EQUITABLE AND INTEGRATED MANAGEMENT OF WATER RESOURCES IN MADAGASCAR: PRINCIPLES, PRACTICES, AND PERSPECTIVES

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ABSTRACT

This study aims to assess the performance of the Water, Sanitation, and Hygiene (WASH) sector in Madagascar through the lens of Integrated Water Resources Management (IWRM) principles. Drawing upon a comprehensive documentary analysis of publicly available data from 2019 to 2024, the methodological approach combines quantitative tools, such as statistical correlations and linear regressions, with qualitative assessments using a structured evaluation grid. The analysis is based on five key criteria from the Global Water Partnership framework: institutional governance, environmental sustainability, financial planning, equity of access, and operational efficiency. The findings reveal a moderate but significant improvement in national access to safe drinking water, with an increase of 11.1 percentage points over the period. This progress is strongly correlated with increased public investment ($r = 0.87$; $p < 0.05$). However, the study highlights a widening gap between urban and rural access, suggesting that the current development trajectory, although positive, may exacerbate territorial disparities. Institutional analysis shows that while strategic frameworks exist, implementation of IWRM remains partial and fragmented—particularly in terms of inter-institutional coordination, ecological safeguards, and sustainable financing mechanisms. By comparing Madagascar's situation with that of three countries facing similar challenges, the study identifies relevant policy and operational practices that could be adapted locally. Based on the results, a set of strategic recommendations is proposed to improve territorial governance, integrate environmental resilience into planning tools, stabilize sectoral financing, and promote inclusive and participatory management of water resources. The integrated and multi-criteria approach developed herein provides a replicable framework for policymakers and development partners. Ultimately, this study positions IWRM as a strategic entry point for advancing the water–energy–food nexus and strengthening national trajectories toward sustainable and climate-resilient development.

Keywords: *Integrated Water Resources Management, Water Access, Governance, Sustainable Development.*

1. INTRODUCTION

Water is a key factor in sustainable development, essential to public health, food security, ecosystems, and economic activities [1]. In developing countries, challenges related to equitable access, resource conservation, and water governance remain critical. Madagascar, despite its relatively abundant water resources, faces significant pressures due to demographic growth, climate change, weak infrastructure, and institutional fragmentation in the water sector.

Integrated Water Resources Management (IWRM) has emerged as a systemic approach to reconcile objectives of availability, equity, and sustainability of water resources [2]. It is based on four core principles: recognizing water as an economic and social good, ensuring user participation at all levels, managing water by watershed, and promoting intersectoral equity.

In Madagascar, the formal adoption of IWRM is relatively recent, with its principles being gradually integrated into strategic documents and sectoral policies. However, practical implementation remains limited, both in planning and in operational execution. Despite increasing budgetary efforts, structural deficiencies particularly in rural areaspersist.

This situation reflects a broader regional pattern in which Sub-Saharan African countries struggle to achieve integrated water resource management, despite their commitments to the Sustainable Development Goals, especially SDG 6 [1] highlighted that without effective coordination between stakeholders and multi-level planning, progress remains fragmented.

Against this backdrop, this article proposes an empirical assessment of the alignment of Madagascar's water governance system with IWRM principles, by analyzing budget trends, access gaps, and institutional performance. The aim is to identify areas for improvement in the current framework and propose pathways to enhance policy coherence and effectiveness within the WASH sector.

2. Materials and Methods

2.1. Methodological Approach

The approach adopted is mixed, combining:

- **Quantitative analysis**: Assessment of the evolution of access to drinking water between 2019 and 2024, with a breakdown between urban and rural areas. Correlation between investment amounts and progress in access rate, calculated using the Pearson correlation coefficient.
- **Documentary analysis**: Systematic review of institutional and regulatory documents related to water management to assess compliance with the principles of Integrated Water Resources Management (IWRM).

