Fourth International MAJI Scientific Conference "Water and Sanitation Solutions amidst Climate Change"
Mlimani City, Dar es Salaam, Water Institute, Ministry of Water, Tanzania, January 29, 2025

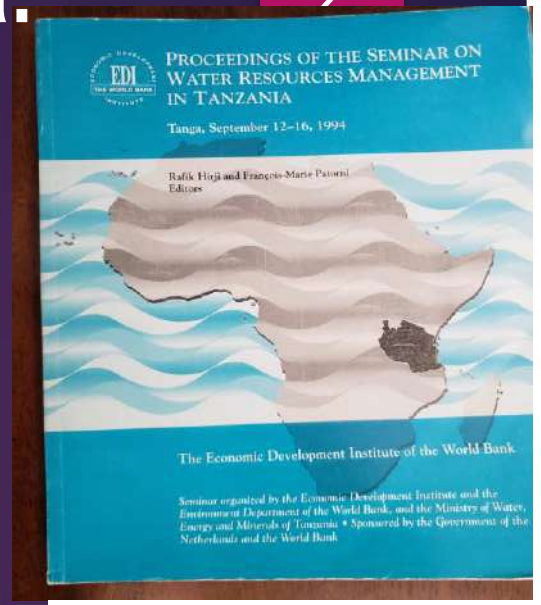
Keynote Address

Enhancing Climate Resilience: Developing Integrated Management Capacity for Lakes and Reservoir Basins in Africa

Dr. Rafik Hirji
Director, Water, Environment and Climate Solutions, USA
Former Technical Adviser, Ministry of Water, Tanzania
Former World Bank Team Leader, GEF Lake Basin Management Initiative

Engagement on IWRM reforms in Tanzania: 1993-2013

1991-93, Mtera Crisis, severe drought, low dam levels, water conflicts, power shortage
1993-94, GOT - Rapid Water Resources Assessment (RWRA)-priority Issues, 4 Priority Basins, WRM gap in capacity & water Policy, A phased WRM Reform strategy
1994 Tanga Seminar shared RWRA lessons & reccomendations Prioritized, sequenced reforms, learning from the past, laying initial foundation for IWRM
1996-2003, River Basin Management and smallholder irrigation improvement project, Pangani and Rufiji basins, Pilot SIIPs and NAWAPO 2002
2000-2012 Lower Kihansi Environmental Management Project
2004-2007 Dar es Salaam Water supply and Sewerage Project, WRBWO, Water supply masterplan, Kidunda Dam and Kimbiji aquifer
2006 World Bank - Tanzania Water resources assistance strategy: improving water security for sustaining livelihoods and growth, laid the foundation for the water sector development program (WSDP) 2006-2025
2007-2015 WSDP I. WRMA, Regulations, 9 BWOs, IWRDM Plans, Priority infrastructure (Kidunda Dam, Deep Kimbiji wellfields, Farkwa Dam, Ndembere Dam, Pangani wellfields



IWRM Implementation at the National & Basin level (2019-20)

Oct 2019 – Inception Report Recommendations, Plain language IWRDM Summary Reports
Dec 2019 – Preliminary Recommendations to the NMSF (1) Lessons from the IWRDM plan review, (2) National Water Policy Review, (3) National Integrated Water Resources Plan, (4) Center of Excellence & (5) National Water Sector Adaptation Program
Dec 2019 – Development Partner meetings – DFID, AFD, AfBD, WARIDI
Dec 2019 – LVB IWRDM Plan Inception Report workshop
Dec 2019 – Zone 3 IWRDM Plan workshop
Dec 2019 – Grid based water supply masterplan (Prof Mkumbo, PS, MAJI)
Feb 2020 – Zone 1 IWRDM Plan workshop
Mar, 2020 – NAWAPO Review
Mar 13 – COVID in Tanzania, Mar 15-20 – GOT cancels MAJI Week & all events
Mar 2020 – Draft Flood Management presentation
Mar – July 2020 – Final Flood Management Presentation, Detailed NAWAPO inputs, etc.
Jun 2023 – End of Contract Report

Two Key End of Contract Report Recommendations

1. In light of growing concerns about climate change and the increasing interest in supporting climate change adaptation and resilience programs in Africa—both directly and indirectly linked to Integrated Water Resources Development Management (IWRDM)—the report suggests ways the MOW can leverage existing work to create a cohesive program. This program could attract vital funding sources for the water sector.

2. Considering that some of the world's largest freshwater lakes hold vast quantities of water but are rapidly deteriorating and face inadequate sustainable management, the report recommends that the Government of Tanzania (GOT) establish a regional center in Tanzania. This center would enhance the capacity for Integrated Lake Basin Management (ILBM) in Tanzania and across Africa. Additionally, the GOT should look to the SADC Groundwater Management Institute as a model for effective practices.

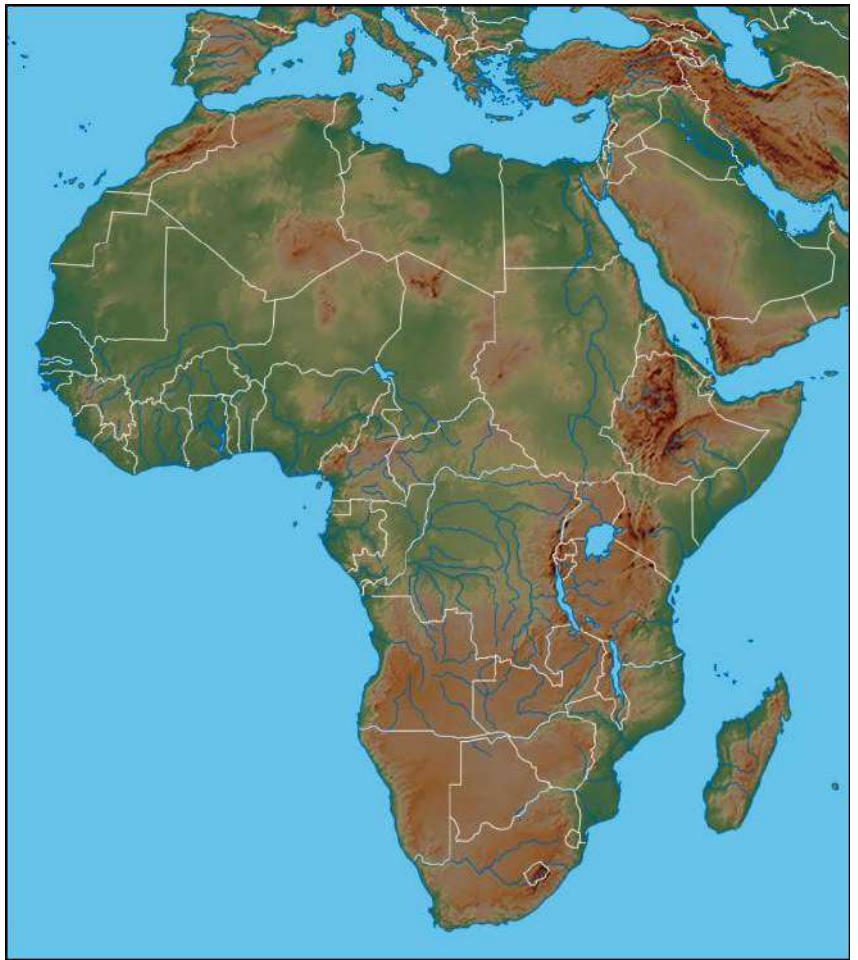
Presentation objectives are to:

