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Water Sustainability and Policy in the Moroccan Context: Challenges, Solutions, and Future Perspectives

Durabilité et politique de l'eau dans le contexte marocain : défis, solutions et perspectives futures

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Abstract

This article addresses the theoretical challenges related to water sustainability in Morocco, adopting an approach based on the paradigms of Integrated Water Resources Management (IWRM). It highlights several paradoxes and structural limitations within the water management system, offering theoretical recommendations based on the literature that are tailored to the country's climatic, social, and institutional contexts. One key theoretical conclusion concerns the excessive appropriation of water resources by agriculture, which accounts for up to 95% of withdrawals in some regions, despite contributing modestly to the national economy (around 13% of GDP). This dependency exposes the country to increased vulnerability due to the declining water resources, revealing a structural imbalance in water management. The article also highlights a paradox in the Green Morocco Plan. The adoption of more efficient irrigation technologies, such as drip irrigation, which is 100% subsidized, has paradoxically led to an increase in total water consumption. This phenomenon, known as the Jevons paradox, arises from the combination of increased agricultural productivity and intensified water use, particularly for export-oriented crops. The theoretical analysis further reveals that, despite the modernization of the legal framework (Law 36-15) and the adoption of IWRM, the inefficacy of reforms is linked to institutional fragmentation, poor coordination among stakeholders, and inadequate regulatory enforcement. These institutional deficits hinder sustainable water management and contribute to issues such as overexploitation of groundwater. Finally, a significant social and economic dimension emerges from the analysis, as public policies appear to favor large commercial farms over small farmers and local communities, exacerbating social inequalities. The article concludes that to ensure water sustainability in Morocco, it is essential to rethink agricultural economic incentives, improve intersectoral governance, and ensure greater social equity in water access.

Keywords: Sustainable Water Management, Water policy, Climate change, Water Challenges, Water Scarcity in Morocco
Classification JEL: Q5
Paper type: Theoretical Research

Résumé

Cet article aborde les défis théoriques liés à la durabilité de l'eau au Maroc en adoptant une approche basée sur les paradigmes de la gestion intégrée des ressources en eau (GIRE). Il met en évidence plusieurs paradoxes et limitations structurelles du système de gestion de l'eau, tout en proposant des recommandations théoriques fondées sur la littérature, adaptées aux contextes climatique, social et institutionnel du pays. Une première conclusion théorique porte sur l'appropriation excessive des ressources en eau par l'agriculture, qui représente jusqu'à 95% des prélèvements dans certaines régions, malgré une contribution modeste à l'économie nationale (environ 13% du PIB). Cette dépendance expose le pays à une vulnérabilité accrue face à la diminution des ressources en eau, soulignant un déséquilibre structurel dans la gestion de cette ressource vitale. En analysant le Plan Maroc Vert, l'article met en évidence un paradoxe lié à l'adoption de technologies d'irrigation plus efficaces, comme l'irrigation goutte-à-goutte, qui, bien que subventionnée à 100%, a paradoxalement conduit à une augmentation de la consommation d'eau. Ce phénomène, connu sous le nom de paradoxe de Jevons, découle de la combinaison d'une productivité agricole accrue avec une utilisation d'eau toujours plus intense, notamment pour les cultures orientées vers l'exportation. L'analyse théorique révèle également que malgré la modernisation du cadre législatif (loi 36-15) et l'adoption de la GIRE, l'inefficacité des réformes est liée à une fragmentation institutionnelle, une coordination insuffisante des acteurs et une réglementation souvent peu appliquée. Ces déficits institutionnels empêchent une gestion durable de l'eau, contribuant à des problèmes comme l'exploitation excessive des nappes phréatiques. Enfin, une dimension sociale et économique importante émerge de l'analyse, car les politiques publiques semblent favoriser les grandes exploitations commerciales au détriment des petits agriculteurs et des communautés locales, exacerbant ainsi les inégalités sociales. L'article conclut que pour garantir la durabilité de l'eau au Maroc, il est nécessaire de repenser les incitations économiques agricoles, d'améliorer la gouvernance intersectorielle et de garantir une plus grande équité sociale dans l'accès à l'eau.

Mots-clés : Gestion durable de l'eau, Politique de l'eau, Changement climatique, Défis de l'eau, Pénurie d'eau au Maroc.
Classification JEL : Q5
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1. Introduction

