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General Features of the Libyan Strategy for Water Resource Management

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ABSTRACT

Current reports highlight a global water crisis affecting humanity and the environment. Libya, with its limited water resources, relies primarily on groundwater, with agricultural use accounting for 78% of consumption, urban at 12%, and industrial at 10%. This paper assesses the challenges of water scarcity and proposes a Libyan water resource management strategy. It reveals that the depletion of groundwater is largely due to previous political decisions allowing unrestricted well drilling. Without intervention, Libya risks complete resource depletion, leading to significant economic and political costs. The proposed strategy emphasizes the need for a clear water policy and effective management practices. It calls for a reevaluation of agricultural consumption policies to enhance efficiency and promote alternative water sources like desalination and treated wastewater. Additionally, it suggests reprogramming investments in the Great Man-Made River and prioritizing water allocations for the most affected areas. Researchers urge adherence to environmental protection regulations and recommend integrating these insights into the Libyan strategy to mitigate negative impacts effectively.

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INTRODUCTION

Water plays a critical role in maintaining ecological balance on the Earth's surface and is of paramount importance for humans, animals, and plants; life cannot be sustained without it. This significance has been recognized by humanity since ancient times, as evidenced by the emergence and flourishing of civilizations in regions abundant in water resources. Although the total volume of water on Earth remains constant at any given moment, as dictated by the Law of Conservation of Mass, the transformation of water between different states and its spatial variability have led to both an abundance of water sources in certain areas and scarcity in others. The Earth is often referred to as the "blue planet" because approximately 70% of its surface is covered by water. However, it is crucial to consider that the majority of this water is saline or locked in glaciers; 97% of the Earth's water is found in oceans and seas, while 2% is held in ice caps, leaving only a small fraction accessible for human use [1].

Natural water resources face significant threats from pollution and overconsumption, both of which are exacerbated by increasing population pressures. In Libya, available water resources consist of both renewable and non-renewable traditional sources (including rainfall, surface water, and groundwater), as well as non-traditional sources (such as desalinated water and treated wastewater). Libya is characterized by a desert or semi-desert climate and critical geographical conditions, making it one of the countries with very limited water resources. There are no renewable surface water sources such as rivers, and the area receiving rainfall does not exceed 100 mm, accounting for only 5% of

Libya's total land area [2]. The primary source of water in Libya is the groundwater reservoirs found in the Jafara, Ghadames, Murzuq, Green Mountain, Kufra, and Sirte basins, which together constitute approximately 95% of the available water resources. Given that over 85% of the population and industrial and agricultural activities are concentrated along the coastal strip, the demand for water in this region has significantly increased over the last three decades [3]. This has led to the depletion of coastal basin waters, resulting in a negative impact on groundwater levels and water quality in the Jafara and Green Mountain basins due to seawater intrusion and improper waste disposal. Additionally, the water quality in the Ghadames and Murzuq basins has deteriorated due to human activities, fertilizers, and chemicals used in agriculture, which have further contributed to the decline in groundwater levels. Occidental Libya has conducted a study on the hydraulic gradient of the Kufra area, which demonstrated that the hydraulic gradient extends 300 km to the northeast, indicating that water movement flows from the southwest to the northeast [4]. Urban and architectural development leads to an increase in per capita water consumption, consequently resulting in a rise in polluted waste and its infiltration into groundwater, rendering it unsuitable for human consumption. This situation poses significant risks to both the environment and public health. The study aims to assess the water situation in Libya by examining the volume of available water resources and the quantity of water requirements. It seeks to identify the relevant authorities and legislation concerning water resources based on previous studies and research. Additionally, the study proposes suggestions or indicators to assist decision-makers in developing a national strategy and action plan for water resource management by recommending alternatives to preserve water reserves in line with available capabilities. Studies have highlighted Libya's water challenges, such as over extraction of groundwater and the inefficiencies in wastewater reuse. Regional comparisons show the importance of regulating groundwater extraction and implementing conservation policies in agriculture to preserve water reserves. Additionally, the effective management of desalination facilities and wastewater treatment plants is essential to meet future water demands. These studies underline those political decisions, such as the unrestricted drilling of wells, have contributed to the unsustainable use of groundwater resources. Libya relies primarily on traditional water sources, such as rainfall, surface water, and groundwater. However, these resources are limited due to climatic and geographical factors, leading to serious water challenges: Libya has an arid to semi-arid climate, with rain primarily falling in the northern regions, ranging from 300 mm/year in Al-Jifarah to 500 mm/year in the Al-Jabal Al-Akhdar region. In contrast, rainfall in southern regions is scarce, often below 100 mm/year, with only 5% of Libya's area receiving over 100 mm/year [2]. Fresh surface water is minimal in Libya, it is estimated at about 200 million cubic meters/year (million cubic meters/year) [5]. Limited to seasonal rivers (wadis) and small dams, primarily in Al-Jabal Al-Akhdar and Jabal Nafusa. Libya operates 16 dams with a total storage capacity of 385 million cubic meters, though actual annual storage averages only 60 million cubic meters due to inconsistent rainfall [6].