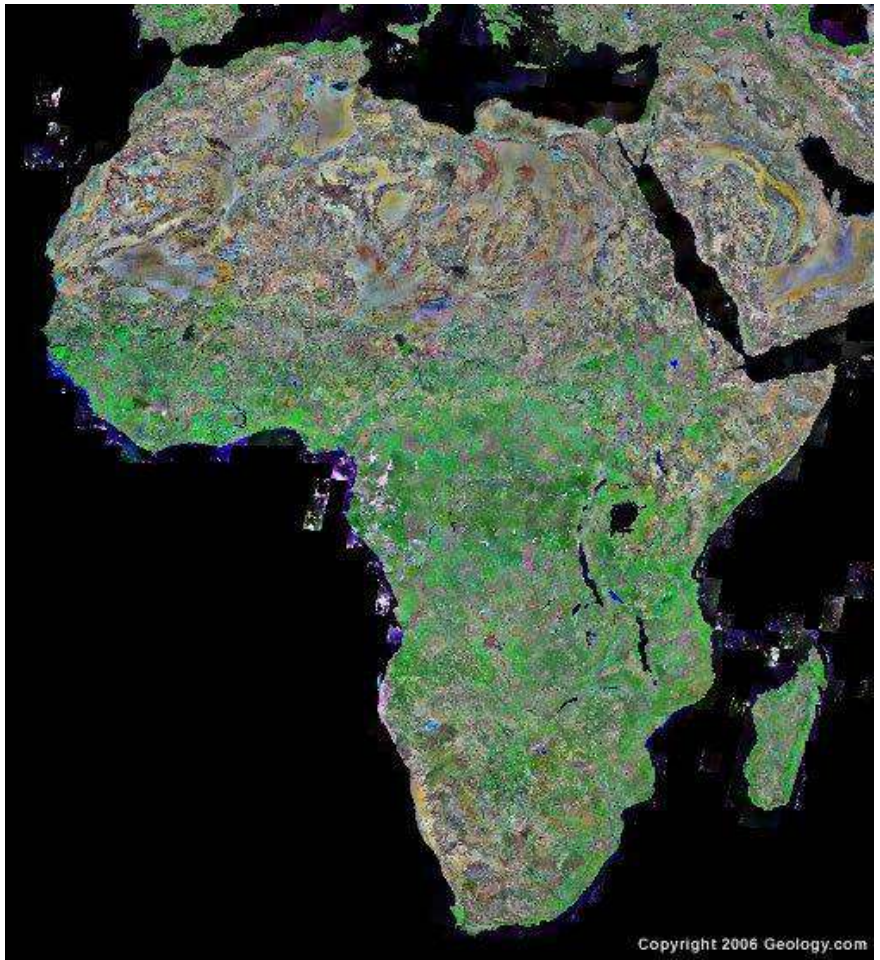
(1) Improve our collective understanding of the
(a) vital role lakes & reservoirs play in ensuring water security & in adapting to climate change,
(b) value of freshwater lakes, and
(c) rapid degradation of lakes & reservoirs & accelerated loss of benefits.

(2) Advocate for establishing a Center for strengthening African capacity for integrated lake and reservoir basin management in Tanzania.

From space, the only one recognizable nation in Africa…Tanzania is a truly blessed nation.

Bordered by Lakes Victoria to the north, Tanganyika to the west, Nyasa to the south & the Indian Ocean to the east.