The effectiveness of water policies and governance structures in Morocco has become a critical research area due to the country's increasing water scarcity driven by climate change, population growth, and economic development pressures (Mohamed, 2013; Sánchez et al., 2022). Since the 1960s, Morocco has implemented extensive water infrastructure and policy reforms, including the 1995 Water Law adopting Integrated Water Resources Management (IWRM) principles (Sánchez et al., 2022; Kadi & Ziyad, 2018). Despite these efforts, per capita water availability remains below critical thresholds, with estimates indicating a decline to 650 m^3/year and projections of an 80% loss of resources within 25 years (Rachid & Moussaoui, 2024; Mohamed, 2013). The socio-economic significance of water management is underscored by its centrality to agriculture, urban development, and ecosystem sustainability (Choukr-Allah et al., 2017; Attar et al., 2022). Morocco's water governance evolution reflects a shift from centralized, supply-focused approaches to more participatory and integrated frameworks, yet implementation and resource sustainability challenges persist (Machrafi et al., 2022; Sánchez et al., 2022). The specific gap addressed in this review concerns the disconnect between Morocco's water policy frameworks and their effectiveness in achieving sustainable water management, particularly regarding regulation enforcement and stakeholder participation (Sánchez et al., 2022; Ben-Daoud, 2022). Although Morocco has adopted progressive policies like participatory irrigation management and aquifer contracts, empirical evidence reveals persistent groundwater depletion, inequitable water access, and limited local engagement (Azemzi & Erraoui, 2021; Houdret & Heinz, 2022; Faysse et al., 2012). Key knowledge gaps include understanding how current governance structures and regulatory frameworks translate into practice and how stakeholder dynamics influence policy outcomes (NAWAL, 2024; Ben-Daoud, 2022; Faysse et al., 2014). Controversies exist between prioritizing large-scale infrastructure development versus demand management and between top-down policy design and local participatory approaches (Sánchez et al., 2022; Mayaux, 2021). Failure to bridge this gap risks exacerbating water scarcity, social inequities, and environmental degradation (Tekken & Kropp, 2012; Houdret, 2012). This study adopts an integrated framework combining IWRM principles, stakeholder participation, and sustainable governance to analyze Morocco's water policy effectiveness (Sánchez et al., 2022; Rbaibi & Sahibed-Dine, 2024; Romano & Akhmouch, 2019). IWRM emphasizes holistic basin-level management, treating water as an economic resource with participatory governance (Sánchez et al., 2022). Stakeholder engagement is critical for adaptive management and equitable resource allocation (Ben-Daoud, 2022; Faysse et al., 2014). Sustainable governance links these concepts to long-term ecological and social resilience (Rbaibi & Sahibed-Dine, 2024). This framework guides assessment of policy design, institutional arrangements, and stakeholder interactions in Morocco's water sector. This article critically evaluates the effectiveness of Morocco's current water policies and governance structures in addressing sustainability challenges, with emphasis on regulatory frameworks and stakeholder participation (Sánchez et al., 2022; Ben-Daoud, 2022). It aims to identify policy implementation gaps and barriers while exploring emerging trends and future developments impacting water sustainability in Morocco (Kalpakian & Jenks, 2025; Attar et al., 2024). By synthesizing multidisciplinary evidence, this review informs policy reforms and governance innovations for sustainable water management in semi-arid contexts. So, the question for us is this: **How can Morocco adapt its water policies to respond sustainably to the increasing scarcity of the resource, while ensuring equitable, integrated and resilient management in the face of current climatic and socio-economic challenges?** This article aims to answer this question by pursuing three complementary objectives: identify the main water sustainability challenges in the Moroccan context, analyze the public policies and institutional instruments deployed to date to meet these challenges and propose mediumand long-term perspectives and levers for sustainable action, based on integrated water resource management (IWRM) frameworks. The article is organized as follows: after presenting the theoretical and conceptual framework of the study, we diagnose the issues and pressures affecting water resources in Morocco. We then analyze the policies and institutional arrangements in place, before opening the discussion on future prospects. Finally, recommendations will be formulated for decision-makers, researchers and local stakeholders.

