The Sustainable Strategy of Desalination in Morocco Versus Water Export and Intergenerational Equity. Case Study: Virtual Water Balance of the Desalination Plant in Agadir

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DOI: https://dx.doi.org/10.47772/IJRISS.2024.8120317

Received: 15 December 2024; Accepted: 19 December 2024; Published: 21 January 2025

ABSTRACT

A transition in water resource management has been taking place in Morocco for some years. Whereas long before, the needs of all user sectors were met without difficulty. Certainly, without water no life is possible.

In this vision, water sovereignty always takes precedence within Moroccan strategies. In the context of structural water stress, actions are multiplying across conventional water boundaries to meet the demands of the sectors that use this vital commodity, moving towards the blue economy.

Desalination of seawater is a sustainable opportunity to be seized, despite the energy-intensive and costly process. Among other things, the phenomenon of exporting virtual water through agricultural goods watered from these desalinated marine waters, deserves a judicious reflection and patriotic decisions on the part of decision-makers, in a vision of equality between present and future generations.

Keywords: Desalination, Sustainable, Virtual water, energy-intensive, Equity.

INTRODUCTION

Can we imagine a life without water? Even a utopian person does not share this erotic dream, similar to an inert life. Nevertheless, many indicators point to the approach of the chaotic situation of water scarcity in Morocco, if current practices of exploitation of this vital commodity which is water continue without taking courageous, realistic, feasible initiatives, fair and sustainable by policy makers.

Since its independence, Morocco has prioritized irrigated agriculture as the main lever for its development and encouraged the export of agricultural production.

The launch of the dam policy and the development of irrigated areas were started with enthusiasm without limits at the level of the different regions of the country.

From 1965, the national development plans succeed one after another, establishing water-based agriculture as the main exporter of agricultural goods, Although the latter take up the largest share of conventional surface and groundwater resources, often exceeding 80% of the availability of this vital commodity which is water.

Since the 1990s, climate change has been accompanied by devastating floods and recurrent droughts as a result of irregular rainfall over time and space.

In this sense, the authors (Balaghi R. & al.,, 2015) advance in their study - Maps of Agriculture's Vulnerability to Climate Change in Morocco -, which most forecasts predict that over the coming decades "signs of aridity would be detected everywhere in Morocco because of the rise in temperatures and the remarkable drop in

rainfall".

Likewise, the ((IRES), Royal Institute of Strategic Studies, 2014) announces in a report that the impact of climate change coupled with increasing water use for domestic, tourism, industrial and agricultural purposes would result in a deficit in Morocco of about five billion m^3 by 2030.

In this worrying context, combined with a structural water stress at the level of the Moroccan territory, conventional water resources are constantly being depleted due to the fact that water supplies are falling steadily and consequently rainfall is lacking, to excessive exploitation of surface and groundwater by humans, and to the appalling duality between different sectors[1] using these rare waters. The present observation may obscure the current programs and endanger the gains of a long experience in the field of water by making fragile the heritage of the achievements of the great hydraulic that have required colossal budgets increasing the debt of the State which will be supported by the present and future generation.

In this sense, the author (Berkoff, J., , 1995) It notes that when countries engage in spending without taking the time to think, subsidies are given to achieve socio-economic and environmental goals, Unable to complete their tasks due to inadequate planning and decisions.

(FAO, 1993) Shows that the use of irrigation water in Morocco fulfils a crucial task in increasing productivity. However, the legal context and social customs governing the use of these resources can undermine water conservation arrangements if no consensus is reached between users and public authorities.

Although Morocco is in possession of a legal, regulatory and institutional arsenal, it is supposed to be able to implement a sustainable and equitable water policy, these are probably still insufficient to allow the water sector to achieve a real reconciliation between the different sectors using these water resources, limited in time and in arid space. Despite the almost aridity of land and the adverse consequences of climate change, Moroccan politicians are unwaveringly committed to agriculture, a high-value-added activity mainly destined for export. Is this paradox explained by the policy of dams, or by the existence of an invisible hand?

In their article entitled "Adapting agricultural technologies: what lessons can be learned from field experiments?", the authors (De Janvry A.S.E., & al.,, 2015) raise the danger of using high value-added varieties by adopting agricultural technologies, as well as the dissatisfaction of farmers through field trials. They reiterate "that in parallel with good performance, too much fertilizer is applied, which is harmful to the environment and human health."

Indeed water is mandatory to guarantee food sovereignty, as mentioned by the Indian writer (Vandana, S., 2002), recalling in her book - the water war, Deprivation, Pollution and Profit -, that "Water is a vital commodity for food production and survival, so the degradation of food and the spread of hunger are the direct consequences of drought and acute water scarcity."

