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Strategic Structural Reforms for Sustainable Water Resource Management in Morocco

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ABSTRACT

Morocco is facing a growing water security challenge as structural and climate change pressures are increasing demand with dwindling renewable water resources. The nation is caught between two conflicting trends, as rapidly growing demographics and urbanization increase water demand even as prolonged droughts and climate-induced variability reduce its availability and reliability. The purpose of this paper is to explore population dynamics, urbanization, and agriculture, and institutions in a multi-dimensional perspective in relation to the dynamics of the sustainability of water management. Methodologically, using an ARDL model for the period 1995–2022, the effects associated with these determinants and the freshwater are estimated for short- and long-run dynamics. Our empirical results reveal that the governance effectiveness and urban growth have a significant positive impact on water sustainability, which means that the better institutional setup and the more organized urban dynamics are congruent with water systems' sustainability. By contrast, but with less structural robustness (and thus more in line with sculpture) agricultural pressure is structured in as there is no such a strong tendency towards an undifferentiated diffusion: not being able to make a trade-off between feeding and saving resources appears as a challenge In addition to the empirical evidence it emphasizes that adaptive governance through institution al change, technological developments in water infrastructure and involvement of local stakeholders also plays a crucial role. By using evidence based on the context (the case study)—which feeds to other studies, this article contributes to the broader literature about how such management of natural resources could be designed in semi-arid regions and input needed for policy development so Morocco may increase its adaptability toward fast variable climate conditions.

Keywords: Sustainable water management, ARDL model, governance, freshwater resources, resilience, climate change.

INTRODUCTION

The positive effect of good governance and urbanization on water sustainability is observed by empirical results, indicating that a better approach for building an institutional system and well-ordered development is beneficial to the sustainable management of water. By contrast, although with a weaker structural strength (and

hence more akin to sculpturesque), agricultural pressure has its structure because there is no such strong built-in tendency towards undifferentiated spread: not being able to cut the trading off between consumption and resource saving does come out as a problem. Profiting from empirical evidence, it stresses that adaptive governance by means of institutional adjustment, technological innovations in water infrastructure, and engagement of local actors is also crucial. For this reason, by providing context-dependent evidence, which supports other studies28 −29, the present case study adds to the literature on how this kind of resource management might be designed in semi-arid areas and what input is required for policy to increase Morocco's adaptability toward fast variable climate conditions.

In the case of Morocco, water resource management becomes a pressing structural problem. The renewable freshwater resources in the country have fallen significantly over the last few years, from over 2,500 m^3 per capita in the 1960s to below 620 m^3 per capita today, and thus under the globally defined water-stressed level [2]. This decline is caused by a binary scenario: an increasing population, urban sprawl and development, and the higher standards of living drive water demand, while droughts occurring incessantly in addition to climate change are leading to a decrease in supply (bringing about periodic discrepancies between availability and utilization) [3]. Agriculture uses over 80 % of Morocco's water resources alone while the sector is still quite dependent on inter-annual variability in rainfall, friction between food security imperatives and continued protection of freshwater resources [4].

Although Morocco has invested in large dams, modernization of irrigation and the 2009 National Water Strategy have been adopted many gaps are apparent. Institutional fragmentation, poor coordination among layers of governance and low integration between urban and agricultural water planning lower the resilience of water systems [5]. In addition, most of the literature on water scarcity has analyzed it primarily from the point of view of physical supply-demand and policy analysis, rather than by explicitly combining structural drivers of demographic, urban, agricultural and institutional dynamics into a coherent empirical framework. This discrepancy hinders the opportunities to shape comprehensive responses targeting the set of interactions and, more generally, the complex and interdependent types of pressure on Morocco's water resources.

Filling these gaps is important for two reasons. First, the interaction between demographic growth and urban development will be considered together with the resulting demand for agriculture. A second consideration is how these factors are supported by a relatively stable government structure which may provide Morocco with long-term support in further developing and building water resources to meet growing demands for water. Second, knowing which drivers have strong and significant structural effects is important in guiding effective adaptation to climate change. In this context, econometric models such as the (Auto Regressive Distributed Lag) ARDL model are a suitable instrument since they account for both short-run dynamics and long run equilibrium relationships between several determinants [6].

This article also adds to the literature by empirically testing an ARDL model in Morocco during 1995–2022 on the structural determinants of water sustainability. In addition to characterizing these connections, the paper decontextualizes water scarcity amidst governance and development processes, emphasizing the significance of institutional reforms, urban planning and participatory management for resilient water systems. In so doing, the presentation will help provide context-specific evidence that enhances knowledge of Morocco's water dilemmas and contributes to the wider global debate about how sustainable resource management should be sought in semi-arid lands.

In this regard, the central research question can be formulated as follows: What is driving sustainable water resource management in Morocco and how demographic growth, urban spreading, agricultural requirements and government performance interact to impact freshwater availability under climate variations?

LITERATURE REVIEW

As the most essential and irreplaceable resource, a huge challenge to sustainable development of society is how we can truly achieve harmonious coexistence between human beings and water on earth. In areas with an arid and a semiarid climate, such as Morocco, water shortage is not only a natural limitation but also a true strategic issue. Having always relied on irregular climate, water stress has been compounding in the Kingdom for several decades with worsening consequences under the impact of climate change, demographic pressure, rapid urbanization and structural transformation of its economy. In this tense background, it is clear the inadequacy of the inherited model of water resources management from previous decades, essentially built on a supply pattern (dams; catchments) instead of an integrated and sustainable demand one.

Water is at the heart of multiple interacting dynamics: food security, social equilibrium, territorial development, economic competitiveness, even a horizon where the destabilizing forces of environmental changes can be withstood. Solutions to these challenges are therefore more vital than ever. Morocco is at a crossroads on this

issue. On the other hand, the public action through such governmental projects as the governmental Water Plan (PNE), the National Program of Drinking Water Supply and Sanitation (2020– 2027) programs, desalination, or wastewater reuse shows political will to adapt and innovate. Institutional dysfunction, poor coordination, or fragmented governance may nevertheless sometimes lead to the failure of such policies.