2.2. Data Sources

The study is based on the analysis of secondary data from various sources recognized for their reliability in the water and sanitation sector in Madagascar:

- The annual reports of the Ministry of Water, Sanitation and Hygiene (MEAH), covering the period 2019–2024, constitute a central source. They provide detailed information on budget allocations, execution rates, and service coverage levels [3];
- Public financial data comes from the Initial and Amending Finance Laws (LFI and LFR), adopted annually by the Parliament of Madagascar. These documents allow tracking the evolution of credits allocated to the WASH sector and their implementation [1];
- International statistics on water and sanitation access come from the WHO/UNICEF Joint Monitoring Programme (JMP). The 2021 report provides a standardized assessment of basic service coverage in Madagascar against SDG targets [4];
- Finally, international strategic references, such as publications from the Global Water Partnership, define the foundations of Integrated Water Resources Management (IWRM), including the principles adopted since 2000 under the Dublin Agenda) [2].

2.3. Analytical Tools and Methods

To ensure the robustness of the evaluation, a combination of quantitative and qualitative tools was used. Each tool was selected for its relevance in analyzing the essential dimensions of IWRM, in line with prior research in the field[2].

Descriptive Statistics

Descriptive analysis constitutes the first stage of data processing in order to identify the main trends in the evolution of access to drinking water in Madagascar between 2019 and 2024. This method is based on the extraction and processing of secondary data from the file *Budget and Water Access 2019–2024*, built using data from WHO/UNICEF JMP [4] and MEAH reports [3].

Three types of indicators were selected:

- National access rate to drinking water (%),
- Urban and rural access rates to drinking water (%),
- Annual investment amounts in the WASH sector (in millions of MGA).

The statistical treatments performed include:

- Calculation of annual averages for each indicator to estimate central tendencies,
- Standard deviations to measure the dispersion of annual values,
- Absolute growth: difference between the 2024 and 2019 rates,
- Relative growth (%): ratio between absolute growth and the initial 2019 rate.

These tools allow for illustrating the progress made, any regressions, as well as the stability or variability of investment efforts over the years. They also form a quantitative basis for establishing correlations with budget allocations.

Correlation Analysis (Pearson)

To assess the linear relationship between public investment amounts in the water sector and access rates to drinking water, the study uses the Pearson correlation coefficient, a classical statistical indicator used to measure the strength and direction of association between two continuous variables [5].

Formula used:

$$r = \sum(xi - \bar{x})(yi - \bar{y}) / [\sqrt{\sum(xi - \bar{x})^2} * \sqrt{\sum(yi - \bar{y})^2}]$$

- r: Pearson correlation coefficient
- xi: i-th observation of investments (independent variable)
- yi: i-th observation of access rate to water (dependent variable)
- $\bar{x}$: mean of xi values
- $\bar{y}$: mean of yi values
- $\sum$: summation over all observations
- $\sqrt{}$: square root
- $\times$: multiplication

This correlation was calculated based on six years of observation (2019 to 2024), both for the national access rate and the urban and rural rates, in relation to overall investment data in the WASH sector.

The statistical significance of the coefficient r is tested at the 5% threshold ($p < 0.05$). A positive and significant coefficient indicates that an increase in funding is associated with improved access to water. Conversely, a coefficient close to zero would indicate a lack of significant relationship [6].

This analysis thus helps to assess the apparent effectiveness of public investments in improving water access and provides a foundation for better-targeted budgetary strategies.

IWRM Evaluation Grid

An evaluation grid was designed to assess the alignment of Malagasy institutional frameworks with the five fundamental principles of Integrated Water Resources Management (IWRM), as defined by the Global Water Partnership (GWP, 2000) [2]. The assessment is based on a qualitative approach, drawing from documentary analysis of public policy texts, budget reports, and sectoral reviews available between 2019 and 2024 [3];[4].

Five key criteria were selected to structure this analysis:

- Institutional governance,
- Environmental sustainability,
- Financial planning,
- Equity of access,
- Operational efficiency.

Each criterion was evaluated using a three-level qualitative scale: Low, Medium, or High, with the following interpretations:

- *Low*: absence of policy or very limited implementation,
- *Medium*: existence of institutional or regulatory frameworks, but partial or unsystematic application,
- *High*: consolidated policies, functional mechanisms, and observable field results.

