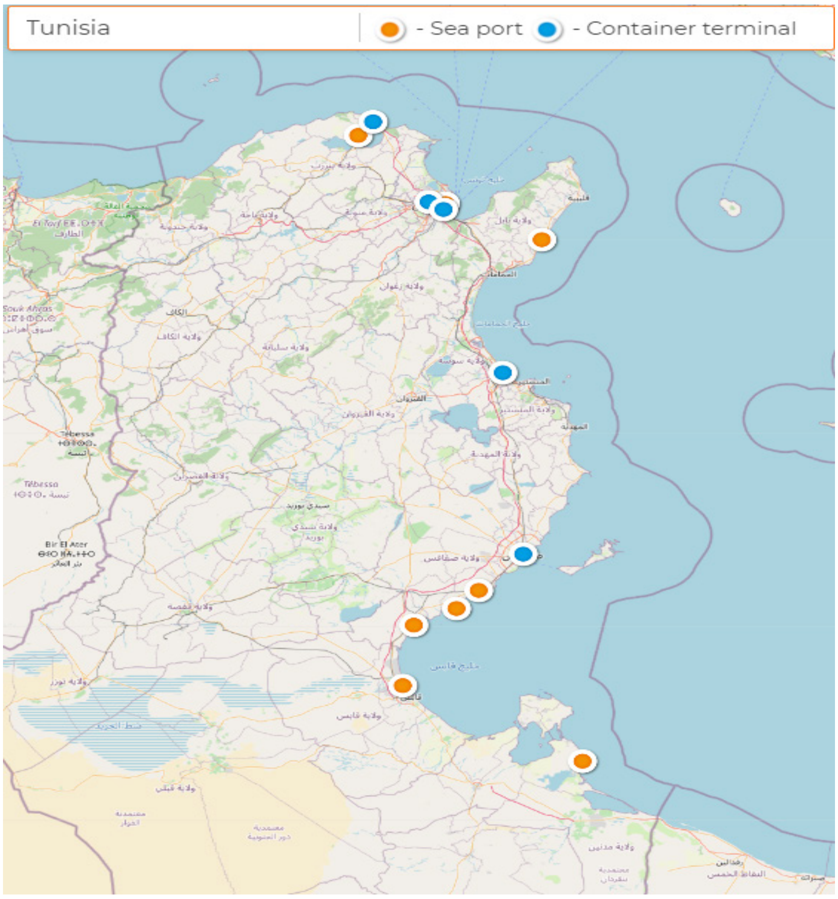

Figure 6. Sea port and container terminal in Tunisia

III.5. Offshore drilling

The US Energy Information Administration (EIA) lists Tunisia as a ‘relatively small hydrocarbon producer’. Oil production in the country declined to 67,000b/d in 2012, from its peak of 120,000b/d in the 1980s. The EIA claims that Tunisia has proven that natural gas reserves are 2.3 billion cubic feet.

Tunisia is currently listed an oil importer due to its limited refining capacity, not because of its reserves. The North African country has only a single oil refinery. Plans for a second are underway, according to EIA.

IV. Water and its uses

IV.1. Water resources

Like Mediterranean countries, Tunisia must deal with a seasonal variability of rainfall concentrated during winter season which affects the surface water regime. This seasonal variability is coupled with an inter-annual variability (great droughts like that of the years 1989-1992 and 2001-2002). Rainfall is characterized by a high spatial and interannual variability. This variability is not only related to the climate but also depends on the physical context and the dominant NW wind direction during the winter season. In fact, the average rainfall varies from 500 mm/year in the North and can reach 1500 mm/year in the extreme North, to 250 mm/year in Central Tunisia. However, it is only about 50 mm/year in the extreme South (Fig.7).