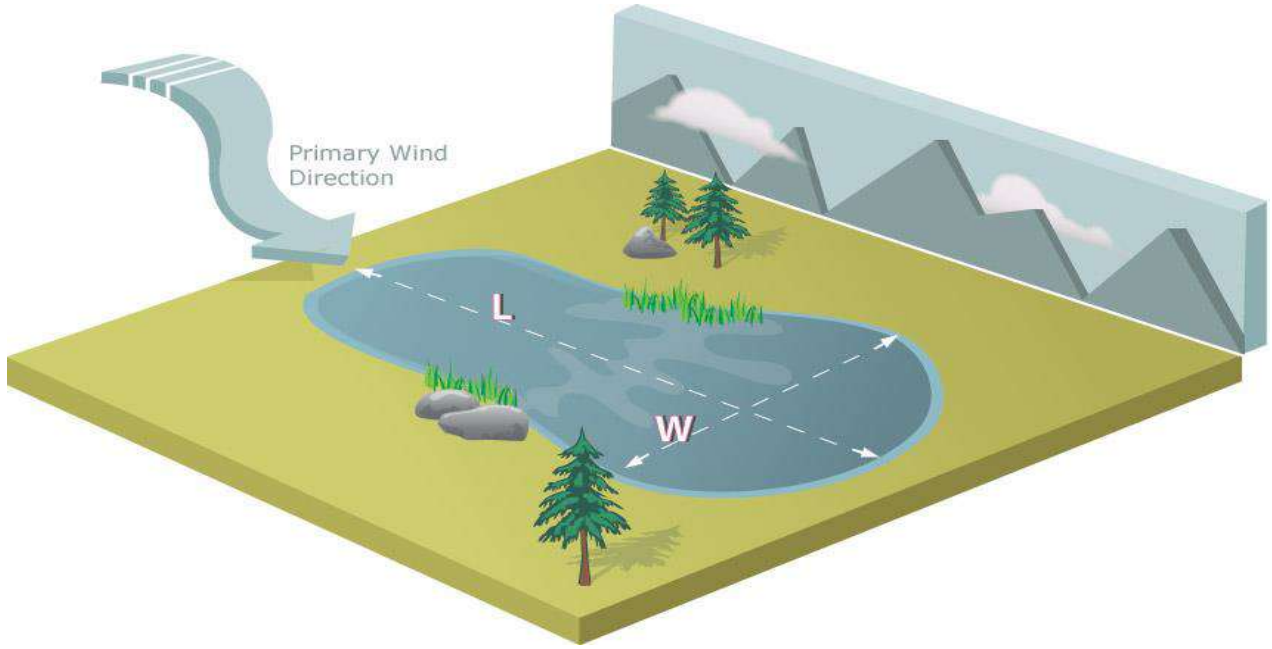




Lotic waters versus lentic waters

Rivers are lotic (flowing) waters

Lakes & reservoirs are lentic (standing) waters



Special characteristics of lentic waters: storage, long retention time, mixing nature & complex dynamics

Presentation Outline

I. Why lakes and reservoirs? Why now?
II. Lakes and reservoirs provide immense storage
III. Socioeconomic and ecological benefits
IV The global value of freshwater lakes
V. Lakes and reservoir basins are rapidly deteriorating
VI. The Opportunity: Mainstream Integrated Lake Basin Management Best Practices
VII. Recommendation

I. Why lakes and reservoirs? Why now?

The UN Environment Assembly adopted a resolution on Sustainable Lake Management in 2022, urging member states to tackle issues such as poor land use, pollution, over-extraction of water, and rising temperatures that are impacting lakes. It promotes the protection, conservation, and improved management of lakes through international cooperation, stakeholder involvement, and enhanced research (UNEP, 2022).

In 2024, a UN passed resolution commemorates World Lakes Day on August 27 each year.

I. Why lakes and reservoirs? Why now?

A 2023 WMO State of Global Water Resources study reports drying catchments, reduced river flows, & reduced réservoir & lake inflows. Urges better monitoring, data sharing, & cross-border collaboration & policy shift to effectively manage increasing extremes of floods & droughts (WMO, 2023).

A 2023 World Bank Integrated Storage Management report notes “Water Storage is at the heart of Climate Change Adaptation” (World Bank, 2023)

II. Lakes & reservoirs provide immense storage

- Total liquid fresh surface water is104,590 km^3; lakes store 91,000 km^3, wetlands 11,470 km^3, & rivers 2,120 km^3 (Shiklomanov, 1993).
- Natural lakes store 87% of all accessible fresh surface water.
- Reservoirs of nearly 62,000 large dams store about 9,000 km^3 of freshwater, or <10% of storage of all lakes, (Hirji & Duda, 2025).

Africa has some of the world's largest lakes & reservoirs

- African lakes include the Great Rift Valley Lakes Nyasa, Tanganyika, Victoria, & Lakes Albert, Baringo, Chad, Chala, Edward, Jipe, Kivu, Maweru, Rukwa & others.
- Lake Victoria is the 2nd largest lake by area globally; Lake Tanganyika is the 2nd deepest globally, & Lake Nyasa is the world's most biodiverse lake.
- Lakes Tanganyika, Nyasa & Victoria store 18,900 km^3, 7,720 km^3, & 2,760 km^3 of water, respectively, which together total 29,380 km^3 or 28% of the world's accessible surface freshwater.

- Lake Kariba, the world's largest reservoir, has a storage capacity of 185 km^3 of water.
- Lake Nasser stores 145 km^3, Lake Volta 132 km^3, the Grand Ethiopian Renaissance Dam 74 km^3, Cahora Bassa 63 km^3 & Lake Julius Nyerere 34 km^3.

Estimated Lake and Reservoir Storage in Tanzania*

Lake storage*

Lake	Area	Volume	% of area	Share of storage
Victoria	68,800 km^2	2,760 km^3	Tanzania (49%) Uganda (45%) Kenya (6%)	Tanzania—1,352.4 km^3 Uganda—1,242 km^3 Kenya—165.6 km^3
Tanganyika	32,600 km^2	18,880 km^3	Tanzania (41%) DRC (45%) Burundi (8%) Zambia (6%)	Tanzania—7,740.8 km^3 DRC—8,496 km^3 Burundi—1,510 km^3 Zambia—1,152.8 km^3
Nyasa	29,500 km^2	7,775 km^3	Tanzania (??) Malawi (??)	?? ??
Tanzania				**(9,093.2 km^3)***

Reservoir storage

Basin	No of existing dams & reservoirs	Total Storage Volume (MCM)	No of planned or under construction
Internal Drainage	119	119.2	88
Lake Rukwa	4	-	8
Lae Nyasa	5	1.1	15
Pangani	156	1191.6	16
Lake Victoria	154	85.61	36
Rufiji	38	37,935.1	50
Wami/Ruvu	167	52.5	24
Ruvuma and SC	75	21.7	14
Lake Tanganyika	59	15	28
Tanzania	777	**39.4 km^3**	279

*** This conservative lake storage estimate does not include Lake Nyasa storage, whose boundary is disputed and under mediation**

III. Lakes & reservoirs provide extensive socioeconomic & ecological benefits, they:

(a) supply water to villages, towns, cities, agriculture, livestock & industries;
(b) generate electricity;
(c) support fisheries, navigation, and recreation;
(d) are habitats for plants, fish, birds, wildlife (biodiversity);
(e) recharge aquifers;
(f) help to control floods & mitigate droughts; &
(g) assimilate wastewater discharged.

IV. The global value of freshwater lakes

(Source: Li and Tsigaris, 2024)

1. The value of the ecosystem services provided by global freshwater lakes is estimated at USD 1.3–5.1 trillion annually.
2. The natural asset value of freshwater lakes is estimated at around USD 87–340 trillion.
3. Estimated value of ecosystem services provided by Tanzanian lakes is USD 25 – 82 billion annually.
4. Estimated asset value of Tanzanian lakes is about USD 1.67-6.5 trillion.