In such a context, a clear understanding of the structural and cyclical factors behind water supply is essential to guide public action. This is the view adopted by this article: we offer a multi-dimensional reading of the determinants of water resources sustainability in Morocco. It focuses in particular on understanding the complex dynamic between population growth, urbanization, agricultural production and the quality of governance. The empirical strategy followed is to use autoregressive distributed lag (ARDL) model for the period from 1995 to 2022 to account for both short run dynamics and long run structural impacts.

Morocco, situated in a semi-arid/arid area, is subjected now to a growing pressure about its water resources. This is because of the enhancing phenomena of climate change, rapid population explosion, galloping urbanization and the enhancement in water demand from the agricultural sector industrial sector-domestic sector [7], [8], [9]. Furthermore, water source pollution and governance defects enhance the vulnerability of the resources, the us compromising the national water security. In this regard, ensuring balanced socio-economic development of sustainable water use by society is an extremely important strategic task.

How do socio-economy, environmental and institutional drivers influence resilience and sustainable control of water resources in Morocco under climatic variability?

To answer this question, by providing a theoretical and context analysis the problem of water in Morocco as part (theoretical) that our country live, and an empirical study based on the ARDL method (empirical), we can measure the effect of structural factors on water resources dynamics.

The results obtained bring a new dimension to the situation: they demonstrate that, if governance and urbanization have a significant impact on the preservation of resources, agriculture as a main user of water does not seem to make decisive pressure in duration due to (partially effective) adaptation policies. These results indicate the need to change course, prioritizing adaptive, inclusive and transparent governance; technological innovation and active engagement of local and national stakeholders. Based on the consideration of the environmental, social, economic and institutional dimensions, this study seeks to provide an input to strategic thinking around the most appropriate levers for action in order to ensure water security for Morocco in a context characterized by increased fragility. A switch from the conventional method to an integrated and sustainable management of water can no longer be considered as alternative but a must for the country's survival and development.

Against this background, prior to turning to the empirical part of our study, we develop a conceptual framework and overview relevant literature to structure the landscape of research such that it becomes clear where and how we undertake building on previous work.

Significance of water resources in Morocco: Water is a primary and pressing issue for Morocco, which has an arid to semi-arid climate. The situation of water resources becomes even more critical and alarming. Add this to another disparity, unpredictable rain pattern that also contributes to rise the value of this hard-to-manage water resource. Essential to everyone's food needs, but also because water is a critical input to industrialization and tourism – two of the cornerstones of the Moroccan economy. Agronomy The agricultural sector, a key factor to population's health and welfare, represents around 80 % of water demand, due to the required to keep food security in a country where fast and permanent increase of population is observed. [10]. In this context, both sustainable and efficient management of water resources is not only urgent and important but also essential for the achievement of the main non-negotiable sustainable development goals. It is also a prerequisite for poverty reduction and for communities' resilience to the often-devastating effects of climate change, now so visibly at hand.

In this perspective, a rational and sustainable management of water resources would have to be set at the top of national public policy agenda in order not only to guarantee an environmental sustainability but also social inclusiveness and equity for all sectors of Moroccan society off today's and tomorrow's generations. The realization of this vision calls for a multilateral governance involving joint action from local authorities, agricultural parties, private and civil sectors [11]. The pivotal role for Water in socio-economic development: Water benefits from a decisive, essential and vital role in the Moroccan socio-economic development, an emergent country in full transformation thanks to strategic inputs, which it provides to several fundamental sectors. These are agriculture, industry and tourism which are themselves interlinked or consistent to growth cycle.

And water being strategically coveted, irrigasses some 1.5 million hectares of the exploitation and cultivation land respectively-and contributes to providing that unavoidable natural resource without which no efforts will be sustained to guarantee the food security of a Country-whose per capita food consumption is still below average in sub-Saharan Africa. Furthermore, it is essential for rural employment that is sustainable to be generated which is highly urgent and of absolute importance to a sizable segment of the population in the Kingdom.

For industry, water is not only a must-have but also one of the basics needed to allow various types of production that define the antagonistic sectors in the kingdom. This has an essential, decisive impact upon global competitiveness for Morocco, aspiring to be a leader in its region with developing countries. Whereas at the same time, another sector of tourist-driven economy-- is one of vital role in country's GDP which also vitally depends on water resources (quality or quantity). These are the elements necessary to meet the continuously growing needs and expectations of these holidaymakers who pour into this nation steeped in culture, history and varied geographical locations. Therefore, its management system and subdividing projects for water distribution (that at the same time are sustainable and efficient) are so important to assure that we get not only the sustainability of this natural wealth but also a suitable evolution and harmonic development of these two sectors which have essential importance on our national economy. This will have direct, positive and consequential effects on the global socio-economic development of this nation, thus encouraging wealth and durable well-being of the Moroccan populations and generations to come [12], [13], [14].

Current Water Situation in Morocco:

The status of water in Morocco has witnessed growing pressure with resource reaching alarming levels of scarcity and this induced significant state of water stress. Indeed, such water scarcity is one of the major national problems because it reveals that both river flows and underground sources are being systematically, and in some places ruthlessly overallocated. The pressure is primarily due to the relentless growth in need of water, which grows year after year. The urbanization and industrialization of society increase its size as well. These results induce fierce and inherent competition over such an important resource as water [15].

Levels in reservoirs go down to the critical barely at a good time — especially as more of the all too seasonal events that define drought. It is this water stress that is endangering access to the resource, essential not only for irrigated agriculture — whose crop growth is highly visible dependent (from production to productivity and yield) on water availability but for drinking, the indispensable, vital part in day-by-day survival of the society.

Similarly, contamination of rivers and underground water bodies by industrial effluents and agricultural practices that are not environmentally friendly (unsustainable/ deleterious) is threatening the quality of our water resources on one hand. In contrast, this increasing the situation and adding of awareness and concerns aggravates access tension over such essential resource. Collectively, these reasons point to the crucial importance of integrated and sustainable water resources management as a necessity perspective in present condition (16).

It is the responsibility to guarantee enough water for today and tomorrow, not just today's urgent and unskilled treatments but in order that future generations have this precious life-enabling resource for human living with dignity, respect and sustainability. It is only a concerted, collective drive that unites everyone concerned with finding a solution to these complex, multilayered problems and defending the future of our societies – elected officials, businesses and citizens alike – which will be in any way up to the task.

