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REBOUND EFFECT OF IRRIGATION SUBSIDY PROGRAMS IN ALGERIA

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ABSTRACT

Irrigated agriculture in Algeria plays an essential role in the national economy and food security historically facing significant water scarcity challenges. This problem has intensified over time, with an average annual rainfall of 89 mm and a weighted rainfall index of 241.50 mm for agricultural land. Furthermore, with an average water endowment of 380 m^3 per person per year in 2021, Algeria is classified as a country with limited water resources. Moreover, Algeria has implemented irrigation subsidy programs to boost the agricultural irrigation sector since 2000. However, it is of crucial importance to assess the possible rebound effect of these subsidies, as they may result in an increase in overall water consumption despite efficiency increases made by enhanced irrigation techniques. The aim of this research is to investigate the impact of irrigation subsidies on water consumption in Algeria. Data from 2001 to 2020 on irrigation sector in Algeria show comparable trends to China, India, Morocco, Tunisia, Australia, the United States, and Spain, where water consumption quantities have mainly increased due to subsidy programs. As a result, the already-stressed water resources are strained even further. These findings highlight the critical importance of prudent and sustainable water resource management for the public policy in the context of irrigated agriculture in Algeria.

Keywords: *Irrigation, rebound effect, subsidy programs, Algeria.*

INTRODUCTION

The aim of this study is to assess the rebound effect at aggregate level in irrigated Algerian agriculture caused by irrigation subsidy programs. Algeria is facing an increasing scarcity of water resources, with an average rainfall of 89 mm per year (FAO, 2015) and a water endowment of less than 400 m^3 per person per year in 2021. Irrigated agriculture accounts for a significant share of the agricultural land, utilizing over 70% of the mobilized water resources. To address these challenges, Algeria has implemented agricultural development programs focused on the adoption of water-efficient irrigation techniques such as drip irrigation and sprinkler systems. However, it seems crucial to assess the effectiveness of these measures by drawing insights from international experiences. It is necessary to determine whether promoting more efficient irrigation techniques is a wise choice to enhance water conservation in Algeria, considering lessons learned from countries facing similar conditions. Strategic thinking is required to assess the continued implementation or potential revision of these techniques based on the country's specific needs.

MATERIAL AND METHODS

To address our research problem, we collected data on water consumption for different irrigated crops, irrigated areas utilizing both surface and groundwater sources, as well as areas equipped with water-saving technologies in Algeria. These data were obtained from the Algerian Ministry of Agriculture and Rural Development and the Ministry of Water Resources and the Environment. Furthermore, we conducted a literature review to enhance the work by incorporating existing research and studies conducted in other countries, providing insights into the effects of irrigation modernization. Our study also highlights the irrigation paradox in the Algerian context, emphasizing the challenges and contradictions faced by the country in managing water resources for agriculture.

Subsiding Irrigation Water Efficiency: A Brief Literature Review

Irrigation has always been recognized as the primary consumer of water in terms of evapotranspiration (ET) and a significant source of water wastage, making it a target for measures aimed at conserving this precious resource (Falkenmark and Molden, 2008). To address water scarcity, many governments subsidize and encourage the use of efficient irrigation technologies (EIT) as a means to reduce water consumption and reallocate resources to other users (Grafton et al., 2018; Scott et al., 2014). Investments in these technologies, widely used to achieve water savings, have become a key lever in many countries (Kendy et al., 2004; Batchelor et al., 2014; Molle & Tanouti, 2017; Frija et al., 2014; Ferchichi et al., 2018; Amichi et al., 2015; Grafton et al., 2018; Belaidi et al., 2022; Belaidi, 2013; Oulmane et al., 2020; Wheeler et al., 2018; Gordon et al., 2020; Berbel et al., 2019; Sampedro Sanchez, 2020).

These water-saving policies in agriculture, implemented in several basins worldwide, such as China, India, Morocco, Tunisia, Algeria, Australia, the United States, and Spain, have two main objectives: firstly, to save water for other uses or environmental purposes, and secondly, to increase agricultural income and water productivity by improving yields and promoting diversification towards higher value crops (Perry & Steduto, 2017). However, the results of these programs have not always met expectations and, in some cases, have even contradicted the objectives of preserving water resources (Perry & Steduto, 2017). Analyses conducted on cases such as India, China, Morocco, Australia, and Spain converge to a similar conclusion: while the modernization of irrigation systems has brought benefits in terms of agricultural production and crop diversification, the total water consumption has generally increased, thus creating increased pressure on available basin-scale resources. This phenomenon, known as the "irrigation efficiency paradox" (Grafton et al., 2018).