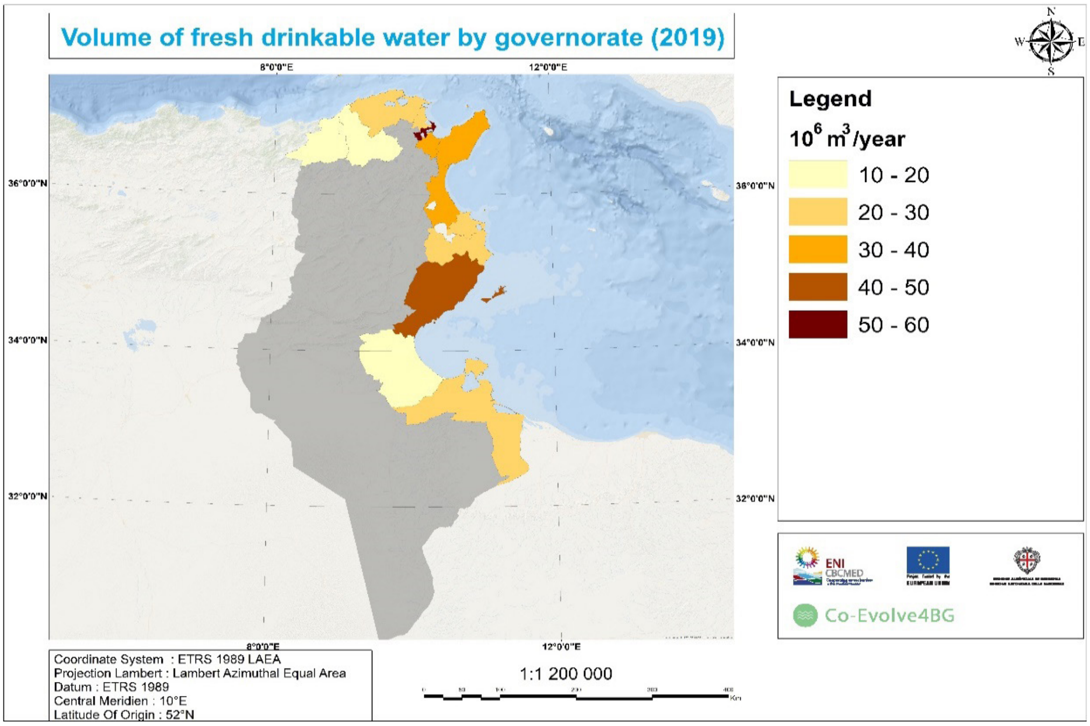

Figure 7. Volume of fresh drinkable waters by costal governorates in Tunisia

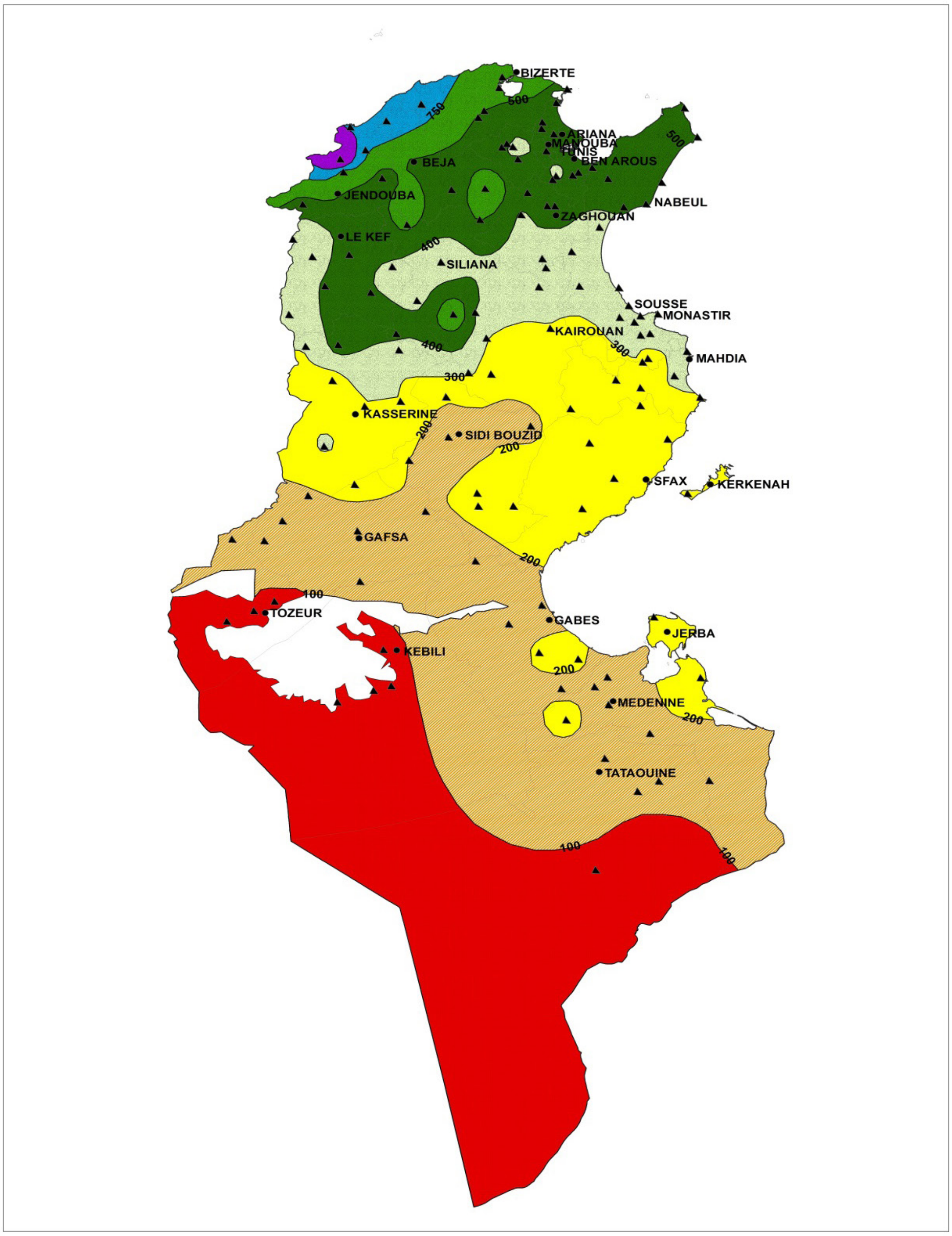

Figure 8. Map of isohyets (DGRE)

In 2010, the total hydraulic resources were evaluated to be around 4.85km^3/year: 2.7 km3/year representing the surface water resource. The groundwater resources were estimated to be around 2 km3 in 2010, representing an effective average rate of exploitation of about 93% of the exploitable resources (estimated to 2.15 km^3/year; Besbes *et al.* 2014).