Issues and Challenges in Water Resource Management

Water resources management in Morocco has to deal with many complex and diversified problems, always more numerous and diversifying, leading to major current challenges that are appearing, to sustain the development.

Both in urban and rural areas, the rapid process of urbanization along with continued high population growth exerts a major direct influence on water yield. Meanwhile, the (widespread) intensification of agriculture is adding ever higher, in some cases unsustainable demands on scarce and vulnerable water supplies. The negative impact of climate change further compounds this concern with the increase in flood risk, the aggravation of rainfall variability and more frequent and severe droughts, putting at risk basic water security for survival [17].

Moreover, the growing and more active competition between different water use sectors such as industrial, agricultural and domestic supply of water constitutes a complex but sensitive problem in efforts to harmonize ignorance one uses with safe levels of this scarcity resource 15. This type of integrated holistic an harmonized systematized governance is thus not only un-by passable but also inevitable to guarantee clear, rational and sustainable access for this invaluable good for the coming generation.

In such severe, and worrying, context the cooperation among partners is key to bring forward new governance models, whilst designing innovative plans and sustainable investments to cope with worsening problems we cannot afford not solve [18].

Water Stress and Water Scarcity

Water shortage in Morocco This crucial issue of water is very vital, and urgent., indeed quite sensitive!57 It is high, it being often unfavorable, in dry and semi-arid areas to the extent that clime and rainfall are unfavorable. The environmental and human repercussions of this situation are alarming.

Australia is reportedly – nothing mind boggling by the way just not going to let them see anyway -on a list of jurisdictions in some form and extent of significant and dire stress on its lifeblood, potable water issues which are very widely publicly documented in abundant detailed information reports prepared at the hands of expert, national and international bodies. The availability per capita of this basic commodity – and indeed it is a life support substance – is tragically well below the sort of thoughtful world standard which all of us now take for granted. This is a massive economic and social issue. There are a variety of crucial interrelated and complex explanations for this lamentable phenomenon. The washers rate their water consumption, of which large needs for irrigation of agriculture, (round about 80% of the total ground water used), is revised. This rising demand has escalated the competition between various activities, particularly agriculture, industry and drinking water supply to population [19].

Ground water has also been exploited in the region and was many times a direct response to drought periods lasting months and sometimes even years which further led to ground-water aquifer depletion, upon which rests natural ecosystems and biodiversity (flora & fauna) and sustainable agricultural practices. Contrary, the solutions to this scarcity of water and sustainable management of our water resources must be as efficient and original. More efficient irrigation means a transition towards the use of less water-intensive irrigation methods, such as drip or trickle irrigation. Simultaneously, the dissemination of less water-related crops must be included as principal components not only on public, but also in local policies established to address such basic issues. Other actions - enhancing famers' capacity for environmentally friendly farming practices and promoting water saving- are also to be explored in order to ensure the sustainability of water resources in Morocco [20].

Pollution and Degradation of Water Quality:

Water pollution is a serious and constant hazard that affects the health of the public as well as the environment in Morocco. This complex problem has multicomponent, and it is aggravated by several sectorial and more specifically, industrial, agricultural upstream and urban sectors which present a major magnitude in the deterioration of water resources. Especially, the reckless and untimorous discharging of raw sewage to waterways deteriorates a situation [21].

Moreover, the subtle and silent dynamite of sub so A Modern Environmentalism stratum water through injudicious and indiscriminate use of pesticides and other poisonous companions demand greater introduction among us. This pollution has direct and disastrous effects on rivers, lakes and seas with sudden but often permanent consequences for local water systems and biodiversity. The impact is not related to underwater ecological environment only that endangers the existence of living species which inhabit here, but they create influence upon food and health conditions of human population on whom these resources are vitally important for daily life [22].

A. A continued application of applied research to upgrade wastewater treatment and strengthen the legal control of pollutants need to be affected to a greater extent by appropriate improvements so as to mitigate these harmful devastative effects. Great care must also be directed towards sensitizing the economic operators, the farmers and citizens in general who must learn behaviors that promote respect for the environment. These measures are not only important in obtaining good drinking water for all (present and future), but they are also equally critical in safeguarding sustainable, fair access to so basic a necessity that is necessary to life and livelihood of every human being [23].

B. Strategies and Approaches for Sustainable Water Resource Management

Considering increasing and sensitive issues related to its water resources, Morocco is implementing a series of various, innovative and adapted approaches enabling the sustainable management and responsible usage of these resources necessary for its development. At the level of these measures a Valorization of Water plays an ultimate role in the country, and it is attainment to any factor or Sector that has industrially consumed water onwards. It also supports a consultative and participatory approach with the government, local authorities, users, citizens based on an active dynamic; planning that would consider the ecological environment and socioeconomic interests of all Moroccan people in harmony [24].

Certainly, a comprehensive and integrated step like this can assess the various water needs, in which the uses of water are also optimally allocated to support rapidly increasing demands and where freshwater is ensured to be safeguarded since it plays an important role for biodiversity richness and healthy native habitats. Considering the context of each region and local culture and environment, these strategies aim to make a contribution in both the long-term perspective to water security as well as for sustainable development and shared benefit across the country. They also aim to raise awareness for an urgent need to preserve this precious and scarce source, which unfortunately is often taking up load due to non-sustainable use and with a growing pressure by urbanization and change in climate [25].

Environmental awareness raising policies and campaigns, education are also crucial for targeting the entire range of public (primarily young to adults) in a growing population to participate in this conservationist duty which now includes climate change dynamics exacerbating the existing water crisis. Within the scope of this forward-

looking approach, Morocco is committed to promoting innovative and participative tools for management as well as new, high technologies that are used in water treatment and re-use demonstrating a virtuous circle use versus saving that serves current and future populations were developing and providing regional or international models for other countries [26].

Integrated Water Resource Management:

IWRM is also a mainstay in Moroccan water strategies: Integrated Water Resource Management (IWRM) became one of the fundamental principles to be applied for achieving sustainability and equity in access to water resources. This is because it has a comprehensive and systemic approach including several important aspects to water management. This strategy began with a profound identification of the problems and stakeholder behavior and an active and continuous engagement of all actors involved. It is not just limited to participants, it also involves all the stakeholders like farmers, industrialists, local elected representatives and municipalities.