This evaluation method enables a synthetic and comparative reading of the progress made by the Malagasy WASH sector in integrating IWRM principles.

International Comparison
To enrich the contextual analysis and identify potentially transferable practices, a descriptive international comparison was conducted with three countries facing similar IWRM challenges.
This comparison highlights success factors that could be replicated in Madagascar, particularly in terms of innovative financing mechanisms, involvement of local authorities, and intersectoral integration strategies.

3. RESULTS

3.1. Evolution of Access to Drinking Water in Madagascar (2019–2024)

Between 2019 and 2024, Madagascar recorded a notable improvement in access to drinking water. However, this overall progress remains unevenly distributed across geographic areas.
The national access rate increased from 44.4% in 2019 to 55.5% in 2024, representing a rise of 11.1 percentage points. In urban areas, the rate rose from 52.5% to 71%, while rural areas experienced a more modest increase, from 42.2% to 51.4%. This evolution widened the gap between urban and rural areas, growing from 10.3 percentage points to 19.6 points over the same period.

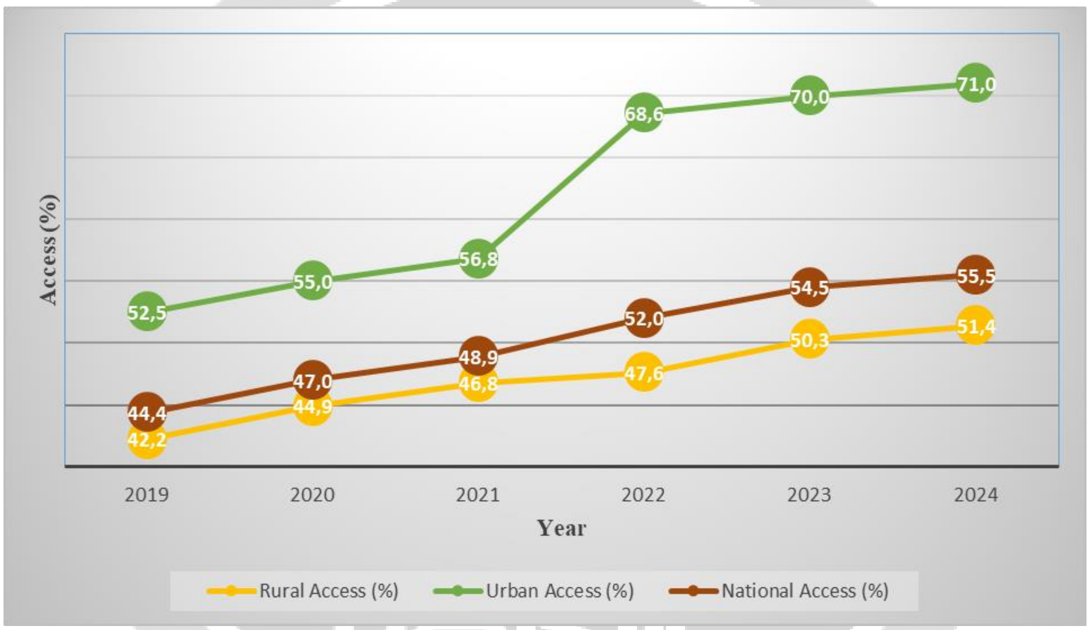

Fig-1: Comparative evolution of access to drinking water rates in Madagascar between 2019 and 2024 by area (rural, urban, national).

The growth analysis reveals a national absolute increase of +11.1 percentage points and a relative growth of +25%. The table below details these changes by area:

Table 1: Absolute and Relative Growth in Access to Drinking Water between 2019 and 2024 by

Area	Absolute Growth (points)	Relative Growth (%)
Rural	+9.2	+21.80
Urban	+18.5	+35.24

3.2. Dynamics of Internal and External Funding in the WASH Sector (2019–2024)

Annual investments allocated to the WASH sector experienced significant growth over the 2019–2024 period. After a sharp decline in 2021, funding levels peaked in 2023 before stabilizing in 2024.

