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Conservation Strategies for Disappearing Lakes in Africa: Insights from Lake Haramaya, Ethiopia

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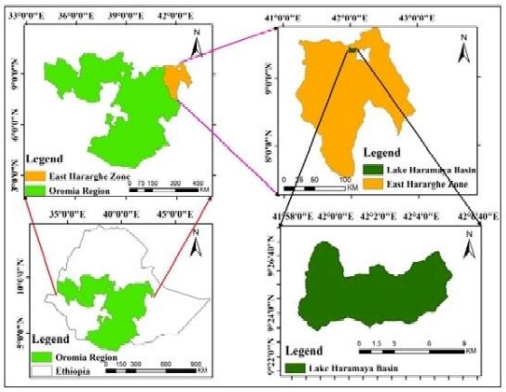
Abstract: ***Lake Haramaya, once a crucial freshwater reservoir in Ethiopia, has suffered ecological collapse due to climate change, unsustainable land use, and groundwater depletion. This review synthesizes research on the lake's decline, conservation gaps, and restoration strategies. By comparing Lake Haramaya to other disappearing lakes in Africa, we identify policy failures, hydrological mismanagement, and socio-economic consequences. Effective restoration requires integrating community-driven conservation, policy interventions, and sustainable water management practices. These findings provide valuable insights for conserving similar degraded lakes worldwide.***

Keywords: Lake Haramaya, Water Conservation, Deforestation, Ecosystem Restoration, Community-Based Conservation, Groundwater Recharge, Climate Resilience

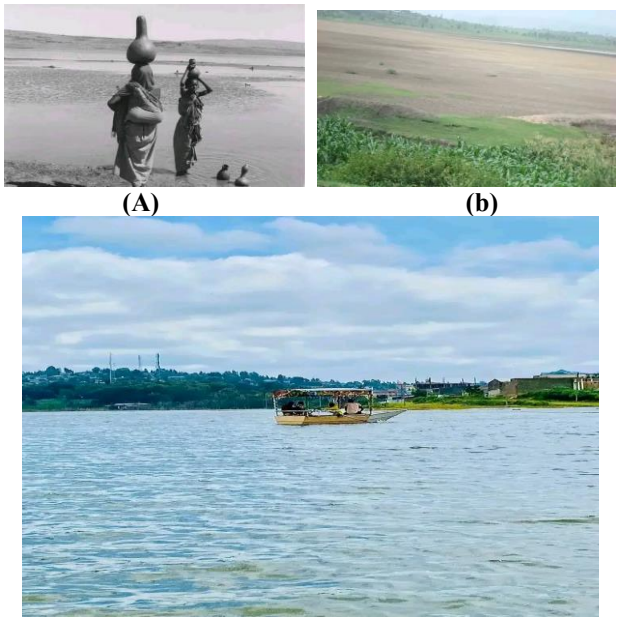
Abbreviations:
AJOL: African Journals Online
IWRM: Integrated Water Resource Management

I. INTRODUCTION

Freshwater lakes play a crucial role in maintaining ecological balance, supporting biodiversity, and providing essential resources for human livelihoods. However, many lakes worldwide face depletion due to unsustainable human activities and climate change. Lake Haramaya Catchment is one of the catchments in eastern Ethiopia, found in Haramaya District, Eastern Hararghe zone, Oromia Regional State (Figure 1). The catchment is situated on the main road from Addis Ababa to Harar town at a distance of 505 km from Addis Ababa and 20 km northwest of Harar town. It is situated at $9^0$23' - $9^0$26' North of latitude and $41^0$59' - $42^0$02' East of longitude. Lake Haramaya, formerly a significant water source in Ethiopia's Oromia region, has experienced a dramatic decline over the past decades [1]. This review examines the primary drivers of its degradation, assesses conservation efforts, and explores strategies for its restoration and preservation.



[Fig.1: Location of Lake Haramaya. Source of Map: [1]]



(A) **(b)**

(c)

[Fig.2: Lake Haramaya at Different Times. (A). In 1937, (B). From 1990 to 2000, and (C). 2014 [Source: Author]]

II. MATERIALS AND METHODS

This study systematically reviewed peer-reviewed literature, academic theses, and institutional reports on Lake Haramaya's ecological decline and conservation efforts. We searched Scopus, Web of Science, Google Scholar, and African Journals Online (AJOL) using keywords such as 'Lake Haramaya degradation,' 'groundwater depletion in Ethiopia,' and 'watershed management strategies.' Studies were selected based on relevance, publication date (2014–2024), and methodological rigour. A comparative analysis was conducted with similar degraded lakes (Lake Chad, Lake Urmia, and the Aral Sea) to identify applicable conservation lessons.