Some studies have indicated that the efficiency of drip irrigation can be lower than that of surface irrigation due to issues such as inadequate maintenance and poor irrigation practices (Wolf et al., 1995; Benouniche et al., 2014). Furthermore, instances of over-irrigation have been observed in several irrigation systems, attributed to the aim of increasing agricultural production and issues with the design and maintenance of the irrigation network (Benouniche et al., 2014). It is worth noting that enhancing irrigation efficiency does not always guarantee water savings, as it may require increased technical expertise from users (Wittling & Molle, 2017).

The adoption of Water-Saving Irrigation Techniques (WSITs) in the Gujarat and Maharashtra regions has led to a significant change in crop rotation (Namara et al., 2005). In the irrigated area of Zaouiet Jedidi, the adoption of drip irrigation by farmers was motivated not only by the desire to save water but also by other factors such as agricultural intensification and labor reduction, as highlighted by Ferchichi et al. (2018). In the Cànyoles watershed, research by Sese-Minguez et al. (2017) revealed that the adoption of drip irrigation was associated with intensified agricultural practices and a shift towards arboriculture. Similar observations have been made in other irrigation systems in Spain, as noted by studies conducted by González-Cebollada (2015), Sese-Minguez et al. (2017), and Berbel et al. (2014), which observed modifications in planting density and crop patterns. The adoption of WSIT offers farmers, particularly those reliant on well or borehole capacity for water supply, the opportunity to use reduced water quantities applied per hectare to expand irrigated areas.

However, it should be noted that transitioning to drip irrigation can sometimes result in an overall increase in water demand compared to the initial demand, as seen in the case of the Kairouan plain in Tunisia, where there has been an expansion of irrigated areas for the most profitable crops (Feuillette, 2001). This phenomenon has been widely observed in several countries, including Spain, Jordan, Tunisia, India, Pakistan, Israel, China, and the United States (Molle, 2017). The studies by Pfeiffer & Lin (2014), Ward & Pulido-Velazquez (2008), as well as Li & Zhao (2018), demonstrate that promoting more efficient irrigation technologies does not guarantee the conservation of groundwater resources.

In Morocco, the major irrigated plains and coastal aquifers are facing water deficits, indicating overexploitation of water resources (Molle & Tanouti, 2017). Irrigated agriculture, supported by ambitious agricultural policies, intensifies the use of groundwater, contributing to the overexploitation of 50% of the aquifers in Morocco (Kuper et al., 2016). Therefore, the question of whether EITs can reduce pressures on water resources remains relevant. There is controversy surrounding the water-saving attribute of EITs: are they truly effective in saving water? How is it that total irrigation water consumption increases despite the use of more efficient technologies? However, water management in agriculture involves multiple scales, ranging from individual fields and farms to irrigation perimeters, basins, nations.

Understanding and assessing the impact of EITs on water consumption, therefore, requires an integrated approach that takes into account these different scales and the complex interactions among environmental factors, agricultural practices, and water management policies.

Irrigation Subsidy Program in Algeria: An Overview

In Algeria, the subsidy program aims to support various sectors of the economy, including agriculture, to promote development and growth. This program involves allocating financial funds or providing incentives to individuals in order to facilitate their activities. Indeed, several agricultural development plans have been implemented, covering the periods from 2000 to 2019 and from 2020 to 2024. The National Agricultural Development Program (known as PNDA) stood out for its considerable ambition, with a funding of 40 billion DZD in the year 2000. Between 2001 and 2004, the allocated amount for this plan, which was later replaced by the National Agricultural and Rural Development Plan (known as PNDAR) in 2002, amounted to 525 billion dinars (Imache et al., 2011; Salhi & Bedrani, 2011).

In August 2008, the Agricultural Orientation Law[1] (Law No. 08-16) reaffirmed the Agricultural and Rural Renewal Policy by strengthening the strategic option of widespread and extensive use of water-saving systems . The budget specifically allocated to the rural development component for the period 2005-2010 was estimated at around 2.6 billion euros (Kherbache, 2021). According to Benaissa (2022), the support provided during the period 2000-2010 by sector (FNDIA, FNRDA), irrigation was the largest beneficiary with 37.65%, adding up to 242 billion DZD. The MADR presented the water-saving program in the hydro-agricultural sector (2010-2014), focusing on the development of water-saving systems covering an area of 900,000 hectares.

The program implemented between 2014 and 2019 aimed to irrigate 2.14 million hectares by the end of 2019. An investment of approximately 3 billion USD was planned to support this initiative. The total amount planned for the support of water-saving irrigation equipment acquisition alone was almost 948 million USD for an area (subsidized) to be equipped of 637,000 hectares. The 2000-2024 program aims to generalize Water-Saving Irrigation Techniques (WSIT) on a total of 150,000 hectares, with a planned conversion of 30,000 hectares per year over this period (MADR, 2020). Each newly irrigated hectare must be equipped with water-saving systems, including with the contribution of state support.