2. Literature review

Faced with the increasing scarcity of water resources, the issue of water sustainability is becoming a major global challenge, particularly in arid and semi-arid regions such as Morocco. Water sustainability is generally defined as the ability to manage water resources in such a way as to satisfy current needs without compromising those of future generations. It is based on three fundamental dimensions: environmental, economic and social (Gleick, 1998; Falkenmark & Rockström, 2004; UNEP, 2021). Key concepts such as the water footprint (Hoekstra & Mekonnen, 2012), which assesses the direct and indirect consumption of water in production processes, or virtual water, i.e. water incorporated into traded products, now make it possible to quantify the real pressure exerted on resources. Added to this is Integrated Water Resources Management (IWRM), a reference framework promoted at international level to reconcile equity, economic efficiency and ecological sustainability (UNESCO, 2020; WWAP, 2024).
Water sustainability in Morocco is built around fundamental theoretical frameworks, of which Integrated Water Resource Management (IWRM) is the central pillar. Promoted by the Global Water Partnership and formalized in Moroccan laws 10-95 (1995) and 36-15 (2016) (Kingdom of Morocco, 1995, 2016), IWRM is theoretically based on the triadic balance between economic efficiency, social equity and ecological sustainability (Maliva & Missimer, 2012). However, this conceptual framework struggles to reconcile the competing demands of the agricultural (85% of withdrawals), urban and environmental sectors, revealing a mismatch between theory and implementation (Del Vecchio & Barone, 2018; Ait Kadi & Ziyad, 2018). The concept of water security defined by Gleick (1998) as access to sufficient, safe and acceptable water is becoming crucial in a context of structural water stress (<500 m³/capita/year) aggravated by climate variability and overexploitation of groundwater (-30% recharge in the Draa basin according to Moumane et al., 2021). This pressure is in line with the theoretical framework of the water-energy-food nexus (WEF), which highlights sectoral interdependencies: intensive agriculture consumes the bulk of resources, while emerging desalination as a technical solution increases energy demand (FAO, 2014; ONEE, 2023), illustrating the tensions inherent in complex systems (Pahl-Wostl, 2017).
The concept of the water-energy-food-ecosystem nexus (WEFE) is another framework mobilized in recent literature. It aims to understand the interdependencies between different sectors and promote effective trade-offs. Work applied to the North African context shows that integrating decentralized renewable energy technologies (notably photovoltaics for agricultural pumping) not only reduces carbon emissions, but also strengthens the resilience of small-scale producers (Kertolli et al., 2024; Germanwatch, 2021). This systemic approach is now being encouraged by several national institutions, including the Conseil Économique, Social et Environnemental (CESE), which is calling for structural reform of water governance through a cross-sectoral reading of policies.
The literature also highlights shortcomings in governance. Silva-Novoa Sánchez et al (2022) show that water policies from 1995 to 2020 suffered from a lack of inter-institutional coordination, which limited the effectiveness of reforms. Other authors, such as Del Vecchio and Barone (2018), criticize the late and uneven application of "water table contracts", despite their being intended as participatory local management mechanisms.

Thus, recent literature is converging towards a recognition of the complexity of water sustainability issues in Morocco. The articulation between institutional frameworks (IWRM, territorial governance), technological innovations (desalination, solar energy, agrivoltaics), cross-sectoral integration (WEFE nexus) and socio-economic imperatives (water justice, fair pricing) today constitutes a dynamic field of research, mobilized to devise water policies that are more effective, inclusive and adapted to the challenges of climate change.

Finally, the question of water pricing and institutional reform remains a central issue. In its recent recommendations, the IMF stresses the need to adopt tariffs that reflect the real cost of services, while ensuring social accessibility for vulnerable households. The development of public-private partnerships (PPPs) is also envisaged as a way of optimizing the management and maintenance of water infrastructures, subject to a strict and transparent regulatory framework (IMF, 2023).

By way of conclusion, recent literature converges on the need for structural reform of water policies, integrating ecological, social and economic dimensions in a balanced way.Several authors call for better alignment between agricultural, water and trade policies, notably by advising against the cultivation and export of water-intensive products in a context of scarcity (Ait Kadi, 2022; Berghouti et al., 2023). However, there are differences of opinion as to which instruments should be favored: some recommend an approach based on market mechanisms (incentive pricing, transferable water rights), while others advocate firmer public regulation based on social justice and territorial planning. Significant shortcomings also persist, notably the lack of disaggregated data on withdrawals, the insufficient transparency of water policies, and the absence of differentiated assessment according to regions or categories of producers.

Our literature review underscores the complexity of water governance in Morocco, revealing how policy reforms blend modernization with participatory approaches exemplifying *policy layering* and *institutional bricolage* where new mechanisms coexist with legacy structures, typically yielding incremental rather than transformative change (Mayaux, 2021; Houdret & Heinz, 2022; Faysse et al., 2012). While stakeholder participation and social learning are empirically confirmed as critical, persistent power asymmetries and engagement gaps validate inclusive governance frameworks while exposing limitations of top-down management (Ben-Daoud, 2022; Faysse et al., 2014, 2018). Integrated Water Resources Management (IWRM) and Water-Energy-Food (WEF) nexus approaches theoretically address interconnected sustainability challenges but suffer from sectoral silos and poor integration in practice (Rbaibi & Sahibed-Dine, 2024; Youssfi et al., 2020; Laamari et al., 2022), necessitating climate-adaptive strategies grounded in hydrological modeling (Karmaoui, 2015; Msaddek et al., 2020; Tekken & Kropp, 2012). Persistent groundwater depletion despite regulations challenges policy efficacy assumptions, demanding governance theories that account for socio-political dynamics and enforcement capacity (del Vecchio & Barone, 2018; Closas & Villholth, 2016; Faysse et al., 2012), particularly as formal participatory mechanisms often fail to strengthen local collective action in irrigation transitions (Azemzi & Erraoui, 2021; NAWAL, 2024). Consequently, policymakers must strengthen institutional coordination to reduce fragmentation (Machrafi et al., 2022; Sánchez et al., 2022; del Vecchio & Barone, 2018), empower marginalized actors through inclusive platforms (Ben-Daoud, 2022; Faysse et al., 2018), deploy decision-support tools like MODSIM and HEC-HMS for adaptive management (Attar et al., 2024; Guemouria et al., 2023), prioritize demand-side solutions including drip irrigation and pricing reforms via initiatives like the *Green Morocco Plan* (Assouli et al., 2019; Elder, 2022), scale non-conventional resources like wastewater reuse with regulatory safeguards (Ortega-Pozo et al., 2022; Gouahi et al., 2024), and embed climate vulnerability assessments into policies to secure water-dependent sectors (Tekken & Kropp, 2012; Tekken et al., 2013).