Estimates of annual surface water inflows during the period 1990-2003 show that the maximum recorded was 3.9 billion m3 in 1996, while the minimum was 1.1 billion m3 in 2001 and 2002. The inter-annual average intake stands at 2.7 billion m^3/year. In addition, surface water, which accounts for almost 60%of total potential resources, is distributed 80%in the North, while underground resources are distributed 72%in the South. This distribution of hydraulic resources has led to imbalances in water resources between regions and has led to rethinking the mobility and transfer of these resources in terms of a certain national balance. To cope with this variability and imbalances, there has been recourse to rainwater harvesting in large reservoirs capable of storing the high flows of the wadis, finding adequate solutions so that the floods of the wadis are not destructive and do not end up by sea or by evaporating in endorheic sabkhas.

IV.2. Conventional water resources mobilization

In Tunisia, conventional water resources that can be mobilized in the form of surface water (in dams and lakes) and groundwater (shallow and deep groundwater) is estimated at 4.8 billion m^3/year: 2.7 is from surface water and 2.1 of groundwater. The mobilization framework is made up of 37 large dams, 257 hill dams, 909 hill reservoirs, 50 water recharge structures in the aquifers, 479 aquifers including, 212 shallow aquifers and 267 deep aquifers whose waters are mobilized by 4900 deep drilling wells and 120,000 surface wells.Table 1 summarizes the evolution of the resources mobilized from 1990 to 2015 (BPEH, 2017).

As shown in table 1, the mobilization of surface water resources continues to increase in the last years and the mobilization rate reached 98% in 2015. On the other hand, the exploitation of groundwater resources continues to grow steadily, especially in the coastal and central regions of the country. The technique of artificial recharge of aquifers, tested in Tunisia from the 1970s, has greatly developed in recent years with the aim of reducing the negative impact of over-exploitation. Since 1992, the volume stored has been 430 Mm^3, or approximately 33 Mm3 per year, and concerns 25 groundwater tables. Heavy investments were made during the last Economic and Social Development Plans, reaching on average 9% of public investments and 2% of annual GDP. Overall, 19% of water investment went to reservoir dams and transfer pipelines, 42% to hydro-agricultural developments, 23% to drinking water and 16% to sanitation. The same trend continues during this Plan (10th Plan 2002-2006). A major part of the availabilities to be mobilized during the next decade is dedicated to surface water mobilization (300 Mm^3), the rest in the form of deep groundwater (80 Mm3). The investments necessary for the development of these conventional resources will amount to one billion dinars, 75% of which is supported by the public sector. The scarcity of hydraulic resources is also increasingly reflected in the unit cost of their mobilization, which will change from 0.100 DT/m^3 for the resources currently exploited to 0.260 DT/m3 for the additional resources to be mobilized.

The most serious threat to surface waters is related to the premature siltation of dams and hill-reservoirs, which is mainly due to the frequency of very intense rainfalls. Considering the installation of dams and siltation, the useful volume under normal dam reservoirs will decrease from 2,200 Mm^3 in 2005 to 1,800 Mm^3 in 2020 (UNEP/MAP/BLUE PLAN, 2007).

The annual rate of loss of storage capacity is estimated at 1.07% for large reservoirs and 4.6% for hill-reservoirs. A vast water and soil conservation program is already in place to treat in the long term about 3 million hectares affected by erosion and thus reduces the risk of silting of the reservoirs (ONAGRI).

To these natural constraints on surface water resources are added others related to the management of groundwater resources and pollution. Although Tunisia is quite rich in groundwater resources, both deep and shallow, these are in some cases heavily exploited (coastal and inland regions). Overexploitation is a growing problem, estimated at 27% of the number of surface aquifers and 14% of fossil aquifers dedicated mainly for irrigation. This phenomenon is often accompanied by deterioration of quality, in terms of increasing salinity. The risk of pollution and resource degradation (extension of urbanization, intensification of pollution and use of fertilizers and pesticides) are other concerns for the sustainability of water resources.

Table 3. Evolution of conventional water resources mobilization (Mm³) (Elloumi,2016)

	Potential resources	Exploitable resources	Mobilized resources			
			1990	2005	2010	2015
Surface water	2,700 (56%)	2,500	1,179	2,200	2,400	27,500
Dams		2,170	1,170	1,927	2,080	2,170
Hills dams		195	5	160	190	195
Hill reservoirs		135	4	113	130	135
Groundwater	2,140 (44%)	2,140	1,576	1,860	2,015	2,100
Shallow aquifers		740	740	740	810	815
Deep aquifers		1,400	836	1,120	1,205	1,285
Total resources	4,840 (100%)	4,640	2,755	4,060	4,415	4,600
Mobilization rate	-	-	59%	88%	95%	98%

IV.2.1. Non-conventional water resources mobilization

In Tunisia, there are currently about 122 wastewater treatment plants that treated 274million m³/year until 2017 and 4 desalination stations for brackish water and sea water treatment allowing the desalination of 26.4 million m3/year (BPEH, 2017). The treated wastewateris used for:

- Agricultural development: 30 sewage treatment plants were dedicated for irrigation of 31 irrigated perimeters (15.4 Mm³).
- Development for recreational purposes: 8 sewage treatment plants irrigate around 10 golf courses (6.5 Mm3 for 1040 ha).0.7 Mm³ of treated wastewater is used for irrigation of 450 ha of green spaces (parks, gardens, and road green spaces).
- Valorization for the preservation of the resource: 2 sewage treatment plants are used for groundwater recharge (0.5 Mm³).
- Industrial valorization: it is still very marginal and not really developed (1 sewage treatment plant (Gafsa) for irrigated perimeters and industrial use [Chemical group - 0.2 Mm³]).
- Environmental recovery: 33.5 Mm3 was used for the benefit of wetlands/ agroecology. This use is not yet a regulated use of treated wastewater. It is rather like a release into the natural environment (wadis and sabkhas).