The current state support covers 50% of the cost of irrigation equipment for individual acquisition and 60% for collective acquisition (Decision no. 943 MADR, 2014). Supported equipment must now pass the crash test of the specialized laboratory of INSID to verify their real efficiency, in accordance with the efficiency rates announced by suppliers. In case of non-compliance, public subsidy will be refused to preserve public funds.

[1] Journal officiel Algérien no 46 du 10 Août 2008, p. 3.

RESULTS AND DISCUSSION

5.1. Evolution of irrigated areas from 2000 to 2018

In Algeria, the irrigated area encompasses two distinct categories characterized by both the size of the developments and the management approach: *Grands Perimeters of Irrigation* (GPI): These are large-scale irrigation projects with a contiguous area greater than 500 hectares. They are under the authority of the National Office of Irrigation (ONID) and primarily utilize surface water from reservoirs, supplemented by deep wells. The management and operation of these projects are carried out by the ONID. *Small and Medium Hydraulic* (PMH): This refers to small and medium-scale private irrigation, directly managed by individual farmers or, in some cases, by associations. The irrigated areas within this category vary in size and predominantly rely on shallow wells or small-scale pumping systems.

The PMH represents a significant portion of the irrigated land in Algeria. In fact, the irrigated area has experienced a substantial increase, growing from 310,000 hectares in 2000 to 1,259,420.95 hectares in 2018. As for the GPI, prior to 2005, their total area did not exceed 50,000 hectares. In 2000, the area was around 40,000 hectares, reaching a maximum of 47,585 hectares in 2004. However, during the period from 2005 to 2018, the irrigated area surpassed an average of 80,000 hectares. This data indicates that the PMH plays a significant role in the overall expansion of the irrigated area in Algeria, with notable growth observed over the years. Furthermore, the GPI also experienced an increase in irrigated land, particularly after 2005. The total irrigated area in Algeria has experienced a significant increase over the years, growing from 350,000 hectares in 2001 to 1,330,670 hectares in 2018 (as shown in Figure 1). Irrigated areas in GPI and PMH reached 1,424,262 hectares in 2020, with 95,259 hectares in large hydraulics and 1,329,003 hectares in small and medium hydraulics. As a result, this expansion highlights the growing importance of irrigation in the country's agricultural sector. These results generally show a rebound effect in irrigated perimeters and small and medium-scale hydraulics, since there has been and will continue to be potential for increasing irrigated areas.

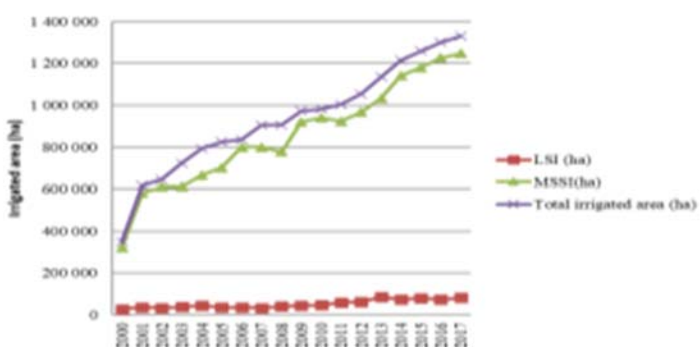


Figure 1. Evolution of irrigated areas in Algeria from 2000 to 2018

5.2. The irrigated areas by irrigation method

In Algeria, various agricultural development plans have been launched with a focus on the widespread adoption of Water-Saving Irrigation Techniques (WSITs). These plans include the conversion of existing gravity irrigation systems to localized and sprinkler systems. Financial support for irrigation development and water conservation promotion ranges from 40% to 60%, depending on the usage and regions. A significant evolution of WSITs has been observed in Algeria between 2000 and 2020.

Between 2001 and 2018, water-saving systems have undergone a considerable evolution thanks to the implemented support programs. There has been a significant increase in the irrigated area using drip irrigation technique, from 5,000 hectares in 2001 to 312,788 hectares in 2018. Similarly, the irrigated area using sprinkler irrigation method increased from 70,000 hectares to 444,706 hectares during the same period. As for the gravity irrigation method, the irrigated area expanded from 275,000 hectares in 2001 to 573,175 hectares in 2018 (Figure 1). The distribution of irrigated areas by technique shows that gravity irrigation covers 43.07% of the total area, sprinkler irrigation occupies 33.42%, and localized irrigation (drip irrigation) represents 23.51% in 2018. Approximately 62% of the total irrigated area is covered by water-saving systems, according to MADR (2020) report.

Since the implementation of irrigation support plans, there has been a trend towards stabilization of the irrigated area using the gravity method. These figures demonstrate the notable progress in the adoption of Water-Saving Irrigation Techniques (WSITs) in the country, showcasing a commitment towards more efficient water use in the agricultural sector.