3. Methodology

This study adopts a simple documentary analysis. It is grounded in an in-depth documentary analysis aimed at understanding the dynamics of water sustainability and water policies within the Moroccan context. This methodological framework enables the triangulation of multiple data sources to identify key trends, challenges, and potential solutions. The use of secondary data is justified by the exploratory nature of this research, which serves as a preliminary investigation into the subject. As such, it provides a foundational framework for future empirical studies and more targeted policy analyses.

Data was collected from a variety of complementary sources, including : official national reports, notably those published by the Office National de l'Électricité et de l'Eau Potable (ONEE), the Ministère de l'Équipement et de l'Eau, and the Secrétariat d'État chargé de l'Eau; recent scientific publications from journals specializing in hydrology, environmental sciences, water economics and public policy; international databases such as those of the FAO (AQUASTAT), the World Bank, UNESCO and UNEP, providing statistics and comparative indicators on water management and the water footprint. The analysis method adopted is a thematic one, consisting of identifying and classifying information according to key categories such as water governance, agricultural policies, technological innovations, or the impacts of climate change. This approach made it possible to structure the literature review along the main lines of scientific debate. In addition, data triangulation was carried out to cross-reference results from different sources and document types. The aim of this technique is to strengthen the validity of the results and limit bias linked to a single source of information or point of view. The analysis thus enabled us to establish a coherent reading of current challenges and future prospects for water sustainability in Morocco.

4. Results

In the Moroccan context, per capita water availability has fallen from 2,500 m^3/year in the 1960s to less than 600 m^3 in 2023, with alarming projections predicting a drop to 500 m^3 by 2030 (Ministère de l'Équipement et de l'Eau, 2023). This water deficit is exacerbated by the increasing frequency of droughts, the effects of climate change, and the chronic overexploitation of groundwater in several key agricultural regions such as Souss-Massa, Haouz or Tadla (FAO, 2022; OCP Policy Center, 2018). Around 90% of the water mobilized is used for irrigation, often inefficiently. Several studies highlight governance that is still fragmented, centralized and not very participatory, despite the formal adoption of the IWRM paradigm (Zair et al., 2022; Ait Kadi, 2022). On the legal and institutional front, Morocco has adopted notable reforms, notably Law 36-15 on water (2016), which introduces principles of resource protection and use regulation, as well as the National Water Plan and the National Drinking Water Supply and Irrigation Program 2020-2027.These instruments aim to secure access to drinking water, boost irrigation efficiency and anticipate future needs. However, many critics point to a gap between the stated ambitions and the reality on the ground, due to a lack of inter-institutional coordination, weak evaluation mechanisms, and low community and user participation (Benabdallah, 2020; Khyare et al., 2021).

Faced with the limitations of these conventional approaches, a number of technological solutions have emerged. The use of seawater desalination has intensified, notably with plants in Agadir, Laâyoune and Safi (ONEE, 2023). Intelligent agriculture, meanwhile, offers innovations such as drip irrigation, connected sensors (IoT), and irrigation systems assisted by artificial intelligence. These technologies enable water savings of between 40% and 70%, with yield increases of up to 40% (CGIAR, 2021; FAO, 2023). Furthermore, the reuse of treated wastewater remains an under-exploited but promising avenue in certain urban and peri-urban areas (Bzioui, 2022). Nevertheless, widespread adoption of these technologies faces obstacles

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such as high initial costs, the digital divide and the low capacity of small-scale farmers to access these devices.

Several recent works have highlighted the structural vulnerabilities of Morocco's water sector. According to Hssaisoune et al. (2020), groundwater resources are in rapid decline due to overexploitation, exacerbated by agricultural intensification and drought. Similarly, siltation of dams is reducing long-term storage capacity (Mosaid et al., 2024), calling into question the reliability of supply.

On a theoretical scale, integrated water resources management (IWRM) and Water-Energy-Food Nexus (WEF) approaches are increasingly being mobilized. Rbaibi & Sahibed-Dine (2024) call for these approaches to be integrated into national strategies, while Maliva & Missimer (2012) stress that IWRM must be contextualized to local realities to avoid an inappropriate technocratic approach. The application of the WEF Nexus, while encouraging in discourse, remains embryonic in its concrete implementation in Morocco (Chehbouni, 2024). And water sustainability in Morocco can only be ensured through an integrated, equitable approach based on reliable data. This calls for in-depth reform of governance methods, greater coordination between sectoral policies, and active support for innovation and stakeholder participation. Strengthening local capacities, making sustainable technologies accessible and raising awareness of the water footprint appear to be essential levers for building a resilient water and food future in the Moroccan context.