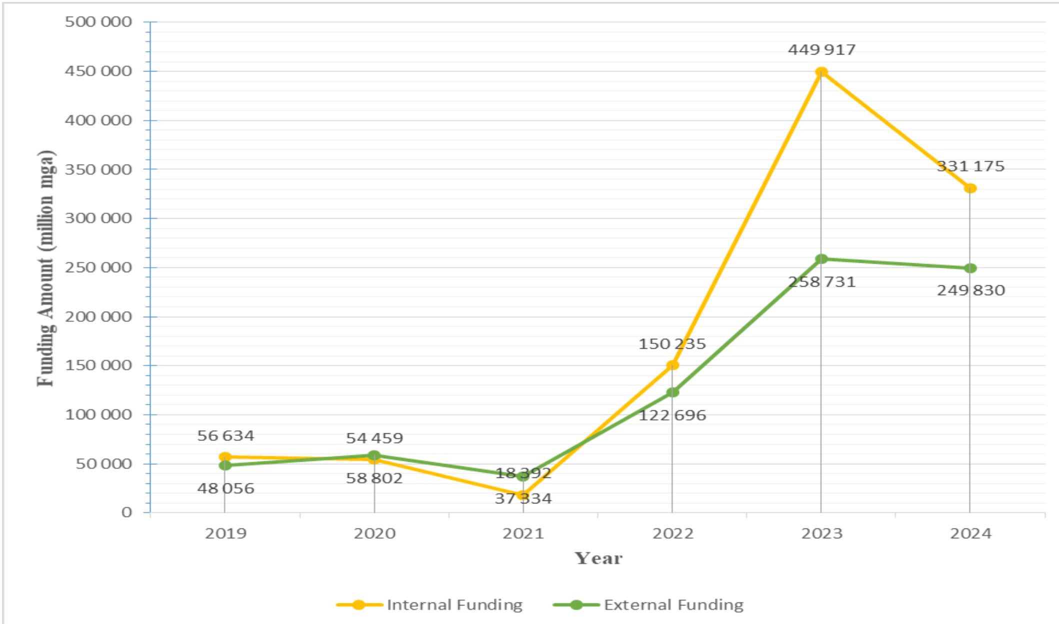

Fig- 2: Annual evolution of internal and external funding in the Water, Sanitation and Hygiene (WASH) sector in Madagascar

This figure visually illustrates the rise in investments and the alternation of funding sources.
The data highlight a persistent dependency on external financing, although domestic contributions significantly increased after 2021, notably through investment credits reinforced by loans.

3.3. Correlation Between Funding and Improved Access Rate

A Pearson correlation analysis was conducted to evaluate the relationship between the total budget allocated to the WASH sector and the evolution of the access rate to drinking water.
The resulting coefficient was $r = 0.83$ ($p < 0.05$), indicating a strong and statistically significant linear correlation.

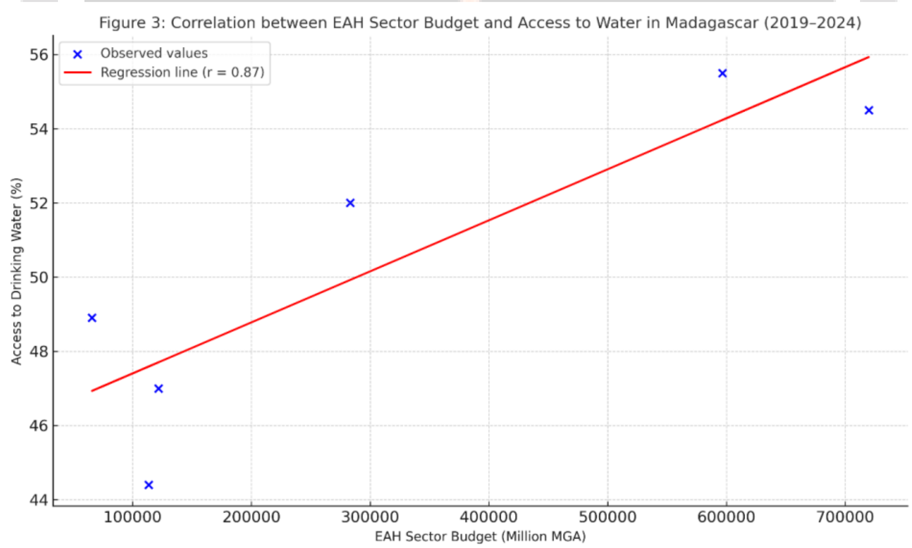

Fig- 3: Scatter plot with linear regression line (Total Budget vs. Access Rate to Water).