No doubt, nobody disputes that realistic, bold and constructive answers to these questions - "How did water resource come to this stage?" , and - "Is this desalination of seawater an alternative project or a sustainable question towards intergenerational equity?" should be clearly formulated by Moroccan policy-makers, in order to avoid the effects of the vicious circle when adopting sustainable alternatives for non-conventional resources within the framework of the blue economy, In sewage treatment and desalination of seawater.

Certainly, the use of these unconventional waters is essential, not only to contribute by a provision[2] to the balance of water deficit, but, in principle, with a view to ensuring sovereignty of drinking water supply, and industrial use at the level of large coastal agglomerations. The ambition of decision-makers takes it to the next level by relying on irrigation of agricultural areas through this technology that is recognized as being energy-intensive,

[1] These are drinking water, agriculture, industry tourism and other

[2] Estimated by the 2009 National Water Plan (PNE) at one billion cubic meters by 2050

and costly when it is set up and operated. The dilemma is at its height when it becomes apparent that agricultural production is destined for export, with subsidized desalinated water being allocated to irrigation.
Undoubtedly, feeding these desalination plants with renewable energies can reduce the cost of energy bills, and will contribute to the reduction in the cost of the cubic meter desalted. However, the production of these renewable[3] energies is still too expensive and characterized by low efficiencies.
Renewable energies in Morocco recorded at the end of 2019, an installed power[4] of around 3701 MW or 34% of the total electrical power at the national level. For 2030, the Moroccan strategy aims to achieve more than 52% of electricity production from renewable energies. (ACHEMRAH, Y., 2022)

This alarming context of water stress has accelerated decision-making to build many seawater desalinations plants, despite the fact that they are energy intensive and expensive. The main aim is to safeguard the agricultural heritage of large-scale water supply and guarantee drinking water for a growing population.

The importance of our research entitled "The sustainable strategy for desalination of sea water in Morocco, in the face of water export and intergenerational equity. Case study: Balance of the virtual water of the desalination plant of Agadir», takes its originality on the one hand, from the difficulty to obtain information from the responsible for these desalination projects. On the other hand, studies addressing in depth the desalination of sea water in Morocco, in this case the virtual water of these stations, are lacking.

The challenge is to address the following issue: "Will the strategy of desalinated marine waters be sufficient to eradicate the consequences of water stress, and will it justify the equity of employment of these exported virtual resources?"

This reflection work will follow a mixed deductive, comparative and composite hypothetical methodology, who justified from the outset that the water issue in Morocco is in the present that in the past characterized by such complexity and that it is impossible to treat it today without having a clear vision of its repercussions in the future thinking about the future generation. Strategies deployed in Morocco in the field of water were often fluctuating in hasty response to cyclical events, policy makers often opt for the short-term path.

The outline of this article consists of three sections

Context of the Moroccan hydraulic policy» is the subject of the first section and will be devoted to conventional and non-conventional waters, including a summary of the history of water-related strategies in Morocco, from dam policy to seawater desalination; The research methodology adopted as mentioned above and will be detailed in the second section; "Virtual water case study and analysis and discussion of results" constitute the third section. Finally, a conclusion with recommendations to decision makers, and proposals for future research, close this paper and will be the starting point for further reflections.

Context of the hydraulic policy in Morocco

Conventional waters.

Since time immemorial, civilizations and developments have been built around the vital commodity that is water. As elsewhere, in Morocco, climate change coupled with excessive human intervention has directly influenced the sustainability of water resources potential by making them increasingly scarce quantitatively and degraded qualitatively.

In Morocco, irrigation of large areas was possible and feasible during the colonial period only through hydraulic installations, whose costs depend on the amount of energy produced, since the use of these waters for irrigation was placed second (Milleron, J.,, 1954)

[3] Energies: solar, wind, geothermal, biomass, hydrolic….

[4] Wind power: 1220 MW, Solar: 711 MW, and Hydraulic: 1770 MW

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue XII December 2024

Morocco is privileged by a versatile geographical situation between the plains, the mountains, the Sahara and two sea views. Its climate is both arid in the South and South-East and Mediterranean in the North.

Since the second half of the XXth century, pressure on water resources in Morocco has been increasing due to demand from the agriculture, tourism, industry and drinking water sectors. The water issue is acute, and the evolution of the water footprint in Morocco can be summarized in Table N°1.