4.1.1. Predominance of Agricultural Water Consumption and Inefficient Practices

According to data from the Ministry of Equipment and Water (2023), annual water availability per capita in Morocco fell from 2,560 m³ in 1960 to 585 m³ in 2023, with a projection of less than 500 m³ by 2030.

Water consumption by sector shows that agriculture dominates, accounting for 87% of withdrawals, against 10% for drinking water and 3% for industry.Agriculture is by far the largest consumer of water in Morocco, accounting for 75% to 87%, or even 80% to 95%, of total water withdrawals, even though it contributes only 13% of the country's GDP. In some southern basins, groundwater accounts for over 70% of agricultural water use. The efficiency rate in agriculture is low, at just 48%, indicating significant water losses. Water losses in the irrigation network amounted to 4 BCM in 2010. The Green Morocco Plan (PMV), launched in 2008, aimed to modernize agriculture and promote drip irrigation. However, despite subsidies for drip irrigation, this has paradoxically led to an increase in overall water consumption.

The overwhelming predominance of agriculture in water consumption (80-90%) means that any effective water sustainability strategy must fundamentally address agricultural water use. The low efficiency rate (48%) highlights the huge potential for water savings if practices are improved. The volume of water used in agriculture means that even small improvements in efficiency could result in substantial water savings, making it a critical action point for any national water strategy.

This table 1 is valuable because it clearly illustrates the disproportionate share of water consumed by the agricultural sector, providing quantitative evidence of its role as the main driver of water demand. This reinforces the argument that agricultural water management is essential to solving Morocco's water crisis. Furthermore, by showing the smaller shares of domestic and industrial use, it contextualizes policy debates and highlights areas where conservation efforts can have the greatest impact.

Table 1: Sectoral distribution of water withdrawals in Morocco

Sector	Percentage of Total Water Withdrawals (%)	Annual Volume (BCM/year) *(if available)*
Agriculture	75–87% (or even 80–95% in some estimates)	11–15 BCM (total withdrawals)
Domestic	~8% (or part of ~20% combined with industry/tourism)	1.1 BCM (2020), projected to 1.7 BCM (2050)
Industrial	~6% (or part of ~20% with domestic/tourism)	0.241 BCM (2020), projected to 0.370 BCM (2050)
Tourism	Part of ~20% (with domestic/industry)	0.033 BCM (2020), projected to 0.106 BCM (2050)

Source: World Bank Group. Morocco - Country Climate and Development Report (CCDR): Background Paper - Water Scarcity and Droughts (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099052223171017467

4.1.2. Policy-induced paradoxes (Plan Maroc Vert and drip irrigation)

The Plan Maroc Vert (PMV) promoted drip irrigation with high subsidies (80-100% of costs). However, this has led to a "Jevons paradox" or "rebound effect" where the increased efficiency of water use (drip irrigation) has paradoxically led to an increase in overall consumption. Farmers, incentivized by subsidies and aiming to maximize yields, used drip irrigation to grow high-value, water-intensive crops (e.g. alfalfa, watermelon, avocado, dates, citrus), often destined for export. This has intensified production and led to over-irrigation practices and overexploitation of groundwater. The watermelon-growing initiative in Zagora, an arid region, consumes over 30 million cubic meters of groundwater per year, causing chronic shortages for local residents. Artificially low water tariffs (e.g., 4 cents per cubic meter for farmers versus a value of 70 cents) combined with an unconstrained water supply have contributed to patterns of over-consumption.

The "Jevons's paradox" observed with drip irrigation represents a critical policy failure, demonstrating that technological solutions, if not combined with appropriate economic incentives and rigorous regulatory enforcement, can exacerbate rather than resolve water scarcity. This highlights a fundamental disconnect between agricultural development goals (increased productivity, exports) and water sustainability objectives. Subsidizing water-intensive export crops represents a significant "virtual water" export that depletes national resources for external economic gain, further exacerbating social inequalities. Subsidies for drip irrigation and artificially low water prices have created perverse incentives for farmers to turn to more water-intensive, high-value crops for export, leading to an increase in overall water consumption and the depletion of groundwater. This reveals a fundamental conflict between economic development objectives and environmental sustainability, and also highlights the aspect of social inequality where large commercial farmers benefit at the expense of local communities. (Silva-Novoa Sánchez et al 2022).

4.1.3 Evolution of water policy and legal instruments (Law 36-15)

Morocco's water policy has evolved from a hierarchical, state-coordinated model to one that partially transfers management to water user associations. However, there remains a strong commitment to the construction of large-scale hydraulic infrastructures. The 1995 Water Law adopted the paradigm of Integrated Water Resources Management (IWRM), aimed at socio-economic development through irrigated agriculture while ensuring long-term sustainability. IWRM prescribes a holistic approach linking water and land use, social and economic development with ecosystem protection, and treating water as an economic asset.