The primary source of water in Libya, providing approximately 95% of the country's water supply. Key aquifers are located in the Al-Jifarah, Kufra, and Murzuq basins. The annual flow from permanent springs is estimated at 185 million cubic meters (m^3/year), while seasonal springs contribute approximately 12 million cubic meters (m^3/year). The total available water from these sources is estimated to be around 70 million cubic meters (m^3). The total volume of exploited water is approximately 4,980 million cubic meters (m^3/year), with the Kufra and Sarir basins, along with the Murzuq basin, accounting for about 64% (1,600 million cubic meters (m^3/year)) of the annually available water from non-renewable reserves. Meanwhile, the renewable and investable water resources are estimated at approximately 650 million cubic meters (m^3/year). The Man-Made River Project (MMRP) transports approximately 6.18 million cubic meters (m^3) of groundwater daily from the depths of the desert to densely populated northern areas via specially designed concrete pipelines. The designated uses of the water from the Man-Made River are allocated as follows: 80% for agricultural purposes, 12% for urban uses, and 5% for industrial applications [7, 8].

Since the 1970s, Libya has built around 400 desalination plants, mainly along the coast, producing approximately 230 million cubic meters annually. However, poor maintenance and mismanagement have rendered many plants inoperative, with desalination covering only 2% of water needs [9]. Out of 74 wastewater plants, only 7 are operational, producing 30.8 million cubic meters of treated water annually—far below the target of 511 million cubic meters. Public resistance to using treated wastewater and a lack of infrastructure have limited reuse, with much untreated sewage being discharged into the sea, violating international environmental agreements like the Barcelona Convention [10]. These challenges highlight the urgent need for policy reforms to promote sustainable water management, expand desalination capacity, and improve wastewater reuse to reduce reliance on groundwater.

METHODS

This research employs a descriptive-analytical approach to assess Libya's water resources, consumption patterns, and the effects of management policies. Data was collected from various sources, including national reports, government

publications, and previous studies on water availability, agricultural consumption, and urban usage. Additionally, semi-structured interviews were conducted with local stakeholders in the Department of Water Resources Management. These interviews aimed to gather qualitative insights on the challenges faced in water management, perceptions of water scarcity, and the effectiveness of current policies.

Descriptive analysis was applied to summarize water use by sector, highlighting trends in consumption and scarcity through measures such as averages and percentages. To further examine the factors driving water scarcity, correlation analysis assessed the relationship between water demand and factors like agricultural expansion and population growth, while regression analysis identified the major contributors to water demand and evaluated each sector's impact on overall water scarcity.

Key findings from the analysis indicated the need to optimize agricultural water use, enhance non-conventional sources such as desalination, and develop targeted national policies for water resource management. Missing data was managed through imputation and historical averages to ensure consistency across the dataset. This approach provided a comprehensive assessment of the factors influencing water scarcity in Libya, leading to informed recommendations for sustainable water management practices.

RESULTS

Libya's water consumption is highly skewed towards agriculture, which accounts for 78% of total water use, followed by urban use (12%) and industrial use (10%). Groundwater levels have dropped significantly, especially along the coastal areas, due to agricultural overuse. Existing desalination plants and wastewater treatment facilities are insufficient, with only 7 out of 74 wastewater plants operational. Desalination contributes minimally to the water supply, covering only 2% of total consumption. The Table 1 figure out the result of the Libya's Water Consumption Patterns from 1995 to 2025.