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III. RESULTS AND DISCUSSIONS

A. Drivers of Lake Haramaya's Degradation

Lake Haramaya has undergone significant environmental degradation due to a combination of anthropogenic and natural factors. Key causes include excessive groundwater extraction, deforestation, and climate change-induced droughts [2]. These major drivers of degradation are summarized in Table 1. Remote sensing studies indicate a dramatic reduction in Lake Haramaya's surface area, from 556 ha in 1973 to complete desiccation by 2020 (Table 2). These fluctuations highlight the urgent need for integrated conservation measures [2].

i. Climate Change and Hydrological Alterations

Climate variability has played a critical role in reducing water levels in Lake Haramaya. Studies using remote sensing techniques have documented significant fluctuations in its surface area between 1995 and 2020 [1]. Increasing temperatures and prolonged droughts have accelerated evaporation, further reducing water availability [2].

ii. Overextraction of Groundwater

Excessive groundwater extraction for agriculture and domestic use has significantly contributed to the lake's disappearance [3]. With no sustainable water management policies in place, the aquifers that feed the lake have been depleted, resulting in irreversible water loss.

iii. Deforestation and Land Use Changes

Unregulated deforestation for agricultural expansion and fuelwood collection has altered the hydrological balance in the Lake Haramaya watershed [4]. The loss of vegetation cover has led to reduced infiltration rates, increased surface runoff, and soil erosion, further aggravating the problem [5].

iv. Soil Erosion and Sedimentation

Heavy sedimentation from the surrounding catchment area has accelerated the lake's degradation. Poor land management practices, such as overgrazing and unsustainable farming, have exacerbated soil erosion, resulting in sediment accumulation in the lake [5].

Table-I: Summary of Key Drivers of Lake Haramaya's Degradation (Sources: Author Developed from the Following Sources)

Driver	Impact	Source
Climate Change	Increased evaporation, reduced rainfall patterns	[2]
Groundwater Extraction	Depletion of aquifers, reduced lake inflow	[3]
Deforestation	Reduced infiltration, increased runoff	[4]
Soil erosion	Increased sedimentation, reduced lake depth	[5]

Table-II: Lake Haramaya Surface Area Fluctuations Over Time [2]

Year	Surface Area (ha)
1973	556
1985	432
1995	275
2005	98
2010	27
2015	5
2020	0 (dry)

B. Socio-Economic Impacts of Lake Haramaya's Disappearance

The disappearance of Lake Haramaya has had a profound impact on local livelihoods, resulting in reduced agricultural productivity, water scarcity, and increased migration [6]. These impacts are summarised in Table 3.

i. Decline in Agricultural Productivity

Lake Haramaya was a primary source of irrigation for the surrounding farms. The loss of this water body has led to severe declines in crop yields, impacting food security in the region [6].

ii. Water Scarcity and Public Health Issues

The drying of the lake has forced communities to depend on alternative water sources, many of which are of lower quality. This has led to an increase in cases of waterborne diseases and worsened the health of the local population [6].

iii. Displacement and Livelihood Disruptions

Many households that previously depended on fishing and farming have faced economic hardships due to water shortages. This has resulted in migration, loss of employment, and increased poverty rates in the affected areas [6]

Table-III: Summary of Socio-Economic Impacts of Lake Haramaya's Disappearance

Impact Category	Description	Source
Agricultural Decline	Reduced crop yields due to a lack of irrigation water	[6]
Water Scarcity	Increased waterborne diseases and poor sanitation	[6]
Livelihood loss	Loss of income from fishing, farming, and tourism	[7]
Displacement and migration	Population movement due to economic hardships	[7]

C. Analysis of Conservation and Restoration Strategies

Several conservation strategies have been attempted in the Lake Haramaya catchment area, ranging from agroforestry to soil conservation techniques. However, their effectiveness varies due to challenges such as poor enforcement and high costs [3]. Table 4 provides a comparative overview of these conservation efforts.

i. Indigenous and Community-Based Conservation Approaches

Historically, local communities practiced soil and water conservation techniques such as terracing, agroforestry, and controlled grazing [3]. Community-based conservation strategies have often shown promise in engaging local stakeholders; however, their success can be hampered by:

- **Limited Resources:** Many local communities lack the necessary financial resources and technical expertise to implement effective conservation practices independently [6].
- **Inconsistent Participation:** Enthusiasm for community engagement can wane over time, especially if immediate

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economic benefits are not readily apparent [3].