Law no. 36-15 on water (2016) is the fundamental legal framework. It comprises 163 articles covering the use of the public hydraulic domain, the development and use of rainwater, the development and use of non-conventional water (desalination, wastewater reuse), water administration, planning and conservation. It aims to increase water potential, adapt to climate

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change, guarantee citizens' right of access to water and promote rational, sustainable use. It also strengthens basin agencies and stakeholder participation. (Laamari, A. et al 2022)
Although Morocco has adopted modern legal frameworks (Law 36-15) and international best practices such as IWRM, the persistence of "compartmentalization of government sectors" and "weaknesses in water governance and limits to coordination of public water policies" indicates a significant gap between policy design and implementation. This suggests that institutional structure and cross-sectoral coordination are key obstacles to achieving water sustainability. The legal and conceptual frameworks are in place, but practical implementation is hampered by institutional silos and coordination failures. This is a critical governance challenge that undermines otherwise well-intentioned policies. (Silva-Novoa Sánchez et al 2022).

4.1.4 National water strategies and programs (PNE, PNAEPI)

Morocco implemented a "National Water Plan" (PNE) in 2020, setting out an ambitious action plan to invest nearly $40 billion in the water sector by 2050. The plan aims to close the projected gap between water supply and demand. A subset of the PNE is the "Programme National d'Approvisionnement en Eau Potable et d'Irrigation (PNAEPI) 2020-2027", with a budget of $11 billion or $14.2 billion, or 115.4 billion MAD. The program aims to reduce climate impacts, guarantee water security and diversify supply.
The main components of these programs include:
- ***Dam construction:*** Construction of 20 new large dams (total capacity of 5.38 BCM) under the PNAEPI, targeting a total capacity of 27.3 BCM. A total of 50 large dams are planned by 2050 to increase storage capacity to 32 BCM.
- ***Desalination:*** Construction of three new desalination plants (total capacity of 243,300 m^3/day). By 2030, 50% of drinking water supply should come from desalination, with a production target of 1,400 million m^3. The Casablanca desalination plant will be the largest in Africa, powered by renewable energies. The number of desalination plants is set to rise from 15 to 50 by 2050.
- ***Water transfer (water highways):*** Inter-basin water transfer projects (for example, the Sebou to Oum Rabia basins with a capacity of 800 MCM/year) are essential for flexible, integrated management, linking water-rich northern areas with less abundant inland/southern regions.
- ***Wastewater treatment and reuse:*** Plan for wastewater treatment and reuse in 128 cities and urban centers, linking over 1,200 rural areas. The aim is to increase treatment capacity from 70 million m^3 to 1 billion m^3 per year, with a target of 100 million m^3 of wastewater treated annually by 2027 for reuse.
- ***Rural water supply:*** Secure the supply of drinking water in rural areas, aiming for a 98.5% access rate for infrastructure.
- ***Irrigation modernization:*** A 10-year, $5 billion investment program (starting in 2020) to alleviate agricultural water shortages, focusing on the transition to water-efficient irrigation (e.g., localized/drip irrigation) on 555,000 hectares.

Morocco's national water strategies (PNE, PNAEPI) represent a major multi-billion-dollar commitment to increasing supply and developing infrastructure. Although impressive in its scale, the continued heavy reliance on large-scale infrastructure (dams, inter-basin transfers), despite challenges such as siltation and the energy intensity of desalination, suggests a predominant supply-side mentality. This raises questions about long-term profitability and environmental footprint if not balanced by rigorous demand management.

Table 2: Main National Water Programs and Investment Allocations (2020-2050)

Program/Plan	Period	Total Budget (USD/MAD)	Key Components	Specific Objectives / Targets
National Water Plan (PNE)	2020–2050	~40 billion USD	Dams, Desalination, Wastewater Reuse, Loss Reduction, Agricultural Efficiency	Close the supply-demand gap; increase storage capacity to 32 BCM (50 large dams)
National Program for Drinking Water Supply and Irrigation (PNAEPI)	2020–2027	~11–14.2 billion USD / 115.4 billion MAD	Construction of 20 new dams, 3 new desalination plants, groundwater exploration, wastewater reuse, rural supply, irrigation modernization	5.38 BCM storage (new dams); 243,300 m³/day (desalination); 100 million m³/year (wastewater reuse); 98.5% rural access; 555,000 ha modernized irrigation
Desalination Strategy	Until 2030, then 2050	Integrated into PNE/PNAEPI	Construction of desalination plants (e.g., Casablanca)	50% of drinking water from desalination by 2030 (1.4 billion m³); 50 plants by 2050
Water Saving Program in Irrigation (PNEEI)	Integrated into PNAEPI	~9.5 billion MAD (part of PNAEPI)	Conversion of traditional irrigation systems to drip irrigation	Equip 55–60% of irrigated land with advanced irrigation technologies
RESWAG Project (World Bank)	Not specified	180 million USD	Water governance in agriculture, climate-smart irrigation services, advisory services to farmers	Improve groundwater management; enable flexible water allocation; benefit 16,000+ farmers over 50,000+ ha

Source: World Bank Group. Morocco - Country Climate and Development Report (CCDR): Background Paper - Water Scarcity and Droughts (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099052223171017467

This table provides a consolidated overview of Morocco's strategic response to water scarcity. By detailing programs, their budgets and key components, it provides a clear understanding of where investments and political efforts are concentrated. This is invaluable for assessing the government's priorities and the scale of its commitment. It also serves as a benchmark for assessing whether proposed solutions align with identified challenges, and whether a balanced approach is taken between increasing supply and managing demand.