V. Lakes & reservoirs are deteriorating rapidly

Over-extraction, pollution, poor land use, invasive species, & climate change threaten the health & sustainability of lentic waters globally, resulting in the accelerated loss of valuable socio-economic & ecological benefits (Hirji & Duda, 2025).

Lakes globally are facing serious problems

Lake Basin	In-lake					Littoral				Basin origin							Regional/ Global		
	Unsustainable fishing practices	Introduced faunal species	Salinity changes	Weed infestations	Nutrients from fish cages	Shoreline effluent discharges	Shoreline industrial discharges	Shoreline water extraction	Loss of wetlands	Excess sediment inputs	Non-point source nutrients	Agro-chemicals	Water abstraction	Changes in run-off	Effluent and stormwater	Industrial pollution	Atmospheric nutrients	Atmospheric industrial contaminants	Climate change
Aral Sea			→						→				→						
Baikal						↓	→			↓								→	
Baringo	→									↓			↓	↓					↓
Bhoj Wetland				→		→	↓			→	→	→			→				
Biwa									↓		→	→	↑ [2]		↑				↓
Chad									↓	↓			↓						↓
Champlain						↑					↑				↑			→	
Chilika Lagoon			↑	↑						↓	↓	↓	↓		↓				
Cocibolca/ Nicaragua						↓				↓		↓			↓				
Constance		↓				↓			→		→	→			→				
Dianchi					↑	→				↓ [3]	↓ [3]	↓ [3]	↓		↓			→	
Great Lakes (N. American)		↓				↑	↑				→	→			↑	→		→	
Issyk-kul		→										↓				↓ [4]			↓
Kariba Reservoir					↓	→													↓
Laguna de Bay	→	↓	→	→	↓	→	→			↓	↓				↓	→			
Malawi/Nyasa	↓ [5]			↓						↓	↓			↓	↓		↓		↓
Naivasha	↑	→		↑		↓		→	→	↓							↓		
Nakuru										→				↓	↓				
Ohrid	→	↓				→	↓		↓	↓	↓				↓				
Peipsi/Chudskoe	↓			→		→					→ [6]				↓	→ [6]			
Sevan	↓	↓				↓			→	↓			↓						
Tanganyika	↓ [5]					↓	↓			↓					↓				↓
Titicaca		↓				→	↓			↓					↓	↓			
Toba	↓	↓		↓	↓	→			↓	→	→	↓	↓	→	↓		↓		
Tonle Sap	↓	↓								↑ [7]					↓				
Tucurui Reservoir				→						→									
Victoria	→	↓ [8]		↑		↓	↓		↓	↓	↓				↓	↓ [4]	↓		
Xingkai/Khanka	↓					→	→		↓	↓		↓			↓	↓ [9]			
Total Occurrences	12	10	3	9	4	18	10	1	11	21	16	12	9	4	19	7	4	4	7

Drying catchments, reducing river flows and reservoir inflows, and increasing sedimentation

In 2022, over 50% of catchments had reduced river flows, and more than 60% of reservoirs experienced below-normal inflow compared to the 1991-2020 average, complicating water management (WMO, 2023).

From 1992 to 2020, 53% of 1,972 lakes and reservoirs studied showed declining water levels, primarily due to warming (36%) and water use (20%). Additionally, 67% of reservoir declines were linked to sedimentation from soil erosion, countering gains from new dams (Yao et al., 2023).

Weyhenmeyer et al. (2024) reveal that 115,000 lakes were rapidly drying, potentially impacting > 153 million people.

Sedimentation is a serious growing problem.

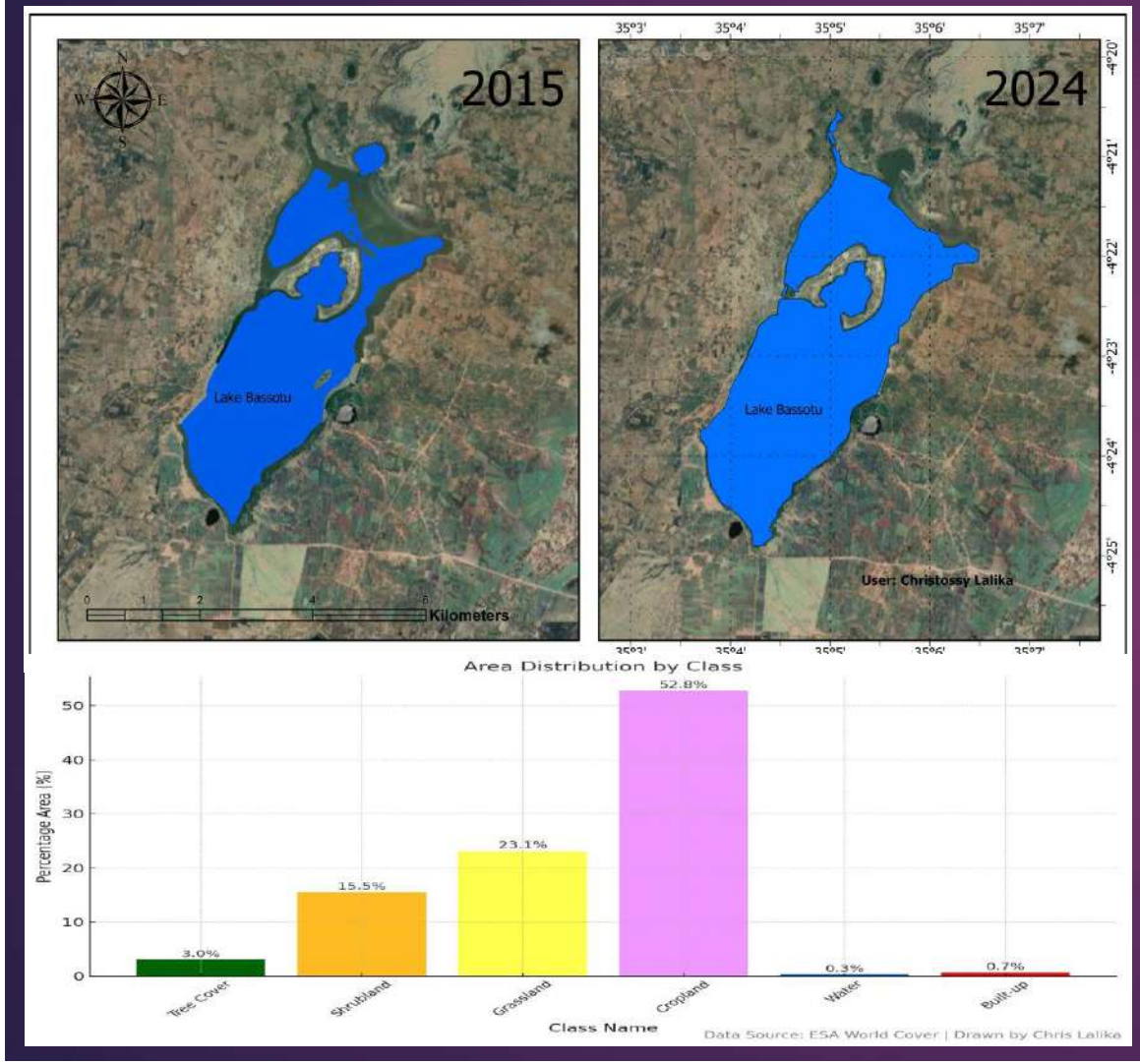
Over 40,000 large reservoirs in 150 nations have lost 13% - 19% of storage capacity; up to 26% loss projected by 2050, impacting water supply, irrigation, power generation, and flood control (Perara et al., 2022).