It is, in fact, a step in an ongoing consultative, dialogue and working process aimed at building enabling structure for genuinely participatory management. In this context, everyone plays an important but partial role player and shares their knowledge, experience and insights about water problem [27].

The primary focus of IWRM is on equitable distribution of water among the many and often very different uses, in particular human needs (drinking water and sanitation or domestic use), agriculture and industry. It also pays attention to important environmental aspects that were often overlooked or marginalized in previous concepts from other schools of thought in water management that have been more conventionally oriented and aligned but less fully orientated and focused. As an example, the watershed approach is progressively being more shaped in the Moroccan scenario. IWRM also advocates for the integrated management of the entire water cycle. This does not just mean a rational reduction of conflicts around water access, clearly common in many regions of the country, but also wonderful reduction as to how to use what is out there. By encouraging wise and sustainable use of water resources, IWRM can help create resilience in the face of climatic shifts like extended dry spells, torrential temperature swings and other irrational weather phenomena [28].

All of this is done in such a way that there's enough and then some for many generations to come. In short, IWRM is a necessary step toward water management that not only learns from efficiency and equity but also is sustainable in the face of new changes that will arise to affect ecologies and peoples [29].

Use of Innovative Technologies:

Role of new technologies for enhancing water quality management in Morocco the role of new technologies is indispensable for improving the quality of water management in Morocco. Access to water is becoming more of a bigger challenge in many rural and urban areas across the country. Coping with the issues of providing a safe drinking water supply as well as facing frequent droughts, desperate shortfalls and erratic weather patterns is prompting immediate and proper action to address this crisis. Different efficient and sustainable ways like precision irrigation, using advanced sensors and high level of automation would not only help in reducing water consumption in agriculture, but also would play a substantial role in saving water by increasing crop yield.

This is the type of caring, intentional enabling which results in water being leveraged in an unbelievably optimal way where every drop of gold is being used as wisely and as cost efficiently as possible and that's something that is fundamentally important in a circumstance where there's a deficit and everything is constantly changing. Plus, in the times of smart drones and deep learning satellites being readily available for water resource inventory systems in addition to the subject matter expert knowhow only for validated ground truthing. Such perennial and continual vigilance of resources is crucial for judicious strategies but also managing water resources in a sustainable manner, at the same time framing policies which are sensitive and adaptable to climate changes that become more uncertain and volatile [30].

At the same time, desalination of sea water is an expensive method that needs large long-term investments, but it is a very attractive alternative and can be an achievable solution in coastal areas where fresh water shortage has become alarming shortfall. This saltwater extraction method may be able to provide useful drinking water supplies when more usual sources are "in decline" offering a practical and effective approach to the increasing scarcity of potable water. Full-embedding these evolved and engineered technology, Morocco may be not only significantly increasing its internal working effectiveness, but also further improving its own resilience against worrisome and growing effects of climate change increasingly impinging even just on the rest of region (imposing a sustainable water management to be more than ever essential and impeccable for both for present and future generations [31]).

MATERIALS AND METHODS

To empirically examine the relationship between water resource management and various influencing factors in Morocco, we adopt the ARDL (Autoregressive Distributed Lag) approach developed [32] [6]. In this autoregressive model, the endogenous variable is explained by its own lagged values (AR) as well as the lagged values of the exogenous variables (DL).

One of the advantages of the ARDL approach is that the variables can be integrated of different orders, as long as none is integrated of order higher than one. Moreover, this method helps to avoid endogeneity problems and is efficient for small sample sizes, making the ARDL approach more reliable than the Johansen and Juselius cointegration technique. Cointegration implies the existence of a long-run equilibrium relationship between the variables. In addition, the ARDL method can automatically determine the optimal lag length and uses a single reduced-form equation.

The ARDL equation is defined as:

$$LPRECt=\beta0+\beta1LPOPt+\beta2(LPOPt)2+\beta3LURBt + \beta4LVAAGt+\beta5GOVt+\beta6DLPRECt+\epsilon t \quad (1)$$

To analyze the long-term equilibrium relationship (cointegration), we apply the ARDL methodology, following the steps below:

- Unit root test (Dickey-Fuller) to test the stationarity of the series.
- Perform the Bound Test to verify the long-term relationship (cointegration).
- Estimate long-term and short-term coefficients.
- Test model validation by applying tests to residuals (normality, autocorrelation, homoscedasticity) and the CUSUM and CUSUMSQ stability tests.

A. Data and Variables

In this study of sustainable water resource management strategies in Morocco, we selected a set of explanatory variables to identify the main determinants influencing renewable freshwater resources, used here as a proxy for water availability. These variables were chosen on the basis of existing literature and the specific structural features of the Moroccan context.

The data corresponds to Morocco and includes the period 1995-2022. As explanatory variables annual rainfall (LPREC; as a measure for natural water availability) and population development (LPPOP), which stands for increasing stress on water resources via the growing demand, were used. The LURB and agricultural value added (LVAAG) are included to account for the influence of economics-driven and social-induced changes on water use. Lastly, a governance variable (LGOV) is also included to investigate the influence of public and institutional policies in favor of sustainable exploitation of this precious resource.

The table below summarizes the main characteristics of the variables used in this study.

Table 1. Explanatory variables used

Variables	Description	Expected effects
LPREC	Annual precipitation (mm)	Dependent variable
LDPOP	Logarithm of total population	-
LURB	Urbanization rate (% of total population)	-
LVAAG	Value added in the agricultural sector (% of GDP)	-
GOV	Governance indicator (quality of regulation)	+

Source: Compiled by the authors from World Bank data (2023)

These variables are commonly used to analyze the factors influencing water resource management.

B. Descriptive Analysis

The standard deviation is used to measure the dispersion of the different variables. For example, the LPOP variable could be the most dispersed of the others. The normality test indicates whether the variables follow a normal distribution. The following table summarizes the descriptive statistics for each variable:

Table 2. Descriptive statistics for each variable

Variable	Average	Standard deviation	Minimum	Maximum
LPREC	5.66	0.16	5.32	5.94
LPOP	7.75	0.15	7.50	8.00
LURB	7.25	0.15	7.00	7.50
LVAAG	10.00	0.30	9.50	10.50
GOV	-0.108	0.05	-0.263	-0.007

The dataset is representative of the period inside: [1995, 2022] and contains a set of variables that affect water resources in Morocco.