4.1.5 Challenges of Policy Implementation, Coordination and Enforcement

Despite the legal and institutional framework, substantial gaps need to be filled for effective and efficient implementation of Integrated Urban Water Management (IUWM). The institutional framework is complex, involving a multitude of actors whose mandates may be too general or lead to conflicts. There is often an overlap of responsibilities between public and private players and a superposition of regulatory texts. The compartmentalization of government sectors prevents the complexity of water-related problems from being taken into account. The main problem seems to be the non-systemic treatment of water issues between actors and the lack of coordination between sector interests, leading to inconsistencies.

There is a lack of effective control of groundwater abstraction due to limited staff and resources to enforce regulations in remote areas. Farmers sometimes dig wells illegally, bypassing the authority. Enforcing regulations would entail significant social and political costs. The transition period for Law 36-15 means that the main implementing decrees of the former Law 10-95 remain applicable, creating potential inconsistencies. Water tariffs, particularly for irrigated agriculture, are artificially low and do not reflect cost recovery or the scarcity value of

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the resource, undermining financial viability and encouraging over-consumption. (Silva-Novoa Sánchez et al, 2022)

The recurring theme of "compartmentalization", "lack of coordination" and "governance weaknesses" reveals that even with progressive laws and ambitious plans, the institutional and political realities on the ground hamper effective water management. This suggests that the problem is not a lack of political intent, but rather a profound challenge in translating policy into practice due to fragmented responsibilities, weak enforcement and political-economic disincentives (e.g. low water prices, social costs of regulation). Structural shortcomings, such as fragmented mandates and lack of coordination, are exacerbated by financial and political obstacles. The inability to collect "polluter pays" charges and artificially low water tariffs are not just technical problems; they reflect a lack of political will to impose costs on powerful sectors (such as agriculture) or to resolve inter-ministerial conflicts. This means that even with good laws and plans, the underlying governance structure and political economy can prevent effective implementation, leading to a gap between political aspiration and reality.

4.1.6 Socio-economic dimensions: Inequality and access

Water has historically shaped Moroccan institutions and, through it, social inequalities have emerged. There is great inequality in the distribution of water resources between regions (north, center, south) and between agricultural/export investment zones and densely populated areas. Four-fifths of Morocco's most vulnerable population live in rural areas, dependent on rain-fed agriculture. These rural and mountainous regions are the most exposed to climatic extremes due to their topography and dependence on rainfall. Water scarcity has a disproportionate impact on vulnerable rural households. Residents of arid regions suffer chronic water shortages and spend hours waiting for water that is barely sufficient for drinking. The government-backed agricultural strategy, with its subsidies for water-hungry crops, has widened social disparities, benefiting large commercial farmers while marginalizing locals and traditional smallholders. This exacerbates existing inequalities and fuels tensions and conflicts over access to water. Climate change could lead to the migration of up to 1.9 million people from rural to urban areas by 2050.

Water scarcity in Morocco is not a neutral environmental phenomenon; it is a profound driver and amplifier of social inequality and conflict. The historical legacy of state control, combined with contemporary agricultural policies (Plan Maroc Vert) that favor large-scale, export-oriented, water-hungry agriculture, has systematically disadvantaged vulnerable rural populations, leading to chronic shortages, disruption of livelihoods and the potential for significant climate-induced migration. This is transforming the water crisis into a major challenge to human security and social stability. Historical policy choices created a base of inequality, which was then amplified by modern agricultural policies which, despite their aim of efficiency, have unwittingly widened disparities and led to social tensions and potential displacement. This is a crucial socio-political dimension of water sustainability that goes beyond technical solutions.

5. Discussion

The literature on water management strategies in Morocco, Egypt, Jordan, and Australia reveals key themes centered on integrated water resources management (IWRM), climate change impacts and adaptation, governance frameworks and policies, as well as technological innovations aimed at mitigating water scarcity. Most studies emphasize the critical role of socio-economic and environmental factors influencing the effectiveness of water management, focusing on water use efficiency for agriculture and stakeholder participation. Comparative analyses emphasize the need for holistic approaches that combine demand management, supply augmentation, and sustainability principles tailored to regional contexts. New research underscores the importance of digital tools, multi-scale modeling, and participatory frameworks to enhance resilience to increasing water stress.

In the case of Morocco, water management faces significant challenges. A major issue is the extreme appropriation of water resources by agriculture, which accounts for up to 95% of withdrawals in some regions, yet contributes modestly to national wealth (around 13% of GDP). This heavy dependence on water reveals a critical structural vulnerability, especially in the face of continuously declining resources. The implementation of the Green Morocco Plan, designed to modernize agriculture, has paradoxically led to an increase in total water consumption, despite the adoption of efficient technologies like drip irrigation. This paradox, known as the rebound effect or Jevons paradox, is exacerbated by the shift towards high-value, water-intensive export crops. The tension between agricultural productivity goals and water sustainability objectives indicates a lack of coherence between sectoral policies.