Sediment core analysis show sedimentation rates have nearly tripled since the 1950s from population growth & land-use changes (Baud et al., 2021).

Major water bodies, e.g., the Aral Sea, Lake Sistan, and Great Salt Lake, are experiencing substantial water loss (Wang et al., 2018).

These impacts complicate water managers' efforts to adapt to climate change and support a growing population.

Rapid changes in Lake Bassotu, Hanang District



Christossy Lalika from Wateraid reports that Lake Bassotu, essential for over 5,000 people in Hanang District, is changing rapidly. Analysis of Landsat 8 imagery from 2015 to 2024 shows the lake's surface area has increased from 11.34 km² to 14 km², but its depth is decreasing due to siltation. Over 50% of the surrounding land is now used for agriculture, leading to soil erosion. Experts warn that if current trends continue, the lake could disappear in 15 years. (LinkedIn Post, December 22, 2024).

The Winam Gulf of Kenya's Lake Victoria

Cyanobacteria proliferate out of control, forming clouds of green algae called cyanobacterial harmful algal blooms or cyanoHABs. Some types of cyanoHABs produce toxins that are harmful not only to wildlife and livestock but also to people using the water.

Lauren N. Hart et al, Metagenomics reveals spatial variation in cyanobacterial composition, function, and biosynthetic potential in the Winam Gulf, Lake Victoria, Kenya, *Applied and Environmental Microbiology* (2025). DOI: 10.1128/aem.01507-24

Scientists believe a toxic algal bloom linked to climate change caused the sudden death of 350 elephants in Botswana. (Credit: Dmitry Ryzhkov)

Such incidents may increase with rising water temperatures, nutrient enrichment, and salinity from environmental changes.

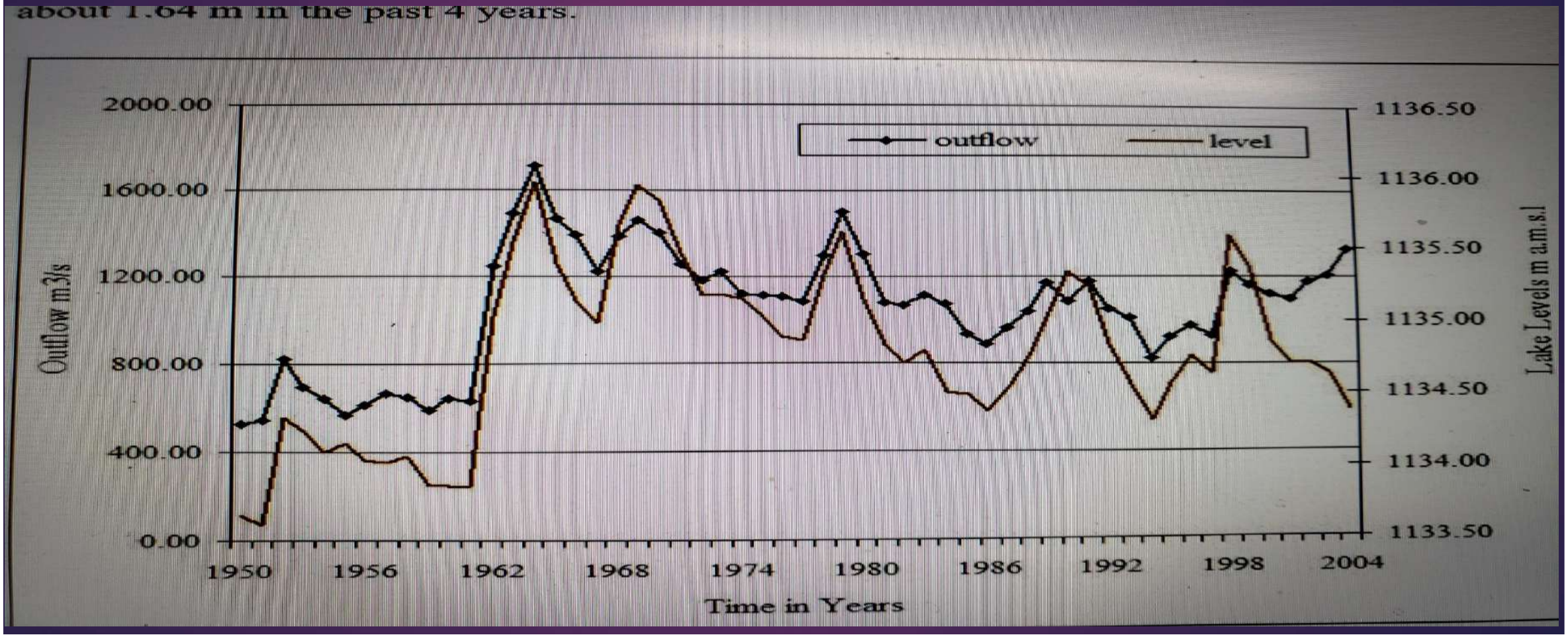
Livelihoods hit as water hyacinth returns to Lake Victoria

The aggressive weed appears when nutrient loads are high in the lake. Currently, the weed covers 1,000 hectares of Nyakach and Winam Gulf in Kisumu County, Asembo Bay in Siaya County, and Kendu Bay in Homa Bay

County.Elizabeth Ojina & George Odiwuor, The Nation
January 18, 2024

Unregulated Lake Victoria outflows threaten livelihoods and the economy—and pose a national security threat

about 1.64 m in the past 4 years.