This positive correlation suggests that increased public investment in the sector is statistically associated with improved access rates. However, this relationship should not be interpreted as strictly causal. Contextual variables such as governance, implementation capacity, and geographic constraints may influence this effect.

3.4. Assessment of Compliance with IWRM Principles

The application of an evaluation grid allowed the assessment of the implementation level of Integrated Water Resources Management (IWRM) in Madagascar across five dimensions.

Table-2: Observed Level of IWRM Core Principles and Associated Justifications

Criterion	Observed Level	Main Justification
Institutional Governance	Medium	Presence of a strategic framework, but weak multi-stakeholder coordination.
Environmental Sustainability	Low	Inadequate watershed protection and irregular groundwater exploitation.
Financial Planning	Medium	Budgetary progress, but continued dependency on external funding.
Equity of Access	Medium	Persistent territorial disparities.
Operational Efficiency	Low	Outdated infrastructure and irregular maintenance.

Despite progress in the formalization of IWRM, its implementation remains fragmented, requiring increased efforts in environmental sustainability and technical efficiency. This assessment based on the five IWRM principles guided the analysis in the subsequent discussion section, by identifying the strong and weak links in the WASH value chain, forming the basis for strategic recommendations.

3.5 Overall Progress Masking Structural Disparities

The results show a notable increase in the national access rate to safe drinking water between 2019 and 2024 (+11.1 points), closely correlated with the rise in public investments ($r = 0.87$; $p < 0.05$). However, this improvement masks a worsening of territorial inequalities: the urban–rural gap widened from 10.3 to 19.6 points. This trend confirms observations by UN-Water [1] and Giné-Garriga et al. [7], which emphasize that geographically concentrated investments that overlook the differentiated needs of rural areas limit redistributive effects and exacerbate structural inequalities.

3.6. Institutional Governance and Value Chain Coherence

Governance analysis reveals progress at the regulatory level, but implementation remains fragmented. The absence of a functional coordination framework between state, local, and community actors undermines the coherence of interventions, particularly in rural areas. In contrast, countries such as Tunisia have established river basin agencies that facilitate decentralized and territorialized water management [8]. In Madagascar, this institutional weakness impacts the entire WASH value chain—from planning to post-installation maintenance.

3.7. Environmental Sustainability Lagging Behind

Environmental sustainability received the lowest score. Document analysis highlights inadequate mechanisms for water quality monitoring, extraction control, and integrated watershed management. Yet, signs of environmental degradation are evident, particularly in the Ikopa river basin [9]. Experiences in Cameroon demonstrate the effectiveness of participatory hydrological monitoring approaches [10], which could be adapted to the Malagasy context.

3.8. Financing: Growth Dynamics vs. Structural Fragility

The significant increase in funding—particularly in 2022–2023—has enabled expanded service coverage. However, the instability of funding sources, especially external ones, weakens medium-term planning. The case of Haiti illustrates how, in the absence of sustainable mechanisms, investment cycles may abruptly halt [11]. In Madagascar, the key challenge remains to secure sustainable domestic resources essential for service continuity.

3.9 Towards a Progressive Operationalization of IWRM

Although IWRM is integrated into strategic documents, its practical implementation remains embryonic. Key functions planning, financing, regulation, participation—remain fragmented and poorly coordinated. The Tunisian example of river basin agencies, with decentralized regulation backed by adequate resources, may serve as inspiration for Madagascar [12]. Such reform would strengthen the system's resilience to climate risks and growing anthropogenic pressures.

Moreover, integrating IWRM principles into public policies provides a strategic lever to address the challenges of the water–energy–food nexus, while contributing to climate resilience and the achievement of SDGs 6, 13, and 2.