Over 75% of treated wastewater is discharged into the environment (directly or via outlets) and re-enters the hydrological cycle as well as untreated wastewater from unconnected municipalities.

Although the mobilization of unconventional waters is considered as an essential alternative water resource, the use of this treated wastewater seems to be slowing considerably due to the mediocre quality of the treated wastewater. In fact, only 6% of the total volume of treated wastewater is used for irrigation.There are also2.5% for golf, 13.3% for ecological areas, and 1.2% for green spaces (BPEH, 2017).

The price per cubic meter of water has not changed since 1998 (20 millimes/$m^{3)}$, while the average cost of treatment varies between 70 and 280 millimes. The rate of coverage of these costs is therefore very poor, ranging from 7 to 29%. The hypothesis that the low cost of treated wastewater would encourage its use proved inoperative in the light of the various constraints encountered by the various stakeholders, farmers, supervisory ministries, *etc.*

In addition to the treated wastewater, the desalination of brackish water has been expanding from the 1980s to improve the quality of drinking water at the local level intended for certain urban agglomerations and islands of the Southeast (Gabès, Zarzis, Kerkennah and Djerba). The total desalination capacity for this use is currently estimated at 59,000 m^3/day; with a production of about 15 Mm^3, *i.e.*, 3.6% of drinking water consumption in 2005. In the industrial and tourist sector, a hundred desalination plants allow the production of a large volume of around 35,000 m3/day (BPEH,2017).

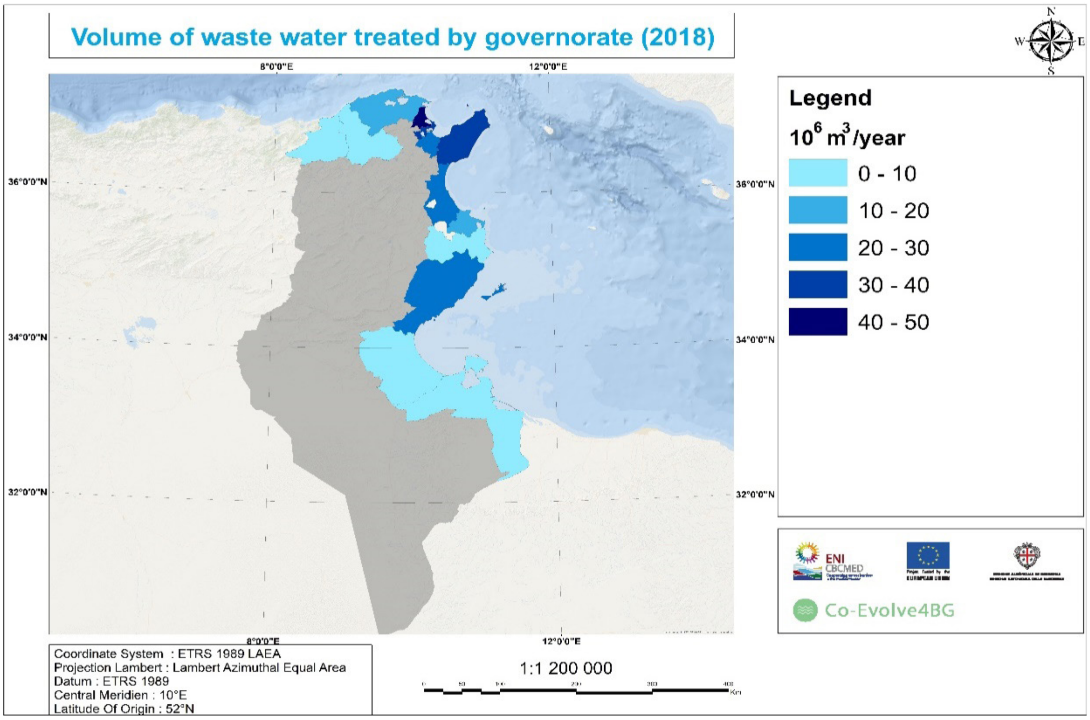

Figure 9. Volume of wastewater treated by coastal governorate of Tunisia, in 2018

IV.3. Water loss

For a total allocated water volume of 3,020 Mm^3/year, only 2,095 are used. This indicates that nearly 925 Mm3/year, is considered as water loss in the national water balance (Elloumi, 2016). It can be distributed as follows:

- Losses on public networks (drinking water) are estimated at 145 Mm^3/year,
- The total losses from the irrigation system reach approximately 660 Mm^3/year,
- About 120 Mm3/year arededicated to Public Irrigation Perimeters in reservoir dams and not used by farmers and feeds the water supply.