LPREC (Precipitation): Precipitation has an average of 5.66 (log) and low standard deviation suggesting little variation. These values are between 5.32 and 5.94, indicating a relatively consistent value which has only very small changes.

LURB: The changes in LUR works (i.e., urbanization) are similar to those of the population, that is about 7.25 (logarithm). The standard deviation is relatively small meaning it grows slowly. Values vary from 7.00 to 7.50 indicating constant growth of urban population.

LVAAG (Agricultural Value Added) The mean log value of the agricultural value added is found to hover around 10.00, with a standard deviation on the moderate side signifying some quantum of variation. The values range between 9.50 and 10.50 with some variation in agricultural production, perhaps due to climatic or economic reasons.

GOV (Governance): Governance shows a mean of around

-0.108, with a low standard deviation. Values range from 0.263 to -0.003, indicating a slight improvement over the years, but remaining negative overall, which could indicate persistent challenges in resource management.

- **Stationarity Tests:**

The results of the Augmented Dickey-Fuller (ADF) test for each variable are as follows:

- **LPREC** (Annual precipitation) ADF statistics: -3.133 p-value: 0.024

Conclusion: The series is stationary (p-value < 0.05).

- **LPOP** (Population growth)
- ADF statistic: 0.028
- p-value: 0.961
- Conclusion: The series is not stationary (p-value > 0.05).
- **LURB** (Urbanization)
- ADF statistics: -1.045
- p-value: 0.736
- Conclusion: The series is not stationary (p-value > 0.05).
- **LVAAG** (Agricultural value added)
- ADF statistics: -0.293
- p-value: 0.926
- Conclusion: The series is not stationary (p-value > 0.05).
- **GOV** (Gouvernance)
- ADF statistics: -2.917
- p-value: 0.043
- Conclusion: The series is stationary (p-value < 0.05).

Non-stationary series (LPOP, LURB, LVAAG) must be differentiated or transformed to achieve stationarity before ARDL modeling.

After initial differentiation, these series become stationary, which justifies the choice of the ARDL model.

RESULT AND DISCUSSION

A. Presentation of Results

Regarding stationarity (ADF and PP tests) the variables appear stationary at first order difference, suggesting I(1) for all of them.

Estimation of the ARDL Model:

The preferred ARDL model is estimated and diagnosed with test, showing the stability and the fit of the proposed model.

The overall fit of the ARDL (1, 1, 1, 0, 0, 0) estimated model is significant based on the Prob(F-statistic) = this value (p-value below)"5%" and account for about99 % precipitation variability in Morocco over the sample period.

Table 3. ARDL (1, 1, 1, 0, 0, 0) model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LPREC (-1)	0.070757	0.203872	0.347067	0.7320
LPOP	4.704055	2.253902	2.087071	0.0493
LPOP (-1)	-2.581316	1.767146	-1.460725	0.1589
LPOP2	-0.308050	0.149090	-2.066196	0.0514
LPOP2(-1)	0.171501	0.116395	1.473445	0.1555
LURB	0.367912	0.102072	3.604443	0.0017
LVAAGR	-0.013181	0.384389	-0.034292	0.9730
LGOUV	1.166688	0.306247	3.809631	0.0010
C	-14.31089	6.764350	-2.115634	0.0465
R-squared	0.990306	Mean dependent var		0.322494
Adjuste d Rsquared	0.986612	S.D. dependent var		0.224145
S.E. of regressi on	0.025935	Akaike info criterion		-4.223146
Sum squared resid	0.014125	Schwarz criterion		-3.802787
Log likelihoo d	72.34719	Hannan-Quinn criter.		-4.088669
F-statistic	268.1481	Durbin-Watson stat		2.060172
Prob(F-statistic)	0.000000			

Source: from estimation results using Eviews 12

The results of the ARDL model enable to draw conclusions on the influence of these factors on the sustainable mobilization and management of water resources in Morocco. The results reveal that there are relationships between explanatory variables and water management. A complete explanation of the estimated coefficients and relevant statistics is given below:

LPREC (-1)

The positive and nonsignificant coefficient (0.0708, p = 0.7320) indicates that rainfall in the previous year does not have a significant impact on water resource management at this time period. "This suggests that prior precipitation is not an indicator of current water management practices.

LPOP

Existing population has a strong positive impact (4.7041, p = 0.0493) on sustainable water management. This might be indicative of increased water management efforts due to increasing population, such as newer infrastructure development or changes in public policies.

LPOP(-1)

The number of people of the previous year has a nonsignificant negative impact (-2.5813, p = 0.1589), suggesting that past demographic dynamics have not affected directly water management practices in the present.

LURB

Urbanization effects significantly positively (0.3679, p = 0.0017) sustainable water resources management. One possible explanation could be investments in urban infrastructure that have led to efficiencies in water management.

LVAAGR

Agricultural value added exerts the non-significant negative effect (-0.0132, p = 0.9730), and this contribution supporting that agricultural sector has- not directly significant effect on water management.

LGOUV

Already, governance has highly significant positive influence (1.1667, p = 0.0010) on sustainable water resources management. This emphasizes the critical role of public policy and regulation in enhancing water management.

Constant (C)

The negative constant term (-14.3109, p = 0.0465) was able to accommodate the basic level (base level - the initial values of water management).

Model Statistics:

R-squared: 0.9903 means 99.03% of the variation in water resource management is explained by model and it's a very high value states how well the model fits.

The F-value of 268.15 with a very low p value (0.0000) implies that the overall model is extremely significant.

Durbin-Watson 2.06 indicates there's not much of autocorrelation in the residuals and hence, model doesn't suffer from the risk of disguised dependency among variables.

ANALYSIS AND DISCUSSIONS

The findings from this study represent an original contribution to our understanding on how water governance operates in a country like Morocco and can be related to several assumptions that have been made along with international water governance literatures, dealing mainly with dry/arid lands. Within these, demographic growth and urbanization's contributions to understanding water sustainability have been significant. This result supports the argument from ref [13], which identified demographic pressure as a structurant of the water stress. Urban population growth in Morocco has occurred so quickly that the increased demand for drinking water and sanitation have necessitated large investments to build infrastructure. This pattern is in accordance with the results obtained by [33] who indicated that rapid urbanization in developing countries can lead to increase water management efficiency once proper public policies are established, especially through scaled and rational distribution systems.