Global media coverage on Lake Victoria level declines

Mugabe, D. and E. Kisambira. (2006) Lake Victoria levels at Jinja raise eyebrows. *East African Business Week*. January 16, 2006. Accessed March 13, 2006.

Olupot, M. (2006) Govt May Close Jinja Dam Over Water Levels. *New Vision,* January 6, 2006. Accessed February 3, 2006.

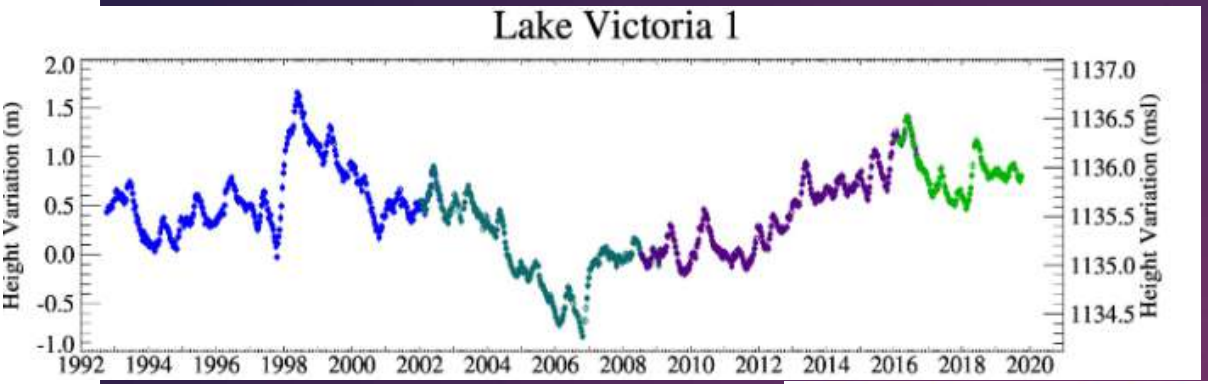
Oywa, J. (2006) Shrinking Lake Leaves Transporters Very Worried. February 3, 2006.

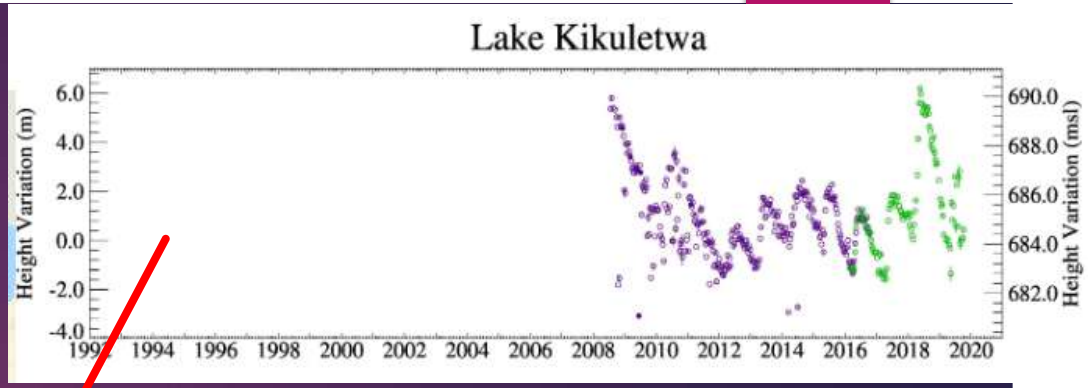
Reynolds, C. (2005) Low Water Levels Observed on Lake Victoria. Report published on the Web site for the Production Estimates and Crop Assessment Division of the USDA Foreign Agricultural Service. September 26, 2005. Accessed March 13, 2006.

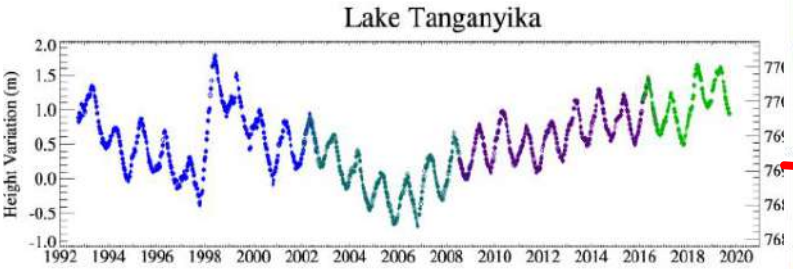
USDA/NASA 2006. Global Reservoir and Lake Monitor Project. Accessed March 13, 2006.

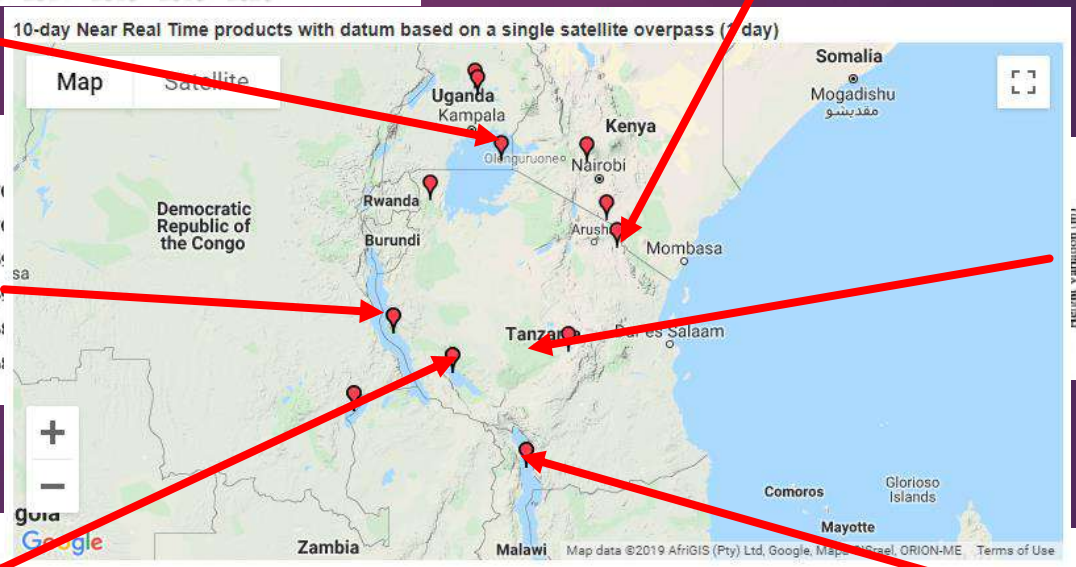
UNEP. (2005) Africa's Lakes: An Atlas of Environmental Change. United Nations Environment Programme. Accessed March 13, 2006.