The losses representing all such amounts in relation to the allocated volumes are temporary or permanent, sometimes uncontrollable, such as some network losses; finally, some are voluntary and desirable, such as the irrigation of land needed for salt leaching through the soil horizons.

IV.4. Water demand per sector

Water withdrawals (both surface and groundwater) have increased quite rapidly, as shown in Table 3. The presented data highlights the very important weight of irrigation in the consumption of mobilized water from all sources,andthe importance of the evolution of withdrawals by sector, in particular the increase in withdrawals for drinking water, industry and tourism.

Table 4. Evolution of indicators on the use of treated wastewater (BPEH, 2017)

	2015	2016	2017
Treated wastewater volume (Mm^3)	243.3	255.2	260.5
Irrigated perimeters surface by treated wastewater (ha)	8.145	8.415	8.475
Number of irrigated perimeters	28	30	31
Treated wastewater volume used for irrigation (Mm^3)	12	14.5	15.4
% of treated wastewater used in irrigation/total volume of treated wastewater	4.9%	5.7%	6%
Treated wastewater volume used for recharge (Mm^3)	2.35	3.23	0.5

IV.5. Strategies to mitigate the consequences of water scarcity

As presented in Table 4, the water mobilization rate is almost 98% of the total resources. However, it is still recommended to improve water balance by mastering their components. To reach this goal, it is essential to make progress in (1) developing soil water resources, and green water, involved amongst others in food production and whose significant potential is not considered in conventional water balances; and (2) producing and reusing additional quantities of unconventional water resources. These technical solutions could increase the water supply.

For example, improving the role of dams in groundwater recharge is an essential alternative to ensure water security for the next decades by storing water in the unsaturated zone. In addition, it is important to emphasize that water security requires preparing a strategy based on continuous monitoring and developing tools for managers and decision makers to manage the exploitable water resources and control its quantity and quality (Slama and Chahed, 2019).

Table 5. Evolution of water consumption by sector at the national scale (In Mm^3; Elloumi,2016)

	1990	2000	2006	2010
Irrigation	1,575	2,123	2,138	2,141
Drinking water	185	273	321	381
Industry	89	120	124	136
Tourism	18	25	26	31
Total volume	1,867	2,541	2,609	2,689

V. Water and tourism in the Mediterranean

Nowadays, tourism plays an important socio-economic and cultural role. Indeed, it enhances the protection and valorization of natural sites and promotes local culture and heritage (Jaziri and Boussofara, 2011). Tourism is also a growth sector that reduces povertyby providing jobs without requiring a lot of capital and technology (El Bekri, 2013). However, tourism has several negative impacts on the environment and is a vulnerable sector to climate change and general stability (security threats like terrorism and/or sanitary global crisis like covid19 pandemics).

V.1. Tourism impacts on the environment

Tourism can have positive impacts on environment through the protection and sustainable management of some natural areas. However, this sector presents several negative impacts mainly related to the pressure on natural resources including soil, water, and energy (Jaziri and Boussofara, 2011). In Tunisia tourism is a highly urbanizing and a space-consuming activity. The development has been mainly coastal on the waterfront and has contributed to the rapid growth of Tunisian coastal cities by the creation of tourist areas, the most important of which are that of North-Sousse (307 ha) and South-Hammamet (240 ha). Major accompanying infrastructure (airports, roads, marinas, recreational parks, golf courses) concomitant with the emergence of many second homes near tourist areas have followed these developments (El Bekri, 2013). In some cases, tourist areas even emerged on fragile wetlands like Yasmine-Hammamet station (Suchet and Hellal, 2009).

There is increasing pressure on fertile farmland where agriculture is one of the most intensive sectors of the economy(agricultural areas in Nabeul-Hammamet and Sousse-Monastir, assigned to more than 2000 ha; El Bekri, 2013). Sethom, (1980) explained that the accelerated urban and tourist expansion on the eastern coast of Cap Bon since independence has quickly found itself in conflict with the intensive agriculture of the region: it has in fact monopolized and sterilized an increasing part of the agricultural land, it has taken away from agriculture an increasing part of the water available in the region and it competed with intensive agriculture for an increasing part of its labor force (Fig.10). These developments and investments in a territory highly coveted by the tourism industry are causing worrisome impacts on natural resources and the environment with loss of resources (agricultural soils), over-consumption of water and energy resources, multiple pollutions (wastewater, waste, air pollution, greenhouse gas emissions, transportation congestion and noise degradation of the landscape; El Bekri, 2013). The emergence of secondary residences as well as illegal constructions was observed near the tourist areas. In this case the impacts on environment are more important than their needs in terms of infrastructure and urban services (roads, sewage networks, waste collection). The absence or an inadequacy of certain services and infrastructure further aggravates the negative impacts on the environment (*e.g.*, spills of wastewater and urban waste in the ecosystem).

Besides, in several cases hotels have been built on dune and foredune areas. Various degradations have thus appeared over the years,mainly due to these touristic buildings, under the form of beach erosion (Jarraya, 2011).It can sometimes lead to a deterioration of the shallows, but above all the disappearance of whole beaches as it was the case of the Sindibad hotel in Hammamet in 1990 and of the Eljazeera hotel in Djerba in 1991 which under the effect of marine erosion had to retreat by destroying part of its rooms close to the sea (Oueslati, 2010).