Table N° 1: Evolution of the water footprint in Morocco (Allowance in m^3/inhabitant/year)

Years	**1955**	**1960**	**2001**	**2006**	**2020**	**2025**
Allowance m^3/inhab/year	2711	2500	1000	950	750	590

Sources: (El Alaoui, M.,, 2006) for the years 1955,1960, 2006 et 2025; the years 2001 et 2020 (The Royal Institute of Strategic Studies- (IRES, 2022)), What future of water in Morocco? - Synthesis report of the scientific day of March 17 2022. Accessed september 30, 2024 on https://www.ires.ma>files

Table prepared by the authors

In the face of this trend in demand for conventional resources, which are becoming increasingly scarce, Morocco has moved towards an overall water deficit despite its provision of more than 150 dams, whose levels are critical and display record low water percentages, due to lack of rainfall and rising temperatures causing significant evaporation. The dams[5] built during the protectorate are twelve (12) in number, regularizing a volume of 1974 million cubic meters, for an irrigated area of around 211900 hectares (Perennes JJ., 1993)

From the dawn of independence in 1956, the colonial system in the agricultural vocation, is continued with a slight adaptation to the Moroccan context. The National Irrigation Office was established in 1960 to promote the colonial heritage of water resources, carry out research studies on agricultural water resources and start the inventory of surface and underground resources, and to supervise the work of equipping the created perimeters.

The water department under the aegis of the Ministry of Public Works. Its departments were responsible for water engineering, water resource assessment, mobilization and development of water resources, as well as dam policy, whose main objectives are the protection of areas and populations against the dangers of floods, the production of clean electrical energy, the assurance of drinking water for the benefit of citizens, Water storage for difficult times during droughts, and irrigation of agricultural areas to ensure food sovereignty. The management of these agricultural irrigation waters within the boundaries of the large-scale hydraulic system is under the aegis of the Regional Offices for Agricultural Development (ORMVA), which are part of the Department of Agriculture.

The author (CHAOUNI M.,, 2023) mentions in chapter 10 of his book [6], With the financial support of the World Bank, Morocco launched the construction of five major dams in the early 1970s.

The regulation governing these waters had its origins in the Dahir of 1 August 1925 on the water regime, of the decree[7] of August 5, 1968 relating to the regulation of human water supply and animal watering, and the

[5] Sidi Saïd Maachou, Oued Melleh, Kasba Tadla, Ait Thelat, El Kansera, Lalla Takerkoust, Imfout, Daourat, Bine El Ouidane, Ait Ouarda, Machra Hammadi, et Taghdout. The first dam (Sidi Saïd Maachou) was built in 1929, the last dam (Taghdout) was built in 1956, the Bine El Ouidane dam was built in 1953, with a volume of 1500 million m^3 or 75% of the total capacity.

[6] An overview of the history of Moroccan hydraulics

[7] Royal Decree on the law n° 644-67 of 05 August 1968

agricultural investment code (CIA)[8] of 1969. It was not until 1995 that Morocco had the privilege of drafting its first water law 10/95, which was repealed and replaced by the water law 36/15 in 2016.

(Del Vecchion K, & Mayaux, PL.,, 2017) argue that the discourse of Moroccan decision-makers to save groundwater resources is only an oral formality to defend their thesis to continue in the way of supply strategies by continuing the construction of storage dams, Inter-basin water transfer pipelines, desalination stations and new irrigation areas. The digging of new water points continues despite the deficit situation of the groundwater.

In order to support the Green Morocco Plan launched in 2008 and support national development to restore water resources that are lacking, the 2009 National Water Plan (NWP) is based on six axes: 1) Actions on demand, to save about 2,5 billion m^3 of water, by converting gravity irrigation to drip irrigation and improving the efficiency of drinking water exploitation; 2) Actions on Supply, via the construction of dams, the transfer of water from surplus basins to deficit basins, and the use of non-conventional waters in this case treated wastewater as well as desalinated waters; 3) Protection of water resources through the limitation of excessive exploitation of the groundwater and its protection against pollution; 4) Reducing vulnerability to water risks by strengthening mechanisms for flood response and adaptation to the effects of drought; 5) Continuing regulatory and institutional reforms and activating the publication of implementing texts; 6) Modernization of information systems (CHAOUNI M.,, 2023), pages 249-250.

The dam policy has allowed more than 150 water storage structures to be built, however in recent years this policy has clearly dismantled its limits as a result of lack of rainfall and rising heat, causing recurrent droughts. Hence the need to search for other water resources.

Unconventional waters

The highlighting of the water problem in Morocco has allowed the description of the hydrological context of the country, which is characterized by a clear irregularity of availability of water resources at the temporal and spatial level, 51% of rainfall resources are only on 7% of the territory, in this case on the North of Morocco. This observation has prompted the decision-makers to start building large water storage structures, increasing the number of desalination stations and constructing pipelines to transport these resources to users.