Table 1. Libya's Water Consumption Patterns (1995–2025)

Year	Agricultural Use	Urban Use	Industrial Use	Total Consumption
1995	3377 MCM/year	364 MCM/year	145 MCM/year	3886 MCM/year
2005	3800 MCM/year	603 MCM/year	500 MCM/year	4980 MCM/year
2025*	6462 MCM/year	790 MCM/year	340 MCM/year	7592 MCM/year

Figure 1 presents water consumption trends from 1995 to a projected estimate for 2025 across three sectors: agricultural, urban, and industrial. The x-axis represents the years (1995, 2005, 2025), while the y-axis indicates total consumption in million cubic meters per year (MCM/year), ranging from 0 to 8000 MCM for clarity.

- Agricultural Use (green): Increased from 3377 MCM/year in 1995 to 6462 MCM/year in 2025.
- Urban Use (blue): Rose from 364 MCM/year in 1995 to a projected 790 MCM/year in 2025.
- Industrial Use (orange): Increased from 145 MCM/year in 1995 but is projected to decrease to 340 MCM/year by 2025.

Each bar is labeled with its corresponding MCM/year value, and a note highlights that the 2025 data is projected. The figure emphasizes the growing water demands, particularly in agriculture.

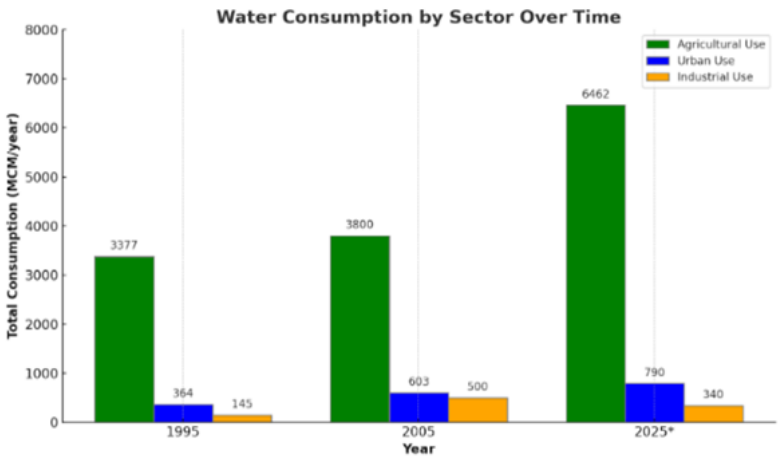

Figure 1. Water Consumption sector over time.

DISCUSSION

The findings of this study indicate that unregulated agricultural practices are the primary driver of water scarcity. Despite the known benefits of water-efficient irrigation systems, such as drip irrigation, the implementation of these technologies remains inadequate. Furthermore, the use of non-conventional water sources, including desalinated water and treated wastewater, has not yet reached its full potential. This paper advocates for a transition toward sustainable water management practices, emphasizing the need to restrict groundwater extraction, rehabilitate existing desalination facilities, and promote wastewater reuse in agriculture. The Man-Made River Project, which supplies water from remote aquifers to coastal cities, represents a critical piece of infrastructure. However, relying solely on this project without adopting sustainable policies poses a significant risk of aquifer depletion, potentially leading to severe social and economic repercussions. Authors should engage in a comprehensive discussion of the results, interpreting them in light of prior studies and established hypotheses. The implications of these findings should be contextualized within the broader discourse on water resource management, and directions for future research should be outlined.

A historical analysis of water production from desalination and treated wastewater, juxtaposed with total water consumption, highlights the limited role of non-conventional water sources in meeting overall water needs. For instance, in 1998, these sources accounted for only 4.01% of total consumption. This contribution is expected to diminish further by 2025, driven by population growth, economic development, and agricultural expansion. This trend exacerbates existing water scarcity challenges, which can be summarized as follows: In the event of groundwater depletion, the absence of accurate studies on the size and quantity of Libya's groundwater resources could result in a humanitarian disaster. Groundwater levels continue to decline due to over-extraction, with no alternative water sources or clear national conservation plan in place. Additionally, pollution from untreated wastewater threatens public health, water resources, and marine and animal life. Non-conventional water sources play an ineffective role in meeting water needs, falling short of sustainable development requirements in Libya. The quantities produced from desalination and wastewater treatment are insufficient and almost negligible, failing to align with the country's geographical and material capabilities. Contributing factors include insufficient maintenance of existing facilities, inadequate training and financial incentives for local and international technicians and engineers, and a lack of new desalination and wastewater treatment plants to meet current demands. Furthermore, there has been a failure to harness solar energy for desalination and urban applications to reduce costs. Expansion in the establishment of seawater desalination plants is limited, and there is no dedicated institution under the Ministry of Water Resources to oversee desalination project implementation and management.