V.2.Water and tourism, key issues

V.2.1. Total consumption and pricing

The tourism sector consumes about 25 million m³/year which represents about 1% of total water uses and 5% of drinking water uses (Besbes *et al.* 2018). However, this activity poses some very specific problems (GTZ, 2010):

- Seasonal concentration (related to tourist arrivals), with peaks coinciding with periods of low water resources (summer).
- Spatial concentration on the coastline, on sites characterized by low local water resources (islands), and often in sensitive natural sites.

Touristic activities often relying on facilities consuming excessive water (golf courses, swimming pools and aquatic centers).

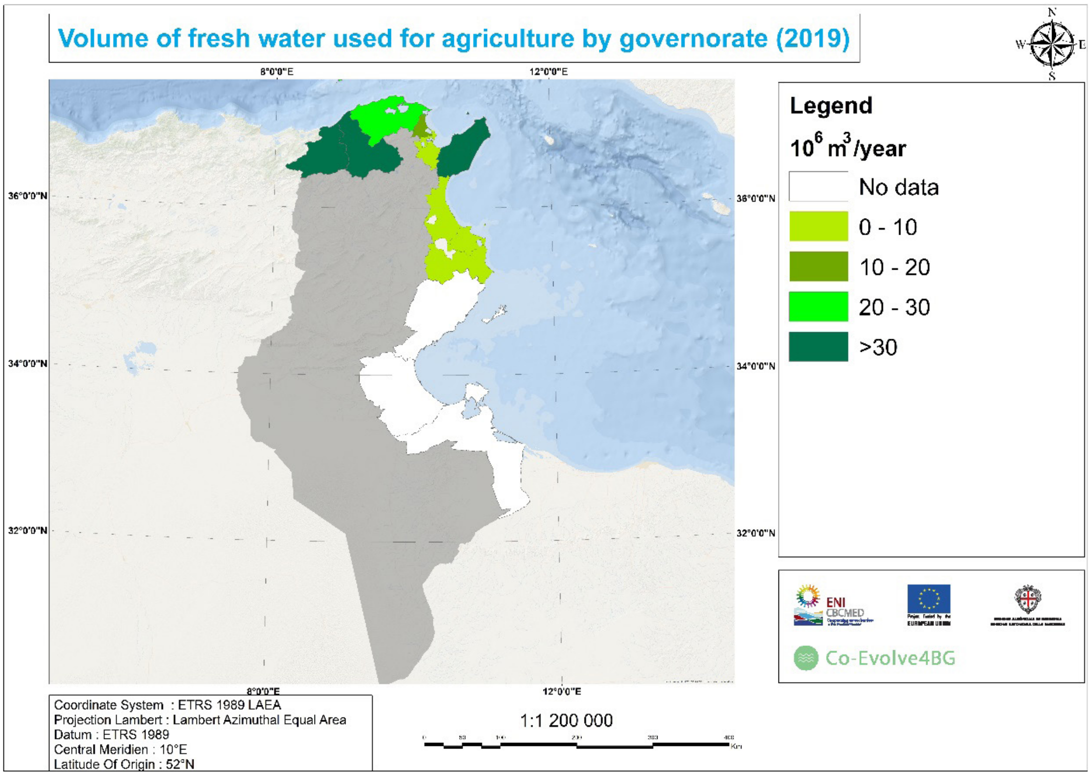

Figure 10. Volume of freshwater used for agriculture in coastal governorates of Tunisia

A study conducted by LahacheGafrej, (2007) also revealed that the average individual tourist consumptionwas very high and reached six times the daily consumption of a Tunisian domestic user (Average of 768 L/day/bed). Besides, several hotels extract important amounts through equipped wells from groundwater. These amounts as well as operating costs (energy) are generally not considered while assessing water use by sector. As sewerage costs are directly calculated from drinking water amounts supplied by SONEDE, the sewerage of amounts extracted from groundwater are also not considered in the total sewerage bill for touristic units.

The water distributed to subscribers is metered and billed according to a progressive tariff rate of water consumption. The rate system, which is the same for all the country, has seven consumption tariff bands with a single rate per band. Rates vary from 200 millimes/m^3 for the first social band (20 m^3/quarter) to 1490 millimes/m^3 for the upper consumption band > 500 m^3/quarter (https://www.sonede.com.tn/index.php?id=111). For tourism uses, the price of water supplied by SONEDE is 1,490 mil/m^3 in 2020.

This pricing system is based on two principles:

- Social solidarity: to guarantee households with modest conditions access to cheap drinking water. The rates for the first tariff bands are indeed lower than the real price of the water service (845 millimes/m^3 of water) and are compensated by those applied to the higher tariff bands.
- Making large water consumers responsible by encouraging them to rationalize their consumption and fight against wastefulness.