97.5% of the total volume of water on the globe is salted, providing an alternative after desalination to secure sovereignty in water supply within countries that suffer from the adverse effects of water stress (Fritzmann, C., Lowenberg, J., Wintgens, T., & Melin, T.,, 2007)

The climate context in Morocco is characterized by structural water stress, marked by a critical rainfall deficit and record low levels of water storage at dams. The finding highlights for decision makers to declare a state of emergency and rethink alternative strategies using non-conventional water from wastewater treatment plants and seawater desalination plants. The success of such strategies must take into account the effects of climate change and the voluntary adherence of all stakeholders using these waters, ensuring that the sustainability of this water is a shared responsibility to achieve the requirements of sustainable development and healthy living.
In order to counteract the bitter consequences of water scarcity, the use of non-conventional water from desalination of seawater on a coastal potential of 3500 km is necessary (Hssaisoune, M., Bouchaou, L., Sifeddine, A., Bouimetarhan, I., & Chehbouni, A.,, 2020).

The desalination projects in Morocco are not new, but for the first time in Moroccan history -the use of desalination of water into drinking water- was mentioned in 1974 in the National Master Plan for the supply of drinking water. The first desalination plant was established in 1976 in Tarfaya, southern Morocco, to supply the population with drinking water due to the arid climate. Admittedly, the current context is not the same as before, many achievements have been started by the National Office of Electricity and Water (ONEE) and are

[8] Governed by the Dahir n° 1-69-25 of July 25, 1969, regulating relations between the State and farmers in developing and managing irrigation

summarised in table N°2, with a demineralized or desalinated water production capacity of approximately 300,000 m^3 per day has been made available to many localities and cities in Morocco (ONEE.,, 2020).

Table N°2: Achievements of the ONEE in desalination

Ville	Technologie	Nature d'eau	Capacité de production (m^3/j)	Année de mise en service
Tarfaya	ED	BW	75	1976 (replaced by the unit realized in 2001)
	RO	BW	800	2001
	MED – VCD: Vapor	SW	250	1977 (replaced by units realized in 1995 and 2005)
Boujdour	Compression Distillation			
	RO	SW	3,700	1995–2005–2011
Laâyoune	RO	SW	26,000	1995–2005–2010
Tan Tan	RO	BW	12,000	2003–2014
Akhfenir	RO	SW	860	2011
Tagounite	RO	BW	400	2008
Khenifra	RO	BW	30,000	2012
Dakhla	RO	BW	17,280	2015
Khouribga	RO	BW	30,000	2019

SW : Eau de mer BW : Eau saumâtre ou terrestre

Source: (El Ghzizel, S., Tahaikt, M., Dhiba, D., EL midaoui, A., & Taky, M.,, 2021), Collected in Table 3, p-13 of the paper «Bibliographical review and case study on desalination of sea water and its impact on the marine environment» November 2023.

Despite the advantage of mobilizing large quantities of desalinated water to compensate for the freshwater deficit, this desalination technology is energy-intensive and produces harmful effects on the environment.

Despite the production of fresh water, brine produced by desalination processes is a major environmental hazard (Sola, I., Sanchez-Lizaso,J.L., Munoz, P.T., Garcia-Bartolona, E., Saez, C.A., & Zazo, D.,, 2019).

Similarly, researchers (Cambridge, M.L.? Zavala-Perez, A., Cawthray, G.R., Mondon, J, & Kendrick, G.A,, 2022) mention that brine can affect the environmental balance due to the presence of considerable salinity and temperature in this release. Salinity could reach 70 g/liter, twice that of sea water, while the temperature of chemical compounds is depending on the technology used and the ambient temperature of the sea water, it could be 1.82 times, often above 22°.

The costs allocated to the disposal of brine range from 5% to 33% of the overall cost of the desalination operation, and depend on the volume of brine, the level of pretreatment and the nature of the environment of disposal ((INRH), National Fisheries Research Institute, 2023) in page 15

Most desalination plants in Morocco are still young, and the quantities produced at present are still modest, with no major concerns.

RESEARCH METHODOLOGY

From the position of exporter[9] in 1960, for a quantity of 80 000 tons of durum wheat, Morocco becomes importer of cereals in 2023, for a quantity of 2.3 million tonnes of soft wheat. In the same year, a quantity of almost 500 000 tons of tomatoes irrigated by the desalinated sea water from the Agadir station were exported to Europe. It is also pointed out that when the Green Morocco Plan 2008-2020 was put in place, the project's founders recommended to cut off 20% of the total area recommended for cereals and to allocate it to other crops recognized for their high added value, and their excessive water consumption. The thesis advanced by these

[9] Source: The Diplomatic World, June 1962, page 13

decision-makers is summarized in «the intensification practiced during plan will increase the yields of cereals and will cover this lack of income of these 20% of surface».

In order to find the elements of answers to the problem and the hypotheses mentioned below, we have been inspired by this last paradoxical situation, by proposing to establish a virtual water balance of these crops of imported common wheat and Agadir tomato exported by Morocco for the year 2023. In parallel two scenarios are proposed, the first is that of the existing situation of 2023, while in the second scenario it is assumed that the 20% cut off from the total area of cereals has not been achieved, and this, with a view to analyzing the expected results.