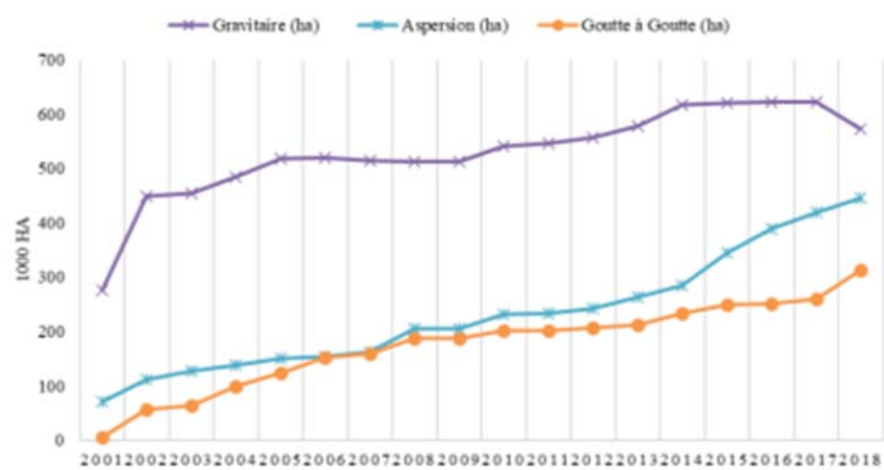


Figure 2. Irrigated areas by irrigation method from 2001-2018 (MADR, 2019)

Concerning the evolution of irrigated areas by irrigation method for large-scale irrigation (GPI) and small and medium-scale irrigation (PMH), Figure 2 indicates that traditional irrigation remains the most widely practiced method in the public perimeters managed by ONID, accounting for 42% of the total irrigated area for the 2020 irrigation season. However, this method has been declining since 2017. Sprinkler irrigation, on the other hand, represents 39% of the total irrigated area for the same irrigation season, showing an increase compared to 2017. Finally, drip irrigation covers 19% of the total irrigated area for the 20012020 irrigation campaign.

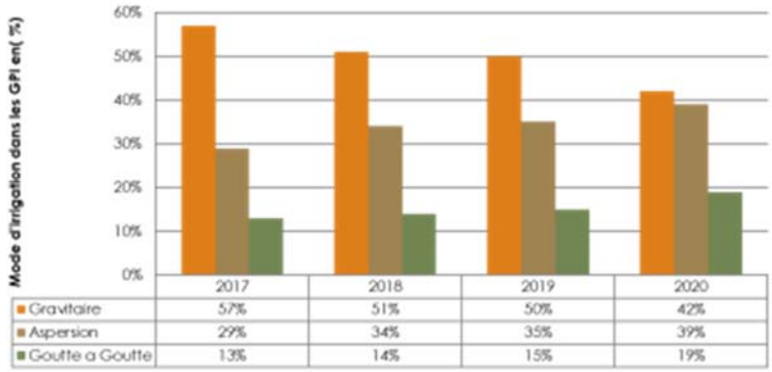


Figure 2. Irrigated areas in GPI by irrigation method in percentages 2017-2020 (ONID, 2021)

Figure 3 indicates that the irrigated areas have increased in recent years, and the installation of water-saving irrigation systems has followed the same trend. In 2003, out of 612,289 hectares irrigated, localized irrigation accounted for only 11.6%. However, by 2006, it had increased to 21.5%, and in 2011, it represented 20.5% with 189,686 hectares irrigated through drip irrigation. This indicates a conversion of existing gravity systems to localized irrigation, while sprinkler irrigation fluctuates between 18% and 19% of the total overall.

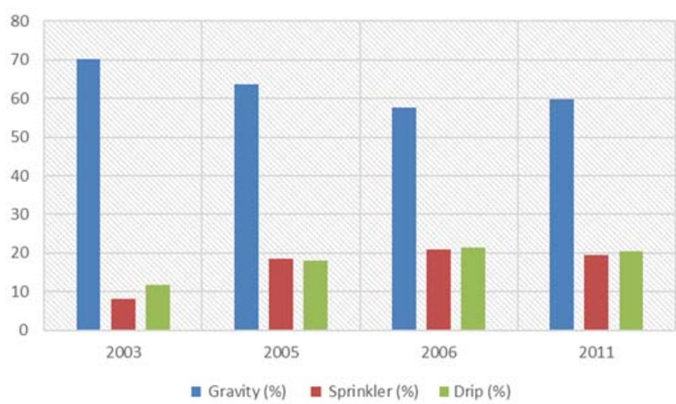
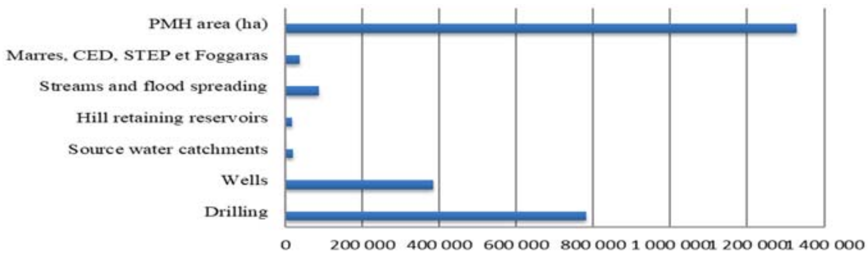