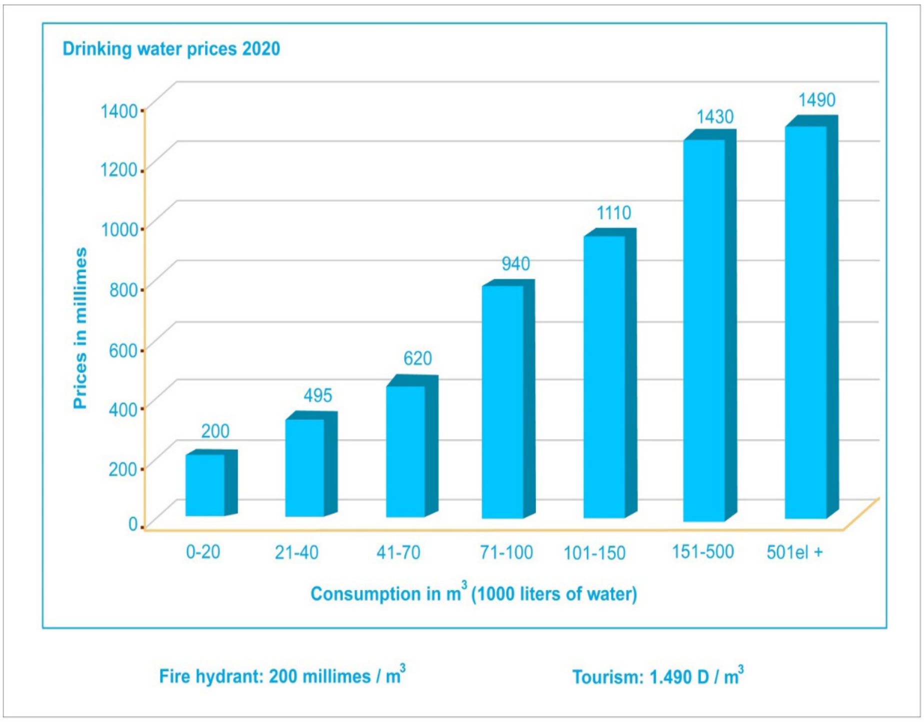

Figure 11. SONEDE tariff bands for 2020 (https://www.sonede.com.tn/index.php?id=111)

V.2.2. Towards an approach to reduce water consumption in the tourism sector

A study entitled "How to reduce water consumption in the tourism sector in Tunisia: Approach and strategy" sector was commissioned from the Land Tourist Agency and was entrusted to the consulting engineerRaoudha LAHACHE starting from 2002 to 2005 (LahacheGafrej, 2007). This study fitted into the framework of the country's policy aimed at saving water for large consumers. It follows the recommendations of the inter-ministerial council of June 21, 2001, to bring the specific consumption of drinking water per hotel bed into line with the specific consumption of water per hotel bed of the Mediterranean basin countries and reduce it to 300 L/day/bed.

The study was based on a technical and functional diagnosis of the water installations of 67 hotels located in the 8 main tourist areas representing 75% of the country's total reception capacity: Monastir (5 hotels), North Tunis (8 hotels), Tunis city and South Tunis (10 hotels), Hammamet (10 hotels), Sousse (10 hotels), Mahdia (7 hotels), Djerba (10 hotels) and Tozeur (7 hotels). The number of units to be diagnosed was chosen according to the capacity of the area and the importance of the water consumption of the different units of different categories.

Site visits to the hydraulic installations and networks as well as an identification of various components of the hydraulic circuit (wells, reservoirs, sprinkler system, fire system, wastewater, treatment plant, water sampling points, swimming pools, *etc.*) were performed. A detailed inventory of all water resources at the entrance to the system (SONEDE water, wells, boreholes, desalination units, *etc.*) was carried out specifying their different physio-chemical characteristics as well as the different uses made of it. For each hotel, a detailed and continuous monitoring of water consumption as well as the evaluation of the losses in the networks over three years was carried out. The average specific consumption of the 67 hotel units is 768 L/day/bed. This consumption seems to increase with the number of stars in the hotels (ranged from 542 L/day/bed to 900 L/day/bed for an unclassified hotel and a 5-star hotel respectively). The breakdown of specific consumption by use given in Fig.10 indicates that the water consumption for watering green spaces represented an average of 22% of the total water consumption. The amount of water loss through leaking pipes or by leaks at water points represented 17% of the quantity of the consumed water. Water consumption for swimming pools represented 13% of total consumption.

In addition to connection to the SONEDE network, 36% of the hotels have wells and/or boreholes. The volumes pumped are not always known and are therefore not accounted for by the General department for Water Resources (DGRE, 2000 in LahacheGafrej, 2007). Groundwater is mostly used for toilets or gardens. However, for some hotels equipped with desalination plants, groundwater consumption can exceed 60% of the hotels' water needs.

Following this diagnosis, various solutions were proposed to reduce specific water consumption. They were evaluated in the short term (from 2005 to 2010), med-term (from 2010 to 2015) and long term (from 2015 to 2030).