- **Social Inequality:** In many cases, marginalized groups within communities may not have equitable access to decision-making processes or the benefits derived from conservation efforts, leading to resentment and resistance [8].

ii. Proposed Improvements:

- **Capacity Building:** Introduce training programs and workshops to develop local skills in sustainable practices, water management, and monitoring techniques. This can empower communities to participate actively in conservation efforts [9].
- **Incentive Structures:** Implement financial incentives, such as payment for ecosystem services (PES), to encourage community participation [10]. By linking conservation directly to economic benefits, stakeholders are more likely to remain engaged.
- **Inclusivity**: Ensure that conservation strategies consider all community members, particularly marginalized groups, to foster equity and broader support for conservation initiatives [11].

iii. Sustainable Water Management Policies

Regulating groundwater extraction through policy interventions is crucial for restoring the lake. The implementation of water conservation regulations, such as controlled irrigation practices, could help replenish underground water sources [2].

Water management policies, while integral to restoring lakes, often face execution challenges such as:

- **Poor Enforcement**: Although regulations may exist, they are rarely enforced, leading to continued overextraction and misuse of water resources [12].
- **Fragmented Governance:** In many regions, multiple stakeholders (e.g., government agencies, local authorities) operate independently, leading to conflicts and a lack of cohesive action [13].
- **Short-term Focus:** Policies often prioritise short-term economic gains over long-term ecological health, resulting in unsustainable practices [14].

iv. Proposed Improvements:

- **Strengthened Governance Frameworks:** Institutions should be strengthened to ensure effective enforcement of water management policies. This can be achieved through clearly defined roles, regular monitoring, and transparent reporting mechanisms [15].

Integrated Water Resource Management (IWRM) promotes a holistic approach that considers the interconnectedness of water sources, ecosystems, and human activities [16]. This approach facilitates collaboration among stakeholders and encourages the adoption of sustainable practices.

- **Long-term Planning:** Policies should be designed with a long-term vision that incorporates climate resilience, ecosystem health, and social equity. Regular assessments of policy impacts can help adapt to changing circumstances [17].

v. Reforestation and Watershed Management

Restoring native vegetation in the watershed can improve water infiltration and reduce sedimentation [4]. Large-scale afforestation programs, combined with soil conservation techniques, can enhance groundwater recharge and stabilize the lake's ecosystem. Reforestation efforts often focus on tree planting without sufficient consideration of local ecological contexts or community needs, and their limitations are:

- **Monoculture Plantations:** Planting a single species can decrease biodiversity and fail to restore the ecosystem's resilience [18].
- **Lack of Maintenance:** Many reforestation initiatives do not prioritize ongoing care and management, leading to high failure rates of newly planted trees [19].
- **Limited Community Involvement:** Local communities may not be involved in the planning or implementation of reforestation projects, leading to a disconnect between the programs and local knowledge [20].
- **Biodiversity-Focused Restoration:** Incorporate native species and local ecological knowledge in reforestation efforts to promote environmental integrity and resilience [21].
- **Aftercare Programs:** Develop systematic aftercare protocols to ensure the survival and growth of planted trees, which may include monitoring, watering, and protection from invasive species or livestock [22].
- **Participatory Approaches:** Engage local communities in the planning and implementation phases of reforestation projects to align efforts with their needs and knowledge, enhancing ownership and success rates [23].

vi. Ecotourism as a Conservation Strategy

Community-based ecotourism has the potential to generate alternative livelihoods while promoting conservation. Ecotourism initiatives in the Haramaya and Gurawa districts have shown promise in encouraging local participation in environmental protection [7].

While ecotourism has potential benefits for conservation, it also poses challenges:

- **Environmental Degradation:** Increased foot traffic and infrastructure development for tourism can lead to habitat destruction, pollution, and resource depletion [24].
- **Economic Leakage:** Profits from ecotourism may not always benefit local communities, as large companies or external interests often dominate the industry [25].
- **Seasonal Nature:** Ecotourism can be seasonal, leading to fluctuations in income for communities and inconsistent support for conservation efforts [26].

vii. Proposed Improvements:

- **Sustainable Development Practices:** Ensure that ecotourism practices adhere to sustainability principles, focusing on minimizing environmental

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impact and preserving natural habitats [27].