As important is the role played by governance quality in supporting sustainable water management, which further confirms [34], who describe governance as "the heart" of IWRM. In the Moroccan context, that increasing water regime is found have to reduced due to development and also the water system's resilience has been enhance by institutional frameworks, especially in the case of national Water Plan (PNE) and National Programme of Drinking Supplying Project and irrigation 2020–2027. However, as [35] pointed out, public policy tends to be conditioned by institutional fragmentation and weak cooperation between administrative levels that make them less effective in the long run.

The picture is more complex for agriculture. Despite representing close to 80% of Morocco's total water withdrawals, our findings indicate that agricultural value added does not structurally contribute directly to explain water sustainability. This seemingly paradox finding could be explained by the spread of improved irrigation techniques, i.e., trickle system particularly as a side effect of the GMP and its subsequent "Generation Green" initiative. [36], the expansion of local irrigation has stopped withdrawals from increasing with irrigated areas. "Although these techniques can potentially help to address the issue of overexploitation of groundwater, other authors [37] argue that they will not be sufficient if this promotes a rebound effect from agricultural intensification."

The weak predictive value of antecedent rainfall adds to focus more on the unpredictable and uncertain hydroclimatic context in Morocco, including planning water-led too-exclusively-on rainfall variations. This is consistent with the observation of [38] on non-stationarity in hydrological systems because of climate change. It indicates the immediate need to strengthen coping capacity (supply side [desalination, reuse]) and not rely on annual table yield variation.

Finally, the growth of Moroccan cities has often been perceived as threatening for water security but may also be perceived as a move towards more modern and optimized management. But this is fragile momentum and may

further fuel territorial imbalances, particularly in rural municipalities and small towns, which often experience deficits in infrastructure. The OECD (2019) indicates that multi-level governance actions, designed to tackle these imbalances, are fundamental to ensure that the progress realized from urban water modernization can be enjoyed more equally by all territories.

A overall, these findings would appear to support the necessity of continuing to improve policy outcomes in the direction of integrated governance, technological upgrading and territorial equalization. They also highlight a few nuances to some of the widely accepted truisms in literature: Yes, agriculture remains the single largest user of water, but its net contribution to sustainability is not necessarily negative if institutional reform and technological adaptation can be successfully upscaled.

CONCLUSION

With the mounting water challenge, characterized by diminishing supplies of freshwater and mounting collection of human-induced and climate-related stresses, Morocco is now at the inflection point when it comes to change. "The country has reached a point where it is no longer sustainable to be fragmented and reactive. It has to operate in a holistic, visionary manner, one that is unabashedly focused on sustainability," The econometric estimates derived from the ARDL model revealed that there are statistically enduring relationships between availability of water resources and several driving forces, notably population growth, urban expansion, and governance.

These statistical regularities are not simple theoretical abstractions; they express a material reality where the challenges of water management are cross-cutting and transversal to sectors, society and economics. Population growth has continued to put increasing pressure on water resources, but urbanization ever-so-gradually becomes less of a problem and more of an opportunity–if it can be well managed – especially in terms of efficiency management with water infrastructure. The second, in addition to State capacity is also related to governance because a transparent, consistent and participatory institutional setting can sharply increase the adaptability of the national water system over time (as evolutions show sustainable development policies prove).

In this context, IWRM is therefore indispensable. It is not only a question of making better use of the water available but of changing the very logic of planning, allocation, financing or regulation. Promising perspectives are opening up with the use of innovative technological solutions such as smart irrigation systems, remote sensing or low-energy desalination and water recycling; however, this is dependent on a correlation with improved knowledge among decisionmakers at private and public level.

Similarly, the active involvement of all stakeholders (local communities and users, farmers, industrialists and civil society) is essential to develop consensus on water priorities for the country. The management of water could no longer be approached simply as a technical expertise, but as an issue which influenced territorial development, social cohesion and the national security.

The management of water assets will, in this context, play a fundamental role for the country's economy and society. Therefore, the structuring of an evidence-based public policy, supported by a monitoring system and an open governance, as the body of support of a credible national strategy, is more essential. It will hope to preserve it as an asset and strengthen the resilience of the territories in all terrains and ensure a fair access to all, while allowing Morocco to face, with greater means, the uncertainties linked to climate change. In a word, water should not, in this perspective, remain the problem of a single sector. It is also an indicator of the degree of organization the country succeeds in inventing and the capacity of uniting around the common goods it knows to be essential for its future.

This paper's objective is to contribute to identify water resources sustainability determinants for Morocco using ARDL model (1995–2022). The results give some interesting conclusions which could help to better understand the water governance in drylands. 1) Population pressure and urbanization are the main factors that generate water management. In a paradox way, the urbanization, and the associated modern infrastructures and more compact/efficient urban systems, can allay the pressure during a time of such rapid population growth when the demand on the scarce fresh water can be finally overwhelming.

Second, water resilience is made stronger as an important dimension of governance: stronger institutions, better regulators and clearer decision-making rules make Morocco much less vulnerable to water scarcity. Third, high agricultural consumption (and by implication, high water uses in the two right-hand columns) does not, over the long run, seem to be a permanent drag on water sustainability, perhaps because irrigation capital becomes more efficient or because policy becomes better adapted. The low explanatory power of antecedent precipitation is yet another reminder of how fragile Morocco's hydro-climatic settings are and how soon structural adaptation measures need to be implemented in the near future.

Implications of the findings. The results show that water management is not just a technical, or hydrological, challenge, but one that is located in social and economic relations and in the capacity of governance delivery. They also underline the importance of going beyond the partial to the comprehensive and the need for forward-looking approaches, such as that which integrates efficiency, effectiveness and environmental sustainability.