This article adopts a mixed deductive, comparative and composite hypothesized methodology in the case of the descripto-Analytics will highlight the reality and the challenges of the new strategy for desalination of sea water by using comparative methodology analyzing the Moroccan context in particular. This is designed to answer the main question that was “Will the desalinated marine water strategy be sufficient to eradicate the fallout of water stress, and will it justify employment equity for these exported virtual resources?” Thus, make the above-mentioned assumptions decipherable, which we consider interesting and the results deserve to be rethought by decision-makers.

To do this, we propose to pose two hypotheses to be verified during our study.

H1: Under the pretext of maintaining a medium-balanced trade balance, policy makers strongly encourage exports of agricultural products with high added value, even if they are hydrovorous like tomatoes from Chtouka Ait Baha -Agadir- which are irrigated from desalinated sea water, whose production process is energy-intensive and financially expensive. Their thesis is that this desalination is sustainable. However, “It is very likely that this desalination will harm the environment and the sustainability criterion of this process is fragile, and the balance between export and domestic use is in jeopardy”;

H2: The advances of decision-makers in Morocco in the preservation of groundwater resources is only a formality of justification to continue in strategies of supply by building new dams, Inter basin transfers and the construction of seawater desalination stations. The reality of the field proves the opposite, there is a fragile equity. Hence, “It is very likely that these farmers are using heavily the groundwater mixed with the water supplied by the desalination plant to get all these yields from this agricultural production.”

VIRTUAL WATER CASE STUDY AND ANALYSIS AND DISCUSSION OF RESULTS

Balance of virtual water of imported wheat and exported Agadir Tomato.

The liberation of the rotation and the withdrawal of the State from guaranteeing the outlets of agricultural production, Farmers' decisions have been profoundly altered by confronting them with the dilemma of water scarcity and the severity of the external market, which demands plentiful quality standards and offers unquestionable prices. This paradoxical context has led farmers to move towards high-value crops despite being water and energy intensive.

Weaknesses in institutional water management mechanisms have clearly shown the limits of environmental and social sustainability of conventional irrigated agriculture. When is it for the management of non-conventional waters, in this case desalinated seawater?

The souss-Massa-Draa region contributes 60% of citrus fruits and 80% of the fresh fruit to the basket of Moroccan exports. Alas, since the 2000s, the alarm bell has been sounded in Sebt El Guerdane in Taroudant north of Agadir, an area of more than 10 000 ha of citrus trees has been completely devastated by the total depletion of its water table, a dramatic drop was also observed in the groundwater of the Souss and Chtouka. Faced with this situation, decision-makers have opted for drip irrigation and desalinated sea water.

In 2023, the population of Agadir is estimated at 979248 inhabitants, the area moves in a grandiose socio-economic evolution in close relation with tourism. Groundwater reserves are showing a continuous annual

decline of about 5%, surface water from dams show low levels due to years of recurrent droughts. The alarming observation highlights decision-makers' recourse to non-conventional waters, namely desalination of sea water, as part of a public-private partnership, as a result of shared visions between the Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forestry (MAPMDREF) and the National Office of Electricity and Drinking Water (ONEE). This project is governed by a BTO or turnkey concession (construction-transfer-operation). The dealer assumes responsibility for construction, operation and maintenance. He must ensure the quantity of water produced that meets quality standards with a manageable cost of production. The purchase of contract water produced is carried out by the ONEE, which markets it. The risk lies in the fragility of technology transfer.

According to (FAO, 2024)[10], the climatic conditions still have a negative impact on agriculture in Morocco, overall cereal production in 2023 reached 5.6 million tons, of which 4,1 and 1,3 million tonnes respectively for wheat and barley.

Tomato exports increased by 62% in volume and 213% in value, from 2 billion Dhs in 2008 to nearly 6.5 billion Dhs in 2018. Other agricultural products achieved interesting results such as olive oil +528%, peppers +366% and green beans +167% (MAPMDREF, 2020).

The production of one kg of tomato requires 190 liters of virtual water, this figure gives us an idea of the considerable quantities used by the greenhouses of Chtouka Ait Baha, exporting in 2023 to about 500 000 tons of tomatoes to Europe. The water situation in Morocco since 2015 is critical with the marked decrease of rainfall especially in the Souss area. The Youssef Ibn Tachefine dam, whose waters are intended to irrigate 20000 ha in vegetable farming, has a water storage level of about 12%, declares itself unemployed.

Despite the succession of years of drought, Morocco continues to record significant quantities in export of virtual water through tomatoes with an average foreign sale price of around 18,90 Moroccan dirhams per kilogram.