Figure 3. Evolution of PMH irrigated areas by irrigation method

On the PMH areas by origin of water used, the data (shown in Figure 3) indeed confirms a significant development of thousands of wells and boreholes, whose exploitation often causes irreversible harm to groundwater aquifers. Despite the scarcity of water resources, the dynamism of this sector seems to be linked to the autonomy it provides (i.e. owning individual wells and boreholes) to farmers in managing water resources. The source of water used for PMH varies from one region to another based on climatic conditions and water availability. At the national level, PMH continues to rely on groundwater for 90% of its water needs (with a proportion of 100% in the southern regions). This could pose long-term risks to groundwater aquifers and fossil aquifers, especially considering the increasing number of wells being drilled.



	Drilling	Wells	Source water catchments	Hill retaining reservoirs	Streams and flood spreading	Marres, CED, STEP et Foggaras	PMH area (ha)
Percentage(%)	58,92	28,89	1,49	1,36	6,53	2,82	100
Area (ha)	782 986	383 895	19 778	18 023	86 778	37 543	1 329 003

Figure 4: Irrigation of Small-Scale Irrigation (PMH) areas by different sources of irrigation in 2020.

Algeria heavily relies on its groundwater resources. Indeed, alarming overexploitation has been observed in more than half of the Algerian aquifers (Kuper et al., 2016). The number of agricultural wells and boreholes has seen a significant increase, rising from 120,000 in 2000 to 238,340 in 2016. According to the 2019 National Water Plan (PNE), the PMH utilizes a total of 79,508 drilling and 15,5719 wells (as shown in Figure 5).

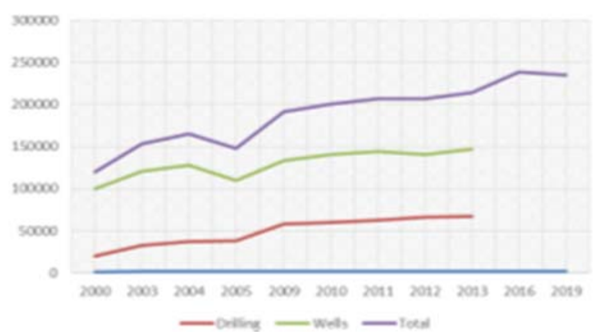


Figure 5: Evolution of number of boreholes and wells from 2000 to 2019

These data globally indicate the rebound effect on water withdrawals, with irrigators who received subsidies and authorizations[2] for irrigation infrastructure significantly increasing their water usage. However, the specific hydrological impact of this rebound effect on water withdrawals at the watershed scale remains unknown.Several territories in Algeria are facing water imbalance issues. The situation of the Macta aquifer is a notable example (Kherbache, 2021), as well as the Chéliff basin (El Meddahi et al., 2014; Amichi, 2013), the plateau of Mostaganem (AGIRE, 2016; Haouichine, 2012; SOGREAH, 2009), the Mitidja region (Imache et al., 2011), and the Biskra region (Amichi et al., 2018; Daoudi et al., 2017).

Table 1 displays the planting densities and number of trees per hectare in Algeria. It is evident that the planting densities under drip irrigation are higher compared to those under gravity irrigation. Consequently, densification and intensification could partially explain these increases in overall water consumption.

Table 1: Planting Density and Number of Trees per Hectare by Irrigation Method in Algeria

Crops	Gravity		Drip irrigation	
	Density	No. of trees per hectare	Density	No. of trees per hectare
Clementine/ Mandarin Orange, lemon	6 x 4	417	4 x 2	1250
	5 x 5	400	6 x 2	833
	6 x 5	333	4 x 4	625
	6 x 6	278	6 x 3	555
	4 x 7	357	4 x 2,5	1000
	6 x 3	555	4 x 4	625
Arboriculture: Apple, Pear, Peach, Apricot	4 x 7	357	4x2	1250
	6 x 6	278	4x2.5	1000
	5 x 7	286	4x3	833
	4 x 6	417	5 x 1.5	1333
	5 x 5	400	4 x 4	625
	5 x 4	500	4 x 3.5	714

Turning now to the evolution of total water consumption in the irrigation sector in Algeria. The government has promoted the use of new technologies and water-saving technologies for agricultural purposes, aiming to improve water efficiency in the sector. In 2018, approximately 70% of the mobilized water potential, which amounted to 8 billion m3, was allocated to agriculture, compared to less than 40% in 2000, which amounted to 1.8 billion m^3 (Pnud, 2020). However, the introduction of water-saving equipment at the plot level has not resulted in overall water savings at the national level. On the contrary, the total water consumption by the irrigated sector has increased (as shown in Figure 6).