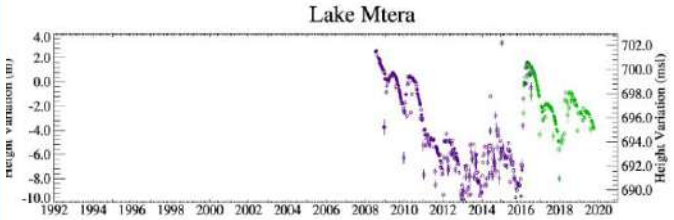
USDA's G-REALM system enables tracking near real-time lake & reservoir levels

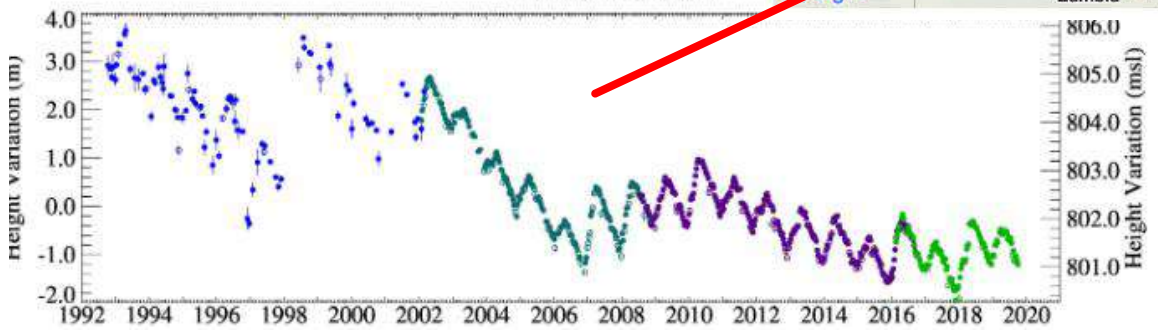


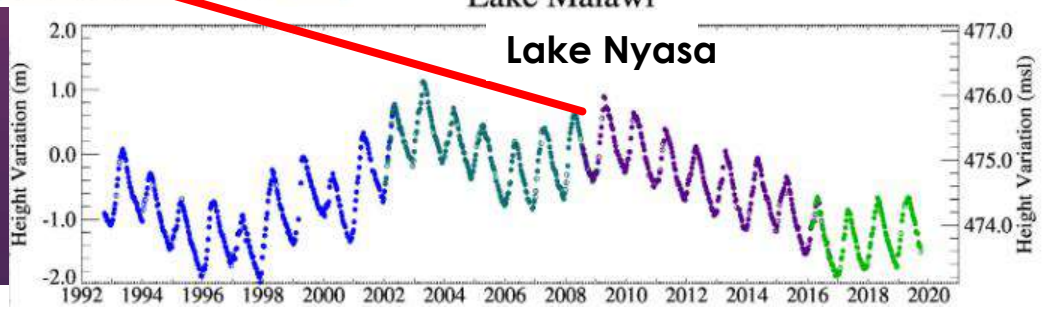






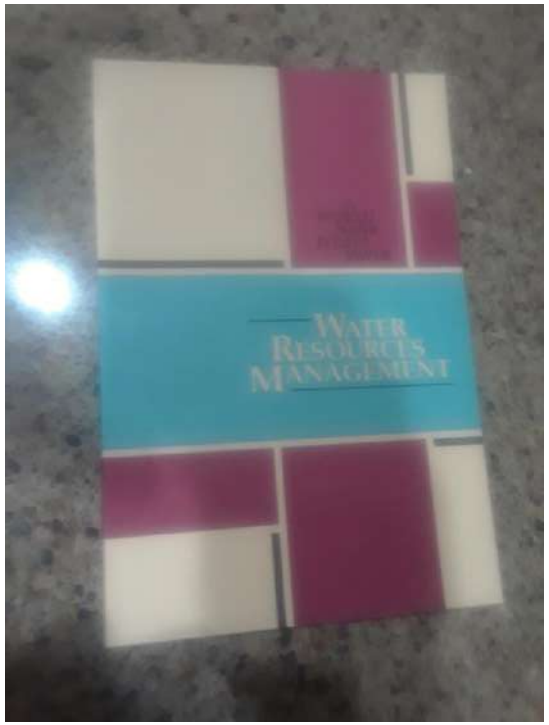




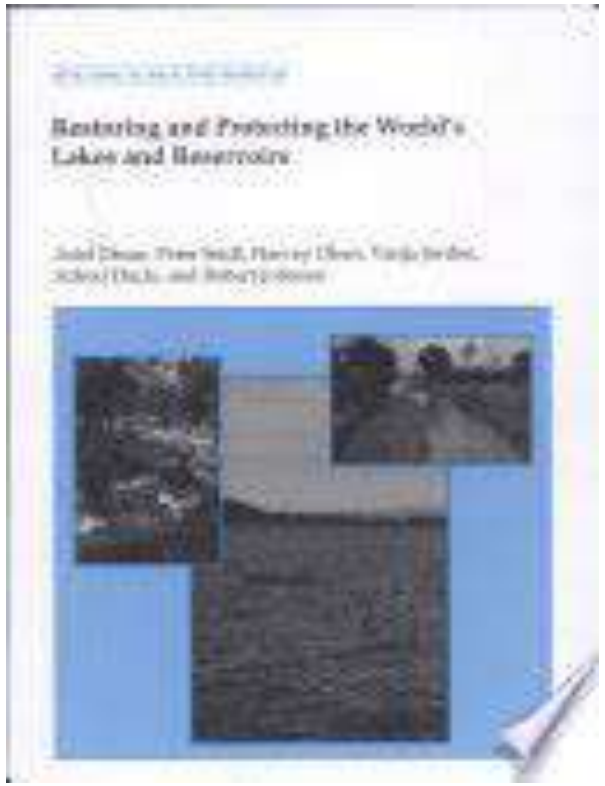


VI. The Opportunity: Mainstream Integrated Lake Basin Management Best Practices to implement the UN Resolution on SLM & advance climate resilience