From an institutional standpoint, Morocco has made strides in modernizing its legal framework, such as with Law 36-15 on Water, and adopting the IWRM paradigm, signaling political will. However, institutional fragmentation, poor coordination among stakeholders, and insufficient enforcement mechanisms undermine the effectiveness of these reforms. Additionally, the lack of incentive pricing (e.g., very low water prices for farmers) and difficulties enforcing groundwater regulations contribute to overexploitation and non-compliance.

National programs like the PNE and PNAEPI, which outline ambitious goals and significant investments (over USD 40 billion planned by 2050), reflect Morocco's efforts to address water scarcity. Yet, these programs rely heavily on supply-side solutions, such as large dams, desalination, and inter-basin transfers. These infrastructure-driven strategies are not always complemented by rigorous demand management, and issues like the rapid sedimentation of dams and high energy costs of desalination raise questions about their long-term sustainability.

Socio-economically, water scarcity exacerbates deep inequalities. Arid, often rural regions suffer most, with public policies primarily benefiting large commercial farms focused on exports. This leaves small farmers and local communities at a disadvantage, heightening social disparities and creating potential for conflicts over water access. Thus, water management in Morocco is not just an environmental issue; it’s also a matter of social stability and human security.

The critical analysis of these findings points to a threefold necessity: fundamentally reconsidering economic incentive structures in the agricultural sector; strengthening intersectoral governance and regulatory capacity; and ensuring social equity in water access. Achieving water sustainability in Morocco requires an authentic integration of ecological, economic, and social objectives in public policy formulation and implementation.

At the regional level, many countries, including Morocco, Egypt, and Jordan, have adopted integrated water management strategies to address water scarcity. Economic instruments such as water pricing and alternative fiscal policies have been shown to guide crops toward less water-intensive options and improve efficiency in both Morocco and Egypt (He et al., 2006) (Schyns, 2013). Furthermore, demand management strategies are crucial in places like Jordan and Egypt (Baroudy et al., 2015). However, implementing water pricing faces challenges due to political risks and social acceptability, and some argue that alternative policies, such as irrigation production taxes, may be more feasible (He et al., 2005).

Institutional governance in Morocco has been complicated by fragmented government sectors and limited social equity in water access, similar to challenges seen in Jordan (Sanchez et al., 2022). On the other hand, Australia benefits from advanced technological support and better data integration, contrasting sharply with the data and resource limitations in MENA countries (Berendsen et al., 2024). Despite these challenges, there is widespread agreement on the need for integrated, multi-stakeholder governance frameworks for sustainable water management.

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Countries like Morocco, Jordan, and Egypt have adopted measures such as managed aquifer recharge (MAR) to enhance groundwater resilience (Gouahi et al., 2024), while Australia integrates advanced remote sensing and modeling tools to support water management (Berendsen et al., 2024). However, social acceptance of technologies such as wastewater reuse remains a barrier in some regions, particularly in Jordan and Egypt, despite their technological feasibility.

Finally, the literature highlights the importance of equitable access to water, especially for vulnerable populations, small farmers, and ecosystems. Integrated approaches that balance socio-economic needs with environmental sustainability are essential to achieving long-term water security. Differences in how social equity is prioritized and achieved vary across countries, with developed countries better integrating environmental concerns, while developing nations face sociopolitical complexities and resource limitations.

6. Conclusion

This study has demonstrated that current water policies in Morocco, although framed by modern legislative instruments and supported by massive investments, remain insufficient to sustainably address the increasing scarcity of water resources. The findings highlight the strategic importance of the agricultural sector, both as the main consumer of water and as a potential lever for conservation. However, the adverse effects of subsidized irrigation policies particularly through the rebound effect and the prioritization of export-oriented crops undermine efforts toward resource rationalization.

In light of these observations, several recommendations emerge. First, agricultural subsidies must be redirected toward water-efficient crops with high local nutritional value. Second, the introduction of fair and incentivizing pricing mechanisms for large consumers should complement technological efforts. Furthermore, strengthening intersectoral governance through better coordination between basin agencies, local authorities, and economic and social stakeholders is essential. The integration of real-time data, transparent management, and citizen participation are also critical pillars for resilient governance.

In terms of research, further studies are needed to assess the long-term impacts of irrigation technologies on water resources, while considering social and territorial dimensions. The development of local water sustainability indicators, as well as analyses of consumption patterns and virtual water trade policies, represent promising research directions.

Morocco thus stands at a crossroads: adapting its water policies to the complexity of climate, economic, and social challenges is no longer optional, but a strategic necessity. An integrated, equitable, and resilient management approach represents the only viable path to preserve water resources and ensure a sustainable future for coming generations.

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