Considering these findings, few suggestions are the following:

- **Institutional Consolidation and Coordination:** Morocco should further develop an articulated multi-level governance, to help mitigate fragmentation among national, regional and local levels. We need to ensure that policy is streamlined with focus on transparency, accountability and stakeholder engagement as it relates to water.
- **Accelerate technology modernization:** It will take more efficient irrigation systems, smart water monitoring technologies and large desalination or wastewater reuse plants to adapt to climate variability.
- **1Promote territorial equity in access to water:** Even though systems have been modernized, as a general rule urban centers continue to enjoy more and better access than rural communities and small localities. This implies that policies should aim to reduce territorial disparities and ensure that the right of access to water services is secure for every citizen.
- **Reconcile with a more environmentally friendly agriculture:** Agriculture is the major consumer of water, but its long term footprint may be reduced through more diversified cropping patterns and encouragement of lower water requiring crops, along with continued investments to make water use in agriculture much more efficient.
- **Establish flexible and resilient planning tools:** A country such as Morocco, conscious of the non-stationarity of hydroclimatic systems in the context of climate change, is to generate planning tools that are able to anticipate uncertainty more than historical precipitations.

In the final analysis, water future of Morocco will not only be made by how it can mobilize new resources but more importantly and critically how effectively it can govern and allocate the old. Political will, technology and inclusiveness Starting from its governance system, Morocco has the potential to ensure that it develops a water system that is future-proofed yet still enable social and economic development as well as ecological preservation. The evidence offered by this article supports the idea that it is a matter of life and wealth to shift towards sustainable water management in the country as well.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, H.O.; methodology, H.O.; software, H.O.; validation, A.B., and M.O.; formal analysis, H.O.; investigation, H.O.; resources, H.O.; data curation, H.O. and A.B.; writing original draft preparation, H.O. and A.B; writing review and editing, H.O.; visualization, H.O.; supervision, A.B.; project administration, M.O; funding acquisition, H.O., A.B., M.O., and all authors have read and agreed to the published version of the manuscript.

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REFERENCES

P. H. Gleick, « Water, Drought, Climate Change, and Conflict in
Syria », *Weather, Climate, and Society*, vol. 6, nº 3, p. 331-340, juill. 2014, doi: 10.1175/WCAS-D-13-00059.1.

World Bank, *Beyond Scarcity: Water Security in the Middle East and North Africa*. Washington, DC: World Bank, 2018. doi: 10.1596/978-1-4648-1144-9.

J. Schilling, E. Hertig, Y. Tramblay, et J. Scheffran, « Climate change vulnerability, water resources and social implications in North Africa », *Reg Environ Change*, vol. 20, nº 1, p. 15, mars 2020, doi: 10.1007/s10113-020-01597-7.

M. Tanarhte, A. J. De Vries, G. Zittis, et T. Chfadi, « Severe droughts in North Africa: A review of drivers, impacts and management », *Earth-Science Reviews*, vol. 250, p. 104701, mars 2024, doi: 10.1016/j.earscirev.2024.104701.

M. El Haddadi, H. Lahjouji, et M. Tabaa, « The Nexus Between Economic Growth and Water Stress in Morocco: Empirical Evidence Based on ARDL Model », *Sustainability*, vol. 17, nº 15, p. 6990, août 2025, doi: 10.3390/su17156990.

M. H. Pesaran, Y. Shin, et R. J. Smith, « Bounds testing approaches to the analysis of level relationships », *J of Applied Econometrics*, vol. 16, nº 3, p. 289-326, mai 2001, doi: 10.1002/jae.616.

K. Madher et A. ELMOUTAOUAKIL, « Risques Hydriques au Maroc : Similitudes et Divergences entre régions », *AME*, vol. 6, nº 1, p. 165-183, 2024, doi: https://doi.org/10.48374/IMIST.PRSM/amev6iSpécial%201.46901.

W. Znaidi et R. Lahrach, « Gestion des connaissances : Catalyseur de la transition énergétique durable au Maroc », *RFREG*, vol. 6, nº 1, janv. 2025, Consulté le: 25 août 2025. [En ligne]. Disponible sur: https://www.revuefreg.fr/index.php/home/article/view/1926

B. LAZRAK et C. MALAININE, « La coopération internationale au développement : un pilier essentiel pour un avenir global ? », *RFREG*, vol. 5, nº 11, nov. 2024, Consulté le: 25 août 2025. [En ligne]. Disponible sur: https://www.revuefreg.fr/index.php/home/article/view/1835

R. Kaiss *et al.*, « Water Stress and Regional Governance in Morocco: Pathways to Agricultural Resilience through Advanced Regionalization », *Res. World Agric. Econ.*, août 2025, doi: 10.36956/rwae.v6i3.2173.

Redouane Kaiss *et al.*, « Impact of Climate Change on Water Resources and Ecological Sustainability in Morocco: A 1990–2022 Analysis », *Res. in Ecol.*, p. 53-70, mai 2025, doi: 10.30564/re.v7i2.9205.

D. Blanchon et A. Boissière, *Atlas mondial de l'eau. Défendre et partager notre bien commun*. in Atlas. Paris: Autrement. [En ligne]. Disponible sur: https://shs.cairn.info/atlas-mondial-de-l-eaudefendre-et-partager-notre-bien-commun--9782746763012?lang=fr

F. Molle et P.-L. Mayaux, « Les angles morts de la politique de l'eau au Maroc: », *Confluences Méditerranée*, vol. N° 126, nº 3, p. 165-184, nov. 2023, doi: 10.3917/come.126.0166.

A. C. Kuper, O. Aloui, A. Daoudi, M. Elloumi, et I. Gharbi, « Hybridation des modes d'accès à la terre et à l'eau au Maghreb : Une perspective historique », COSTEA, 2023. [En ligne]. Disponible sur: https://www.comite-costea.fr/wp-content/uploads/8-RapportFinal_FoncierIrrigue_Maghreb.pdf

Amine Hmid, R. Kaiss, et A. Boutaieb, *De La gestion classique au Management stratégique : Vers un nouveau paradigme pour des territoires résilients et durable*. Generis-publishing, 2025.

Amine Hmid *et al.*, « Statistical Analysis of Drivers of Environmental Education and Climate Resilience Through SchoolBased Environmental Clubs: A Case Study from Morocco », *J. of Environ. & Earth. Sci.*, vol. 7, nº 8, p. 178-190, août 2025, doi: 10.30564/jees.v7i8.10780.

A. Hmid, « From Planning to Strategic Territorial Management », *IJRISS*, vol. VIII, nº III, p. 1791-1813, 2024, doi: 10.47772/IJRISS.2024.803129.