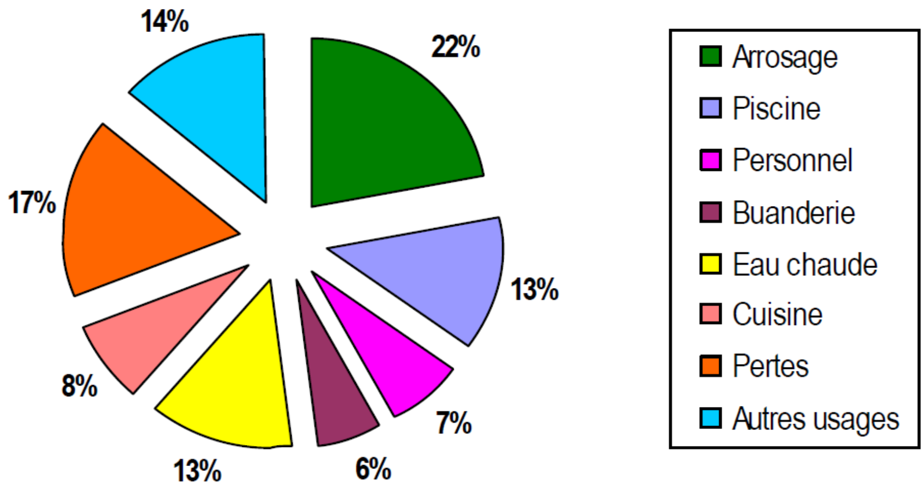

Figure 12. The breakdown of specific consumption by use, in 2003 (LahacheGafrej, 2007)

Short term measures

Short-term solutions, up to the 2010 deadline, can be summed up in the application by hoteliers of decree no. 2002-335 of February 14, 2002, which requires them, as major water consumers, to carry out an audit of their water system. These measures would bring this type of consumption (in 2010) to 346 L/day/bed allowing a short-term economy of 39%.

Mid-term measures

In the mid-term, continuing the audit operation required every five years, as well as the adoption of new technical measures (implementation of a Computerized Maintenance Management System (CMMS), subcontracting of vegetable washing, recovery, and recycling of grey water) and continuation of the awareness campaign, would make it possible to achieve the objectives of the study. In fact, over the period 2010 to 2015, water savings would represent 25.5%, which would bring this type of specific consumption to 201 L/day/bed.

Long-term measures

For the long term, LahacheGafrej (2007) proposed to increase the use of non-conventional resources as a mean of a better water management and environmental protection. The objective was not to further reduce specific consumption but optimize the use of good quality water, which is constantly decreasing. Among the non-conventional resources, LahacheGafrej (2007) identified the desalination of seawater and the reuse of treated wastewater. However, these two solutions must be examined at the national level and not at the level of the tourism sector.

Finally, the implementation of this strategy at the short and mid-term solutions through the simple application of decree no. 2002-335 of February 14, 2002, would help Tunisia to gain about 80 Mm^3 of water in 10 years, which is the capacity of Kesseb dam and would make it possible to extend the deadline for the use of non-conventional water.

V.2.3. Water and tourism: future trends: The effects of Climate change

In 2010, the Tunisian Ministry of Environment and Sustainable Development (MEDD) launched with the German Technical Cooperation (GTZ) a project entitled "Tourism and climate change in Tunisia: evaluation of the environmental and socioeconomic impacts of climate change on the main tourist activities in Tunisia".

The project concerned the development of a strategy for adaptation to climate change of the Tunisian tourism sector. It revolves around three phases (GTZ, 2010):

- Phase 1: evaluation of the environmental and socio-economic impacts of the climate change on the main tourist activities in Tunisia.
- Phase 2: proposal of an adaptation strategy to climate change for the tourism sector in Tunisia.
- Phase 3: development of an action plan and two priority projects.

The first phase of the project identified indirect and direct impacts of climate change on the tourism sector in Tunisia.

V.2.4.Direct climatic impacts

An example of a studythrough temperature or precipitation tested the change in theattractiveness of the destinations. At this level, a displacement of optimal conditions towards higher latitudes and altitudes was expected. Some destinations could even see their competitive position eroded, while others (the South of England for example) would benefit from it. However, it is not obvious to predict the possible redistribution of flows, due to an accumulation of uncertainties (level of the global warming, regional and local modalities, and climate requirements of the tourists). Overall, direct climatic factors have no more impact on the location of flows than on their overall volume.

V.2.5.Indirect impacts on resources via the environment

Tourism is highly dependent on local environmental resources. Consequently, a wide variety of environmental changes resulting from climate change could have significant effects on tourism: loss of biodiversity, decline in water resources, loss of aesthetic value of landscapes,changes in agricultural production, sea level rise, coastal erosion, disappearance of beaches, natural risks and health impacts are just some examples. Here again the impacts could be profound and lead to a redistribution of flows, without however changing the level of global demand at the international level.

VI. Conclusions

This bibliographical feedback highlights the impact of geographical framework, climate change and human activities to the Tunisian'sbio-capacity.

An analysis of over-tourism's impact on natural resources (water and coast) was established in relation to the expected climate change.

The historical records made by USAID have shown that there is a trend towards an increase in average maximum temperatures of about 1.5°C to 2.5°C by 2030 and 1.9°C to 3.8°C by 2050.Climate change threatens nearly 1,150 km of Tunisian coastal areas through sea level rise.

The vulnerability of coastal aquifers to salinity shows an excess of salinity at 20g/L by 2100 demonstrated by the APAL authority.

The economic development in Tunisia was accompanied by an evolution of water demand, and by an overexploitation of groundwater to satisfy drinking, irrigation, industry, and tourism industry. Agricultural activities using great amounts of fertilizers, manure and pesticides were shownin literature asthe main origin of water quality degradation.

The coastal aquifers in Tunisia are threatened by seawater intrusion such as theKorba aquifer located in CapBon in Tunisia.

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