[2] According to the Agence Nationale des Ressources Hydrauliques (ANRH), more than 20,000 permits for drilling and wells have been allocated to farmers for the year 2021.

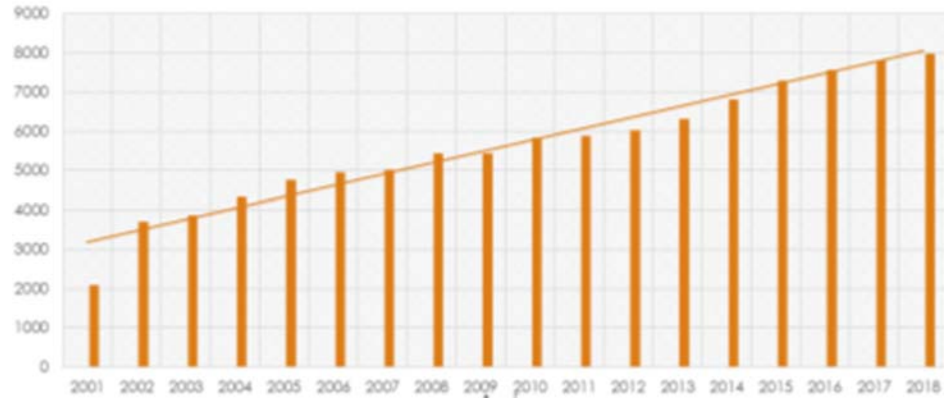


Figure 6. Evolution of irrigation water consumption for the period 2001-2018 (MADR ,2019)

The overall water consumption by irrigated areas, across all irrigation techniques, has risen from 2.10 billion m^3 in 2000/2001 to over 7.98 billion m^3 in 2017/2018. Nevertheless, at the farm level, the adoption of water-saving technologies has led to increased profitability due to significant additional benefits. The saved water has been utilized to intensify the cropping system. However, it is worth noting that the major objective of reducing overall water consumption has not been achieved. Instead, the focus has been on reducing water consumption per hectare in order to expand the cultivated area.

CONCLUSIONS

The aims is to demonstrate that despite irrigation subsidy programs, the overall water consumption in Algeria continues to increase in the irrigated sector (rebound effect), as well as the extensive reliance on groundwater, leading to the worsening overexploitation of aquifers. The Algerian government promotes the adoption of more efficient irrigation technologies to achieve water savings, but this claim is questioned in the literature. Using efficient techniques should, therefore, make it possible to achieve similar agricultural yields to those initially obtained using a smaller volume of water. However, a more efficient irrigation system may paradoxically encourage farmers to increase their water usage. This phenomenon is known as the rebound effect. The purported water savings are based on measurements in experimental stations and do not reflect actual efficiency on farms. In many cases, actual efficiency may be similar to gravity irrigation due to equipment issues and inadequate irrigation practices. Farmers can adjust their behavior by opting for more profitable and water-intensive crops or by irrigating previously non-irrigated land. This can offset the efficiency gains achieved by irrigation technologies.

Even when water savings are achieved at the plot level, it is common to observe an increase in water demand at other scales, such as the farm, regional, or basin level. The adoption of efficient irrigation technologies often encourages farmers to expand irrigated areas or cultivate water-intensive crops. The lack of contracts and monitoring between the government and farmers for the adoption of efficient irrigation technologies, as well as limited subsidies for equipment installations, affects the expansion of irrigated areas. By prioritizing increased production over water savings, the government neglects the consequences on groundwater resources, which are an essential source of irrigation in Algeria. Water-saving policies need to be reassessed, taking into account farmers' behavior, crop choices, and the expansion of irrigated areas. This requires a comprehensive and integrated approach to effectively assess water consumption in agriculture.

REFERENCES

AGIRE (2016). Actualisation des Inventaires des ouvrages et infrastructures de prélèvement d’eau du D.P.H à usage agricole. Mission II : Enquête de terrain de la Wilaya de Mostaganem, Version finale. Algérie.

Amichi F., Bouarfa S., Kuper M., Caron P. (2018). From oasis archipelago to pioneering Eldorado in Algeria’s Sahara. Irrigation and Drainage n/a, 9.

Amichi H. (2013). Quand tenanciers et attributaires s’arrangent pour exploiter les terres publiques irriguées : du déni à l’émergence d’une configuration de tenure inversée. Cas de la commune d’Ouarizane dans le Bas-Chéliff, Algérie. Thèse de doctorat. AgroParisTech.

Amichi H., Mayaux P. L., Bouarfa S. (2015). Encourager la subversion: recomposition de l’État et décollectivisation des terres publiques dans le Bas-Chéliff, Algérie. Politique Africaine, (1), 71-93.