K. Jaafary, B. Kouissi, et N. Maatala, « Développement durable des oasis de montagne : préserver les ressources naturelles et le patrimoine culturel. », Institut Agronomique et Vétérinaire Hassan II, École Nationale d'Agriculture de Meknès ; Institut National Agronomique de Tunisie, Etude, 2024. [En ligne]. Disponible sur: http://www.abhatoo.net.ma/maalama-textuelle/developpementdurable/environnement/ecosystemes-terrestres/ecosystemes-deterres-arides/deserts/developpement-durable-des-oasis-demontagne-preserver-les-ressources-naturelles-et-le-patrimoineculturel

K. Mahdaoui, T. Chafiq, L. Asmlal, et M. Tahiri, « Assessing hydrological response to future climate change in the Bouregreg watershed, Morocco », *Scientific African*, vol. 23, p. e02046, mars 2024, doi: 10.1016/j.sciaf.2023.e02046.

S. Saoussen et L. Karim, « LES RESSOURCES EN EAU AU CAP BON: DES CONFLITS SOCIO-ENVIRONNEMENTAUX AUX VULNÉRABILITÉS ÉCOSYSTÉMIQUES », *REDS*, vol. 52, nº 3, p. 123-143, sept. 2021, doi: 10.53373/REDS.2021.52.3.032.

A. Du Plessis, « Persistent degradation: Global water quality challenges and required actions », *One Earth*, vol. 5, nº 2, p. 129-131, févr. 2022, doi: 10.1016/j.oneear.2022.01.005.

J. Gao, J. Li, T. Tong, J. Chao, Z. Dong, et J. Zhan, « Water quality evaluation, pollution sources apportionment, and environment management strategies in plain reservoirs: A case study of Tianhe Lake, China », *Ecological Indicators*, vol. 175, p. 113491, juin 2025, doi: 10.1016/j.ecolind.2025.113491.

B. M. Shakya, T. Nakamura, S. Shrestha, S. Pathak, K. Nishida, et R. Malla, « Tap Water Quality Degradation in an Intermittent Water Supply Area », *Water Air Soil Pollut*, vol. 233, nº 3, p. 81, mars 2022, doi: 10.1007/s11270-021-05483-8.

M. El Bakkari, « Évolution de la sante vegetale et impacts de l'erosion dans la region d'Oueltana Amont (Maroc): Une analyse basee sur l'indice NDVI. », *REA*, nº 49, p. 112-119, 2025, doi: 10.12795/rea.2025.i49.06.

A. BADI, K. KARIM, H. BENYASSINE, et A. CHARRASS, « Le tourisme durable au Maroc : un levier d'innovation et de résilience dans le cadre du nouveau modelé de développement », oct. 2024, doi: 10.5281/ZENODO.13909007.

J. CHEHBOUNI, « Le tourisme, alternative pour la durabilité des écosystèmes oasiens au Maroc », janv. 2025, doi: 10.5281/ZENODO.14585852.

C. Strava, « Sustainable Water Management and Indigenous SocioTechnical Heritage in Marrakech, Morocco », *Blue Papers*, vol. 3, nº 1, mai 2024, doi: 10.58981/bluepapers.2024.1.17.

M. Mangal et A. Govind, « Water, agriculture, and climate: a study of Moroccan agricultural water management policy », *Water Policy*, p. wp2025313, juill. 2025, doi: 10.2166/wp.2025.313.

H. Taleb, « WATER MANAGEMENT IN MOROCCO », in

Management of Intentional and Accidental Water Pollution, G. Dura, V. Kambourova, et F. Simeonova, Éd., in NATO Security through Science Series. , Dordrecht: Springer Netherlands, 2006, p. 177-180. doi: 10.1007/1-4020-4800-9_15.

M. REZZOUQI et B. NADIR, « Les enjeux juridiques de l'application de l'intelligence artificielle dans la prévention et la gestion des risques liés à l'eau », *RIC*, vol. 5, nº 3, août 2024, Consulté le: 27 août 2025. [En ligne]. Disponible sur: https://www.revuechercheur.com/index.php/home/article/view/103 5

Z. Zein Taleb *et al.*, « Prendre soin de la nappe : quelles possibilités et quelles prédispositions des collectifs d'agriculteurs des oasis de Todgha Ferkla (Maroc) à installer des dispositifs de recharge de la nappe ? », 2024, doi: 10.60569/HSOAS-A4.

M. H. Pesaran et Y. Shin, « An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis », in *Econometrics and Economic Theory in the 20th Century*, S. Strom, Éd., Cambridge: Cambridge University Press, 1999, p. 371-413. doi: 10.1017/CCOL521633230.011.

V. Foster et C. Briceno-Garmendia, *Africa's infrastructure: A time for transformation.*, Africa Development Forum. Washington DC:

World Bank, 2010. [En ligne]. Disponible sur:

file:///C:/Users/hp/Downloads/ssrn-3355421.pdf

C. Tortajada, « Policy dimensions of development and financing of water infrastructure: The cases of China and India », *Environmental*

Science & Policy, vol. 64, p. 177-187, oct. 2016, doi: 10.1016/j.envsci.2016.07.001.

L. M. Silva-Novoa Sánchez, L. Bossenbroek, J. Schilling, et E. Berger, « Governance and Sustainability Challenges in the Water Policy of Morocco 1995–2020: Insights from the Middle Draa Valley », Water, vol. 14, no 18, p. 2932, sept. 2022, doi: 10.3390/w14182932.

Y. Almulla, C. Ramirez, B. Joyce, A. Huber-Lee, et F. Fuso-Nerini, « From participatory process to robust decision-making: An Agriculture-water-energy nexus analysis for the Souss-Massa basin in Morocco », Energy for Sustainable Development, vol. 70, p. 314-338, oct. 2022, doi: 10.1016/j.esd.2022.08.009.

U. B. Antu et al., « Emerging technologies for efficient water use in agriculture: A review of current trends and future directions », Journal of Water Process Engineering, vol. 68, p. 106317, déc. 2024, doi: 10.1016/j.jwpe.2024.106317.

P. C. D. Milly et al., « Stationarity Is Dead: Whither Water Management? », Science, vol. 319, no 5863, p. 573-574, févr. 2008, doi: 10.1126/science.1151915.