According to the Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forestry, “The irrigated sector of Chtouka Ait Baha, specialized in the production of market gardening and vegetables, was at the door of the fault because of the overexploitation of the groundwater, recording a deficit of 90 million m^3 annually, which allowed the intrusion of seawater and the salinity of water into various wells and boreholes.” It is in this critical context of the impossibility to supply this area with surface water, that the Department of Agriculture has decided to build the plant for desalination of sea water named Douira, Located in the Chtouka Ait Baha area of the Agadir Wilaya. This desalination project consists of: two water inlets and two salt water supply lines to the treatment plant, each 1.1 km long; a seawater treatment plant; basic agricultural irrigation infrastructure; Numerous storage tanks for irrigation water and drinking water; Five stations for the discharge of treated water with a main pipe over a length of 18.4 km; and a distribution network of 480 km.

According to data collected during the summer of 2024, from the heads of the equipment department of the Regional Office for Agricultural Development of Souss Massa in Agadir, the productive potential of the start-up of Chtouka Ait Baha station reached 275 000 m^3 per day, or 100 million m^3 of desalinated sea water, shared between the supply of drinking water in Agadir and irrigation of agricultural areas in Chtouka Ait Baha with daily allowances in m^3 of 145 000 and 125 000 respectively. At the same time, the station’s capacity should gradually increase to reach its final output of 400,000 m^3 per day half of which will be used for irrigation, or 73 million cubic meters of desalinated water per year. The production of desalinated water is divided between the drinking water supply of the city of Agadir and the irrigation of an area of fruit and vegetables of approximately 12500 ha within the Chtouka area, almost all of this agricultural production is destined for export, with 85% of the first-fruits and 97% of the tomatoes at national level.

Chtouka Ait Baha desalination plant uses reverse[11] osmosis technology, and its electricity demand is estimated

[10] https://Lakome2.com/economie/338770/ . Accessed on August 17, 202

[11] Seawater is filtered using a semi-permeable membrane with holes of a few nanometers in diameter to stop salt and other impurities, before remineralizing the water at the end of the process. This process requires

at 68 Megawatts.

Likewise, these officials added that, "the budget allocated to this project is around 4.48 billion dirhams, the goal is to save an area of 15000 ha for the benefit of 1500 farmers, and supply the city of Agadir with drinking water". Although the cost of the cubic meter desalinated is about 5,40 Moroccan dirhams, it is far from the real cost which ranges between 9 and 15 Moroccan dirhams per m^3, depending on the process used.

Given these considerable efforts of the Moroccan state and these paradoxical situations, the idea has come to us to draw up a mini virtual water balance for the year 2023, taking the production of exported tomatoes, the irrigation is done in desalinated water from the Chtouka Ait Baha station as a vector of export and soft wheat imported by Morocco as a vector of import. Two scenarios are studied, the first of which relates to the current situation, consisting in a 20% reduction in the area of cereals. The second scenario assumes that the 20% reduction in cereals area did not take place. For this we will use the concept of virtual[12] water of a culture to contextualize these balance sheets by drawing up matrices, whose results will probably allow us to answer our problems and our hypotheses.

Scenario 1: current situation, 20% reduction in cereal area.

During 2023, Morocco imported 2,3 million tons of soft wheat from France, irrigated mainly by rainwater, with an average purchase price tending towards 2000 Moroccan dirhams per ton. (Virtual wheat water = 1350 Liter/kg).

Calculation of quantity of imported soft wheat

2300000 * 1000 * 1350 = 3105 million m^3

Cost of imported common wheat

2300000 * 2000 = 4600 million Dhs (Expenditure: budget of the Moroccan State)

In the same year, Morocco's export of tomatoes reached a quantity of 0,5 million tons produced in the Chtouka Ait Baha area and irrigation by water from the seawater desalination plant, the average selling price of this tomato abroad is 18900 dirhams per ton. (Virtual water tomato = 190 Liter/kg)

Calculation of quantity of exported tomato

500000 * 1000 * 190 = 95 million m^3

Calculation of the gross amount of tomato exported

500000 * 18900 = 9450 million dirhams

Scenario 2: assumes no 20% reduction in total cereal area

Taking into account an average yield of 1.7 tons/ha recorded nationally in 2023 and a surface area of around 1,2

between 2.5 and 3 kWh per m^3, which is more energy efficient than the distillation process that requires 30 kilowatt hours (kWh) to desalate one m^3.