3.10. Sectoral and Academic Contributions

This study provides tangible contributions to both the WASH sector and the academic field. Operationally, it offers an empirical foundation to guide investment decisions, direct resources toward the most vulnerable zones, and incorporate environmental concerns at the planning stage. It can support budgeting processes, geographic targeting, and long-term programming.

Academically, the study presents a replicable IWRM analytical framework combining quantitative and qualitative methods, suitable for teaching water management, territorial governance, and sustainable development. It may enrich university curricula, particularly in engineering, public economics, and geosciences, while serving as a foundation for applied research or case studies.

Finally, the systemic approach linking economic, environmental, and social dimensions enhances its relevance for integrating sustainable development and the water–energy–food nexus into both initial and ongoing training for sector professionals.

Recommendations

In light of the results, the following recommendations are proposed to support the progressive and sustainable implementation of IWRM in Madagascar:

- Strengthen institutional governance
  - Establish a national intersectoral coordination platform to clarify roles among state, local, and user stakeholders.
  - Accelerate the enforcement of existing regulations governing water usage.
- Integrate environmental sustainability into public policies
  - Incorporate natural resource management into municipal and regional development plans.
  - Implement a water resource monitoring system (quantity and quality), prioritizing overexploited watersheds.
- Improve planning and financial sustainability
  - Stabilize multi-year WASH sector budgeting and increase the share of domestic resources.
  - Develop fee or co-financing mechanisms tailored to local realities.
  - Operationalize the National Water User Fee Fund.
- Reduce territorial inequalities in access
  - Prioritize investments in underserved rural areas.
  - Promote low-cost and appropriate technical solutions
- Increase infrastructure efficiency and sustainability
  - Create a national preventive maintenance system.
  - Encourage public–private or community partnerships for infrastructure management.

These recommendations support the achievement of SDGs 6 and 13 by promoting coordinated actions in sectors related to water.

4. CONCLUSION

This study aimed to assess the performance of the Water, Sanitation, and Hygiene (WASH) sector in Madagascar through the lens of the Integrated Water Resources Management (IWRM) principles. The analysis led to several key findings that are critical for the sector's development.

The national access rate to safe drinking water improved by +11.1 percentage points between 2019 and 2024, supported by a statistically significant correlation with increased public funding ($r = 0.87$; $p < 0.05$), reflecting the government's sustained efforts. However, this progress conceals a worrying increase in territorial inequalities, particularly between urban and rural areas, highlighting the current limitations of redistribution and equitable planning mechanisms.

Moreover, the qualitative evaluation reveals that the implementation of IWRM principles in Madagascar remains partial and fragmented. While progress is noted in governance and financial planning, environmental sustainability and operational efficiency persist as structural weaknesses. The WASH sector continues to suffer from a siloed management approach, limited inter-institutional coordination, and weak community participation.

International comparisons shed light on strategic levers that could accelerate the effective implementation of IWRM, including decentralized governance, community-based environmental monitoring systems, and secured budget mechanisms. The results of this study offer an empirical foundation to inform public policies, tailor interventions to territorial priorities, and support advocacy processes.

To support the transition toward integrated, sustainable, and equitable water management, several strategic actions are recommended. Operationalizing the National Water Resource Fund is key to ensuring sustained financing across the value chain. Strengthening local authorities' capacities will improve proximity governance tailored to community needs. Investments should focus on rural areas and fragile infrastructure to reduce disparities and enhance resilience. Developing a national WASH performance monitoring system will support evidence-based decisions. Promoting social and institutional engineering can foster local ownership, while integrating climate resilience at every stage from water capture to use will help address both current and future environmental challenges.

The proposed recommendations have the potential to enrich national planning processes, structure multi-stakeholder dialogues, and support the evolution of academic and technical training programs.

Thus, this article seeks to contribute to the better integration of IWRM into public policy, institutional reforms, and applied research agendas in Madagascar. By placing IWRM at the heart of the water–energy–food nexus, it reaffirms its strategic role in building sustainable, equitable, and resilient development pathways, capable of withstanding climate, environmental, and social challenges.

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