Batchelor C., Reddy V.R., Linstead C., Dhar M., Roy S., May R. (2014). Do water-saving technologies improve environmental flows? Journal of Hydrology, 518(PA), 140-149.

Belaidi S. (2013). Les déterminants de choix de l'irrigation localisée par les exploitants de la Mitidja. Les Cahiers du CREAD, 103, 157-184.

Belaidi S., Chehat F., Benmehaia M.A. (2022). The adoption of water-saving irrigation technologies in the Mitidja plain, Algeria: An econometric analysis. New Medit, 21(1), 53-73.

Benaissa R. (2022). Politiques agricoles nationales : analyse contextuelle. Colloque National Politiques Agricoles, Développement et Sécurité Alimentaire : Enjeux et Perspectives 28-29 nov. Université de Bejaia, Algérie.

Benouniche M., Kuper M., Hammani A. (2014). Mener le goutte à goutte à l'économie d'eau: ambition réaliste ou poursuite d'une chimère? Alternatives Rurales (2).

Berbel J., Expósito A., Gutiérrez-Martín C., Mateos L. (2019). Effects of the Irrigation Modernization in Spain 2002–2015. Water Resources Management, 33(5), 1835-1849.

Berbel J., Gutiérrez-Martín C., Rodríguez-Díaz J.A., Camacho E., Montesinos P. (2014). Literature review on rebound effect of water saving measures and analysis of a Spanish case study. Water Resources Management, 29: 663-678.

Berbel J., Mateos L. (2014). Does investment in irrigation technology necessarily generate rebound effects? A simulation analysis based on an agro-economic model. Agricultural Systems 128, 25–34

Daoudi A., Lejars C., Benouniche N. (2017). La gouvernance de l'eau souterraine dans le Sahara algérien : enjeux, cadre légal et pratiques locales. Cahiers Agricultures 26, 35004.

Elmeddahi Y., Issaadi A., Mahmoudi H., Abbes T.M. Goossen M.F.A. (2014): Effect of climate change on water resources of the Algerian Middle Cheliff basin. Desalination and Water Treatment, 52(9-12): 2073-2081.

Falkenmark M., Molden D. (2008). Wake up to realities of river basin closure. International Journal of Water Resources Development 24, 201–215.

FAO (2015). AQUASTAT Profil de Pays – Algérie. Organisation des Nations Unies pour l'Alimentation et l'Agriculture. Rome, Italie.

Ferchichi I., Zaïri A.A., Marlet S., Ajmi T. (2018). Gestion de la pénurie d'eau dans les périmètres de sauvegarde des agrumes au Cap Bon: une analyse croisée des politiques publiques et des pratiques locales d'irrigation. Alternatives Rurales (6).

Feuillette S. (2001). Vers une gestion de la demande en eau en accès libre: Exploration des interactions entre ressource et usages par les systèmes Multi-Agent : Application à la nappe de Kairouan, Tunisie Centrale. Thèse de Doctorat, Université de Montpellier II, France.

Frija A., Chebil A., Speelman S., Faysse N. (2014). A critical assessment of groundwater governance in Tunisia. Water Policy, 16(2), 358-373.

González-Cebollada C. (2015). Water and energy consumption after the modernization of irrigation in Spain. WIT Transactions on The Built Environment, 168: 457-465.

Grafton R.Q., Wheeler S.A. (2018). Economics of water recovery in the Murray-Darling basin, Australia. Annual Review of Resource Economics, 10(1), 487–510.

Grafton R.Q., Williams J., Perry C.J., Molle F., Ringler C., Steduto P., Udall B., Wheeler S.A., Wang Y., Garrick D., Allen R.G. (2018). The paradox of irrigation efficiency. Science, 361(6404), 748-750

Haouichine A. (2012). Assessment of risk and uncertainty related to coastal aquifer management in Algeria. Management of Coastal Aquifers and Groundwater. MedPartenership. National report, Algeria.

Imache A., Hertani T., Bouarfa S., Kuper M. (2011). La Mitidja, vingt ans après: Réalités agricoles aux portes d'Alger. Editions Quae.

Kendy E., Zhang Y., Liu C., Wang J., Steenhuis, T. (2004). Groundwater recharge from irrigated cropland in the North China Plain: case study of Luancheng County, Hebei Province, 1949–2000. Hydrological Processes, 18(12), 2289-2302

Kherbache N., Molle F. (2021). La surexploitation des ressources en eau : le cas du bassin de la Macta en Algérie. G-EAU Working Paper/Rapport de Recherche No. 11.

Kuper M., Faysse N., Hammani A., Hartani T., Hamamouche M.F. & Ameur F. (2016). Liberation or anarchy? The janus nature of groundwater use on North Africa's new irrigation frontiers. In: Integrated Groundwater Management, Springer. 583-615.