[12] A virtual water or water footprint of a crop is a concept that has been implemented since the 1990s, its unit of measurement is the liter per kilogram, This is invisible water used for the extraction of a product through the manufacturing stages to packaging and export, some examples being: Sugar cane: 1500 L/kg; Rice: 3000 L/kg; Cotton: 8500 L/kg, Beef: 16000 L/kg; But: 900 L/kg; Wheat: 1350 L/kg; Apple: 700 L/kg; Orange: 500 L/kg; Potato: 250 L/kg; Tomato: 190 L/kg. (Source : //les.cahiers-developpement-durable.be/outils/eau-virtuelle-et-empreinte-aquatique/ and https://www.cieau.com/l-metier-de-leau/ressource-en-eau-eau-potable-eaux-usées/quels-sont-les-usages-domestiques-de-leau. Accessed on August 30,2024

million ha corresponding to 20% of the estimated unreduced cereal area, the corresponding production is therefore of the order of: 1200000 * 1,7 = 2,04 million tons of cereals.

This quantity will be deducted from the one that was imported from France in 2023, so the quantity that should be imported would only be 260000 tons = 2300000 – 2040000.

In 2023, Morocco would have had to import only 0,26 million tons of common wheat instead of 2,3 million tons from France, this soft wheat is irrigated by rainwater (free), with an average purchase price of 2000 Dhs per ton. (Virtual water wheat = 1350 L/kg)

Calculation of quantity of imported soft wheat virtual water:

260000 * 1000 * 1350 = 351 million m^3

Cost of imported common wheat:

260000 * 2000 = 520 million Dhs (Expenditure: budget of the Moroccan State)

In the same year 2023, Morocco's export of tomatoes reached a quantity of 0,5 million tons produced in the Chtouka Ait Baha area and irrigated by water from the desalination plant of sea water, the average price of selling this tomato abroad is 18900 dirhams per ton (Virtual water tomato = 190 L/kg)

Calculation of the quantity of water exported from the tomato:

500000 * 1000 * 190 = 95 million m3

Calculation of the amount of Gross exported tomato (Inputs: farmers private cash)

500000 * 18900 = 9450 million dirhams

Analysis and discussion of results

Strengthening efficiency, sustainability and equity should always be prioritized. In this sense, we try to analyse objectively the data and results obtained.

Regarding scenario 1, the current situation with 20% reduction of total cereal area, we start by analyzing the virtual water component.

The virtual quantity of imported wheat water = 3105 million m^3

The virtual quantity of water exported from the tomato = 95 million m^3

When analyzing the gross figures, it is noted that the balance sheet (3105 – 95 = 3010 m^3) is largely in favor of importing wheat, but one must raise the origin of each irrigation resource for these crops being compared. It should be noted that the wheat imported from France was almost irrigated by free water coming from the sky, this is rainwater. For the exported Moroccan tomato, it should be noted that the water resources allocated to this crop are desalinated from sea water which required colossal budgetary charges covering production and electrical energy consumed, increasing public debt, undermining intergenerational equity and directly impacting the environmental footprint.

So, the two crops do not have the same origin in irrigation water, therefore they do not have the same common denominator that will validate the comparison in virtual water, from where we proceed by financial analysis, and the coverage rate of import.

Expenditure on imported wheat = 4600 million dirhams

The amount of sale of exported tomato = 9450 million dirhams

Looking at the results obtained, it is noted that the income from tomato exports (9450 million Dhs) are far higher than the expenditure of soft wheat imports from France (4600 million Dhs). It seems at first sight beneficial and profitable when looking at the raw figures.

But, as an objective analyzer, we must look for net inputs by deducting costs, which will allow us to compare and calculate the rate of coverage of imports by exports of tomatoes. Following visits and recurring requests to the accounting services of professional exporters, an average amount of about ten (10) dirhams was established as the production cost[13] of each ton exported to Europe, from the Chtouka area of Ait Baha- Agadir- in Morocco

After deduction of charges. The net revenue from tomatoes will be 500000 * 8900 = 4450 million dirhams

In this case, which is close to reality, we are allowed to announce that the net amount of the export revenue from tomatoes (4450 million Dhs) will not cover the amount of the import expenses of common wheat (4600 million Dhs). On the other hand, the profit from the export of these tomatoes feeds the farmers' private coffers.

Scenario 2, which assumes that the cereals area is not reduced by 20%, follows the same path as in Scenario
By analyzing the results of the virtual water of wheat and tomato crops, it is noted that the volume of virtual water of soft wheat imported from France has decreased significantly from scenario 1 (3105 million m3) to scenario 2 (351 million m3), which allows us to assume that scenario 2 has won over scenario 1 in terms of virtual water saving. From this result, it can be argued that the non-reduction of 20% of the area could have been the cause of saving a good amount of virtual water, provided that both crops, common wheat and tomato had the same source of irrigation water, to allow for proper comparisons.