CONCLUSION

The assessment of Libya's water resources reveals significant challenges but also opportunities for sustainable management. With groundwater as the primary source of water, the country faces severe depletion due to policies that allowed unrestricted well drilling. Urban, industrial, and especially agricultural demands continue to exceed the capacity of renewable water sources, placing immense pressure on groundwater reserves. Additionally, public awareness of water scarcity is limited, as media coverage and educational efforts have not sufficiently highlighted the economic and social consequences of resource depletion. Compliance with environmental laws, including Law No. 15 of 2003, remains inconsistent, and emergency preparedness measures are lacking.

To address these pressing issues, a national water strategy is essential. Such a strategy should prioritize efficient water use, especially in agriculture, by adopting modern irrigation techniques suitable for Libya's conditions. Strengthening regulatory and institutional support for the Ministry of Water Resources, including enforcing well-drilling restrictions, is crucial for protecting remaining reserves. Public awareness and education campaigns will help foster a culture of conservation and encourage responsible usage. Expanding non-conventional water sources, such as desalination and wastewater treatment, with a focus on renewable energy sources like solar power, will further reduce reliance on groundwater. Additionally, regional and private sector collaboration can support sustainable water resource management, inviting investment and innovation in water services. By implementing these strategic measures, Libya can establish a resilient and adaptive water management framework that not only meets the immediate needs of its population but also safeguards its water resources for future generations. Such an approach will contribute to sustainable economic growth, environmental preservation, and social stability, ensuring that Libya's limited water resources are managed wisely and effectively in the face of ongoing and future challenges.

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Conflicts of Interest
The author declares no conflicts of interest.

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الملامح العامة للاستراتيجية الليبية لإدارة الموارد المائية

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الملخص

تشير التقارير المحلية والدولية إلى أزمة المياه العالمية التي تؤثر على الإنسانية والبيئة بشكل كبير. وتعتمد ليبيا، بمصادرها المائية المحدودة، بشكل رئيسي على المياه الجوفية، حيث يشكل الاستهلاك الزراعي 78% من إجمالي الاستخدام، والاستهلاك الحضري 12%، والاستهلاك الصناعي 10%. تهدف هذه الورقة إلى دراسة تحديات ندرة المياه واقتراح استراتيجية وطنية لإدارة الموارد المائية في ليبيا. وتبين الدراسة أن الاستنزاف الأساسي للمياه الجوفية يعود بشكل رئيسي إلى قرارات سياسية سابقة سمحت بحفر الآبار دون قيود. وفي غياب استراتيجية شاملة لإدارة الموارد المائية، تواجه ليبيا خطر استنفاد مواردها بشكل كامل، مما سيترتب عليه تكاليف اقتصادية وسياسية كبيرة. تؤكد الاستراتيجية المقترحة على أهمية وضع سياسة مائية واضحة وتبني ممارسات إدارة فعّالة. كما تدعو إلى إعادة تقييم سياسات استهلاك المياه في القطاع الزراعي بهدف تحسين الكفاءة وتشجيع استخدام مصادر بديلة مثل تحلية المياه وإعادة استخدام المياه المعالجة. توصي الاستراتيجية المقترحة بإعادة توجيه الاستثمارات في مشروع النهر الصناعي العظيم وتخصيص المياه بشكل أولوي للمناطق الأكثر تضرراً. ويشدد الباحثون على ضرورة الالتزام بكافة بنود النظام العام لحماية البيئة ولوائحه التنفيذية واللوائح والتصاميم المتعلقة بحماية البيئة، مع مراعاة توصيات هذا التقرير عند إعداد الاستراتيجية الليبية لضمان التحليل السليم وتخفيف الآثار السلبية قدر الإمكان.

الكلمات المفتاحية: إدارة الموارد المائية، سياسة المياه، ندرة المياه، الاستهلاك الزراعي، حماية البيئة.