Li H. & Zhao J. (2018). Rebound effects of new irrigation technologies: The role of water rights. American Journal of Agricultural Economics, 100(3): 786-808.

MADR (2014). Décision no 943 fixant les conditions d'éligibilité au soutien sur le compte d'affectation spéciales no 302-139 intitulé « fonds national de développement agricole », ligne 1 « développement de l'investissement agricole », ainsi que les modalités de paiement des subventions au titre de développement de l'irrigation agricole et de la promotion de l'économie de l'eau. 40.

MADR (2019). Final report on expansion of irrigated areas in Algeria. Ministère de l'Agriculture et de Développement Rural, Algérie.

MADR (2020). Feuille de route : Actions projetées 2020-2024. Document du Ministère de l'Agriculture et de Développement Rural, Algérie

MADR (2020b). Mise en œuvre du plan d'action du gouvernement 2020-2024. Feuille de route actions projetées 2020-2024. pp.37

Molle F. (2017). Conflicting policies: Agricultural intensification vs. water conservation in Morocco. G-Eau Working Paper.

Molle F., Tanouti O. (2017). La micro-irrigation et les ressources en eau au Maroc: un coûteux malentendu. Alternatives Rurales, 5, 22-39.

Molle F., Tanouti O. (2017). Squaring the circle: Agricultural intensification vs. water conservation in Morocco. Agricultural Water Management, 192, 170-179.

Namara R., Upadhyay B., Nagar R.K. (2005). Adoption and impacts of microirrigation technologies: Empirical results from selected localities of Maharashtra and Gujarat States of India, Vol. 93. IWMI.

ONID (2021). Campagne d'irrigation 2020: bilan et plan d'action 2021. Direction de l'Exploitation et de la Maintenance des Périmètres d'Irrigation (D.E.M.P.I). Rapport final. Algérie.

Oulmane, A., Chebil, A., Frija, A., & Benmehaia, M. A. (2020). Water-Saving Technologies and Total Factor Productivity Growth in Small Horticultural Farms in Algeria. Agricultural Research, 9(4), 585-591.

Perry C., Steduto P. (2017). Does improved irrigation technology save water? A review of the evidence. http://www.fao.org/documents/card/fr/c/I7090EN/

Pfeiffer L., Lin C.Y.C. (2014). Does efficient irrigation technology lead to reduced groundwater extraction? Empirical evidence. Journal of Environmental Economics and Management, 67(2), 189-208

PNE, 2019. Actualisation du Plan National de l'Eau et des PDARE : Identification des zones d'extension de la PMH (Horizon 2020). AGIRE, DEAH et Enabel, Coopération Technique Belge.

PNUD. (2020). Algérie : Rapport National Volontaire – Progression de la mise en œuvre des ODD. Programme des Nations Unies pour le Développement. Algérie, 176p.

Salhi S., Bedrani, S. (2011). Reconversion au goutte-à-goutte : les limites du PNDA. In: La Mitidja Vingt Ans Après: Réalités Agricoles Aux Portes d'Alger. pp. 220-226.

Sampedro Sánchez D. (2020). Efectos sociales y territoriales en la Cuenca del Guadalquivir. Universidad de Sevilla.

Scott C.A., Vicuña S., Blanco-Gutiérrez I., Meza F., Varela-Ortega C. (2014). Irrigation efficiency and water-policy implications for river basin resilience. Hydrology and Earth System Sciences 18, 1339-1348

Sese-Minguez S., Boesveld H., Asins-Velis S., van der Kooij S. & Maroulis J. (2017). Transformations accompanying a shift from surface to drip irrigation in the Cànyoles Watershed, Valencia, Spain. Water Alternatives, 10: 81-99.

SOGREAH (2009). Etude d'inventaire et de développement de la PMH. Partie 1 : Rapport définitif RA3 Wilaya de Mostaganem, No. 2 34 0074.

Ward F.A., Pulido-Velazquez M. (2008). Water conservation in irrigation can increase water use. Proceedings of the National Academy of Sciences, 105(47): 1821518220.

Wheeler S.A., Carmody E., Grafton R.Q., Kingsford R.T., Zuo A. (2020). The rebound effect on water extraction from subsidising irrigation infrastructure in Australia. *Resources, Conservation and Recycling*, 159, 104755.

Wittling C.S., Molle B. (2017). Evaluation des économies d'eau à la parcelle réalisables par la modernisation des systèmes d'irrigation. Etude réalisée avec le soutien du Ministère de l'Agriculture et de l'Alimentation. UMR G-EAU Montpellier. 149p

Wolf G., Gleason J.E. & Hagan R.E. (1995). Conversion to drip irrigation: Water savings, fact or fallacy—lessons from the Jordan Valley. In: Proceedings of the 1995 water management seminar, irrigation conservation opportunities and limitations. US Committee on Irrigation and Drainage, Sacramento, CA, 5-7 October. pp 209–217.