- **Community Ownership Models:** Promote models where local communities own and manage ecotourism ventures, ensuring that profits support regional development and conservation [28].

Table-IV: Existing Conservation Practices at Lake Haramaya and Their Effectiveness

Conservation Method	Effectiveness	Challenges	Source
Agroforestry & Reforestation	Moderate	Requires long-term maintenance	[4]
Soil & Water Conservation Structures	Low-moderate	High cost, limited adoption by farmers	[3]
Community-Based Conservation	Moderate	Needs stronger community engagement	[7]
Groundwater Regulation	Low	Poor enforcement and over-extraction continue	[3]

D. Comparative Analysis: Lessons from Other Degraded Lakes

The decline of Lake Haramaya shares similarities with other disappearing lakes globally, such as Lake Chad in Africa, Lake Urmia in Iran, and the Aral Sea in Central Asia (Table 5). Each of these water bodies has suffered from unsustainable water extraction, climate change, and land-use changes. However, restoration efforts in Lake Urmia have focused on controlled water release and afforestation, which could be applied in Ethiopia's context. Management strategies highlight the need for integrated watershed governance in Lake Haramaya's conservation [30]. These cases highlight the necessity for an integrated watershed management plan for Lake Haramaya, with a focus on policy enforcement, reforestation, and community-led conservation. Below is a summarized table that includes the decline drivers, restoration efforts, lessons learned, and sources for each lake. After the table, a list of references is provided.

- **Diversified Income Streams:** Encourage the development of multiple income-generating activities to reduce reliance on seasonal tourism, thereby providing economic stability to local communities [29].

Table-V: Comparative Analysis of Lake Haramaya's Degradation and Restoration Efforts with Other Degraded Lakes Worldwide (e.g., Lake Chad, Aral Sea, and Lake Urmia)

Lakes	Drivers of Decline	Restoration Efforts	Lessons Learned	Sources
Lake Haramaya	Over-extraction of groundwater	Community-based conservation initiatives	Integrated Management: Consider ecological, hydrological, and socio-economic factors.	[2] [3] [6]
	Deforestation and land use changes	Reforestation and soil conservation practices	Community Engagement: Involve local communities for sustainable interventions.	
	Climate change is exacerbating drought conditions.	Promotion of ecotourism		
	Soil erosion and sedimentation			
Lake Chad	Overuse of water for agriculture and population growth	Regional cooperation agreements for sustainable water management	Regional Cooperation: Collaboration among countries is essential	[30]
	Climate change is reducing rainfall.	Enhancing irrigation efficiency and promoting drought-resistant crops	Adaptation Strategies: Sustainable agricultural practices can help mitigate the impacts of climate change.	
Lake Urmia	Water diversion for irrigation	Implementation of water rights systems	Water Rights Management: Clear water rights improve resource management.	[30]
	Increased evaporation due to rising temperatures and drought	Reforestation and wetland restoration projects	Public Awareness: Engaging the public fosters a culture of conservation.	
	Unsustainable agricultural practices	Public awareness campaigns for conservation		
Aral Sea	Large-scale irrigation diverting rivers	Construction of the Kok-Aral Dam to restore the northern sea	Ecosystem Engineering: Engineering solutions should be part of a broader strategy.	[31] [32]
	Mismanagement of water resources	Restoration of wetlands and support for local fisheries	Economic Diversification: Diversifying local economies away from water-intensive practices is vital.	

E. Challenges and Future Directions

i. Institutional and Policy Challenges

Despite various conservation efforts, weak governance and a lack of effective enforcement mechanisms have hindered the implementation of effective restoration strategies. Strengthening institutional frameworks and integrating environmental policies into national development plans is crucial for achieving long-term success.

ii. The Need for Integrated Conservation Approaches

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A multi-disciplinary approach that incorporates hydrology, agroecology, and socio-economic research is crucial for sustainable restoration. Future studies should focus on innovative conservation techniques, such as artificial groundwater recharge and nature-based solutions [2].

To ensure long-term restoration, integrated strategies must address both ecological and socio-economic challenges. These strategies, including afforestation, controlled water extraction, and ecotourism, are outlined in Figure 3 and Table 6.

iii. Integrated Water Resource Management Plan for Lake Haramaya

Lake Haramaya has suffered severe ecological degradation due to groundwater overuse, deforestation, climate change, and poor watershed management. To address these challenges, an Integrated Water Resource Management (IWRM) Plan is essential for restoring the lake, ensuring sustainable water use, and improving community resilience. This plan follows a holistic approach that combines watershed protection, efficient water management, ecosystem restoration, and sustainable livelihoods.