As regards the financial aspect, the monetary results of wheat and tomato crops show that the cost of soft wheat imported from France has decreased significantly from scenario 1 (4600 million Dhs) to scenario 2 (520 million Dhs), which allows us to say that scenario 2 has outperformed scenario 1 in terms of the economy's expenditure on wheat imports of around 4080 million. Regarding the comparison between the expenditure allocated to wheat imports (520 million Dhs) and the net income of tomato exports (4450 million Dhs), it is noted that it is largely in favor of tomatoes, without considering intergenerational equity and the sustainable issue.

From these results, it can be argued that the non-reduction of 20% of the area could have been the cause of a significant saving in the level of government expenditure on the import of common wheat, of almost 4080 million dirhams.

Following all these results, we can conclude that our two hypotheses are verified, this desalination of sea water is energy-intensive and the culture of exported tomato is hydrovorous, so the sustainability of this sector is far from being achieved, the calculated quantity to be allocated for tomatoes is 95 million m3, which is higher than the allocation allocated for tomatoes or 45 million m^3, from the Chtouka Ait Baha desalination plant. We ask ourselves the question of where does complementary water come from? In this situation of the limit state of surface resources, this supplement can only come from pumping into the groundwater. Finally, in response to our problem, it can be stated that the export of tomatoes irrigated by desalinated sea water is not justified, given the colossal expenses allocated to this technology of desalination, the costs of which are borne by the present and future generations, while the profit is shared only among 1500 farmers, hence intergenerational equity is in danger, and subsequently the export of these tomatoes is unjustified and unsustainable, the fact that it oscillates between unstable economic and political conditions of international trade, and remains at the mercy of the unstable attitudes of decision-makers in the countries on the other side.

[13] Bills grain, water, input and energy, transportation and other costs

CONCLUSION

The overview of the history of water in Morocco, from dam politics to sea water desalination, clearly shows the considerable efforts made by policy-makers. This strategy of desalination as an essential alternative in the context of water stress remains surrounded by danger limiting its sustainability, and the outcome to intergenerational equity, while many selfish practices remain encouraged, the extension of irrigated areas, the hasty decision-making and the export of agricultural products watered by these energy-intensive desalinated waters subsidized by the State budgets.

Following a case study[14] of the Chtouka Ait Baha station which was commissioned in 2022, Other impacts related to the cost and energy consumption of certain desalination processes and their indirect environmental effects from an ecological point of view are due mainly to their carbon footprint. This problem would not arise in Morocco, because it can use renewable energies, although they are still expensive.

Certainly, in order for this desalination to be sustainable, rigorous monitoring and follow-up of the environmental plan is necessary without respite.

The task involves us in proposing recommendations for rethinking by decision-makers:

Water sector officials have shown their inability to manage the water issue in the context of climate change, so it is time to make bold restructuring by looking at other new development models;

The supply of electrical energy to seawater desalination stations from renewable energies, such as wind or solar, will reduce the cost of producing m^3 of water, so the desalination solution is «green» could be a choice to reduce energy bills and serve the environment;

The integration of important co-benefits at the level of the desalination region in terms of development of industrial sectors, the creation of jobs and service enterprises, to take care of training for young people in the area of desalination under the heading of technology and skills transfer;

Establish for each irrigation sector a rigorous monitoring of the consumption of water for desalinated irrigation and the allocation would be based on growing crops and not on the overall area;

Carefully ensure optimal mobilization of water resources and educate farmers on the practice of water-efficient and climate-resistant crops;

All users of these desalinated waters must be made aware, by strengthening the extension by showing that pumping and desalination consume fossil energy, are expensive and emit greenhouse gases that can damage the environmental balance;

Review the billing scale of the cubic meter of irrigation water, by approximating the unit price of this water to the actual cost price, in addition it is necessary to adopt consumption tranches of this irrigation water at the same time as domestic drinking water sales and this to penalize wasters. (Waster, payer)
We insist on ensuring mutual trust between farmers and farm project managers, changing the mindset and putting it first for eventual sustainability and intergenerational equity.

Occasionally, we can suggest interesting and relevant future research topics:

“In what context do Moroccan policy makers continue to mobilize massive funds for agriculture in arid areas surrounded by barrages that are almost dry?”

[14] Synthesis prepared by Benhra Ali in the paper “Bibliographical review and case study on desalination of sea water and its impact on the marine environment, published by the National Institute for Fisheries Research (INRH) in November 2023. Available at https://www.inrh.ma>upload_PDF Accessed on August 29, 2024

"Role of extension to users for the success of sustainable desalination" is important and rich as research, especially when we learn that: According to a study by the non-partisan research institute (Afrobaromètre), only 9% of Moroccans consider water supply as an "absolute priority". This percentage seems low compared to other African countries such as Guinea, Benin, Cameroon and Niger, with respectively 49%, 47%, 40% and 39%. Furthermore, it can be noted that good governance of water must start from the user to the decision-maker and not from the decision-maker to the water user. (Saad Bouzrou, 2024)[15]

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