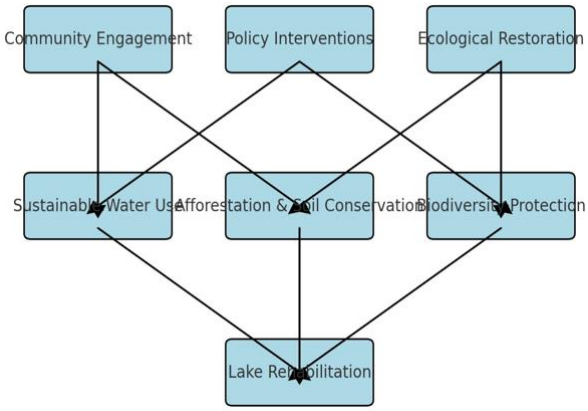
A key component of the IWRM strategy is watershed zoning and sustainable land-use planning, which aim to control soil erosion and prevent further degradation. Establishing buffer zones around the lake, promoting agroforestry, and implementing reforestation programs using native species can help reduce sedimentation and improve groundwater recharge. Additionally, efficient water utilization measures such as rainwater harvesting, regulated groundwater extraction, and modern irrigation techniques will prevent excessive water loss and support long-term water availability.

To restore the lake's hydrological balance, check dams, recharge wells, and wetland rehabilitation are necessary to enhance water retention and improve overall water quality. Alternative livelihood options, such as eco-tourism, beekeeping, and sustainable fisheries, can also help reduce dependency on water-intensive agriculture, thereby ensuring environmental and socio-economic stability. Furthermore, strengthening policy enforcement through the establishment of a Lake Haramaya Watershed Management Authority will ensure coordinated action among government agencies, researchers, and local communities.

By integrating scientific, policy-driven, and community-based approaches, the IWRM plan provides a long-term strategy for reviving Lake Haramaya while serving as a model for other degraded lakes in Africa. Its successful implementation requires strong institutional collaboration, local participation, and adaptive management to ensure sustainable conservation and water security in the region.

iv. Considerations for Future Research

Future studies should focus on evaluating the long-term impacts of implemented conservation strategies, assessing their ecological outcomes and socio-economic benefits. Research should also explore innovative solutions tailored to the unique contexts of specific lakes, fostering a deeper understanding of effective restoration practice.



[Fig.3: Integrated Framework for Lake Haramaya Conservation]

Table-VI: Proposed Strategies for Lake Haramaya Restoration

Strategy	Expected impact	Implementation need
Reforestation	Improved infiltration, reduced erosion	Large-scale tree planting, community participation
Controlled Water Extraction	Sustainable groundwater recharge	Strict regulations, water conservation awareness
Soil Conservation Techniques	Reduced sedimentation	Terracing, mulching, contour farming
Ecotourism Development	Alternative livelihood sources	Infrastructure, marketing strategies

IV. CONCLUSION AND RECOMMENDATIONS

The conservation of Lake Haramaya requires urgent and collaborative action. Sustainable land management, policy-driven water conservation, and active community participation are crucial for reversing ecological degradation. By integrating scientific research, traditional knowledge, and government policies, a comprehensive restoration framework can be developed to revive the lake and ensure water security for future generations.

To prevent further degradation, Ethiopian policymakers must adopt an integrated watershed management strategy, enforce water-use regulations, and invest in afforestation projects to restore groundwater levels. Additionally, establishing community-based conservation programs and ecotourism initiatives could provide sustainable economic incentives for local populations. Lessons from Lake Urmia's afforestation projects and Lake Chad's transboundary water-sharing models highlight the need for regional collaboration in water conservation policies. Without urgent intervention, Lake Haramaya's disappearance will set a dangerous precedent for Ethiopia's freshwater resources.

In general, the following recommendations were forwarded to be implemented:

- Implement water-use regulations to prevent over-extraction.
- Invest in afforestation projects for soil and water conservation.
- Develop community-based ecotourism to

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support sustainable land use.
- Strengthen inter-agency collaboration for watershed management.

By addressing these recommendations, Ethiopia can enhance its freshwater conservation efforts while contributing to broader discussions on international frameworks for biodiversity conservation and sustainable development.

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