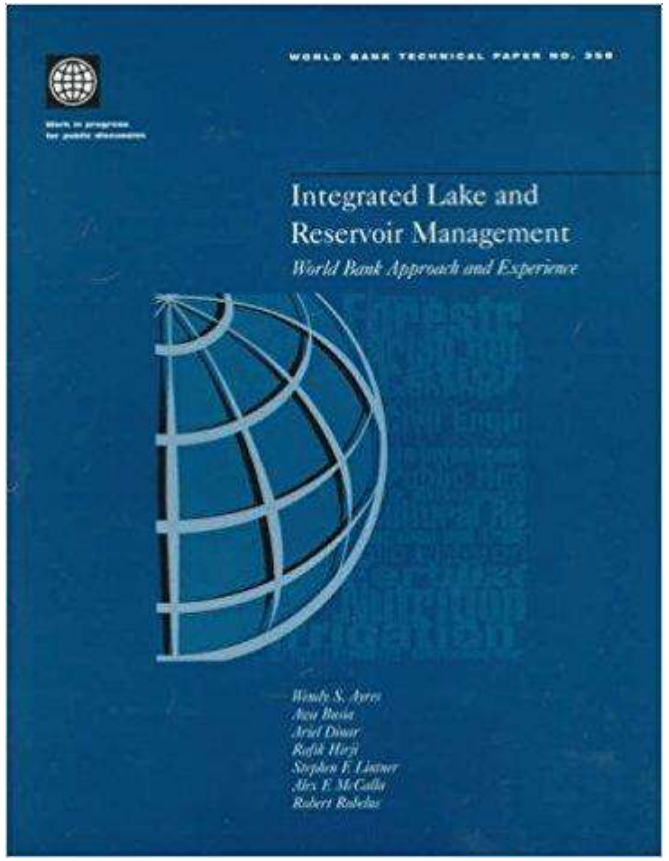
Early World Bank experience on Lake and Reservoir Management 1993-2003



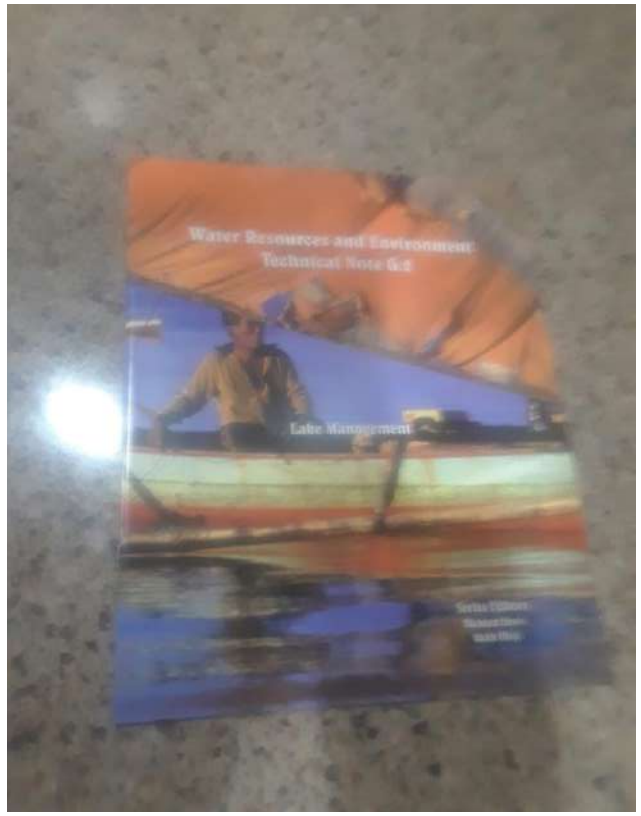
World Bank 1993



Dinar et al 1995

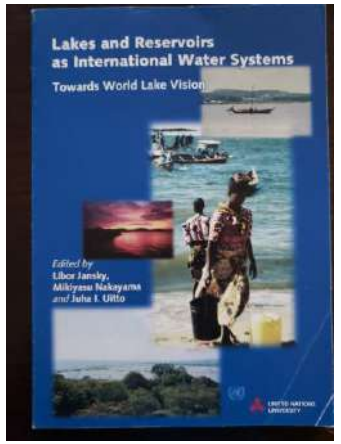


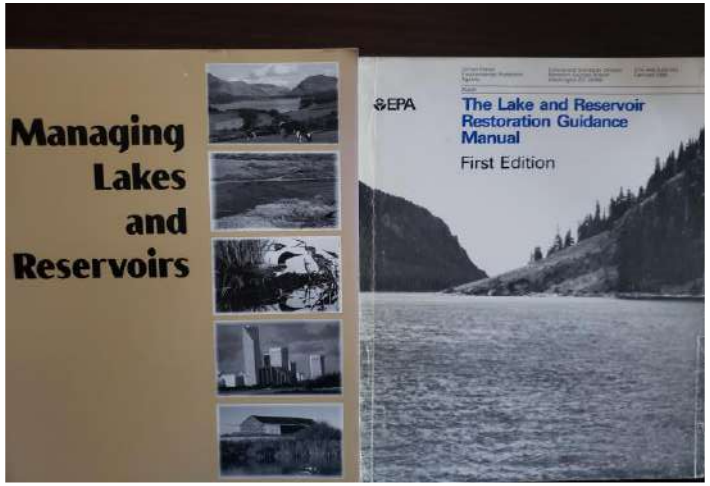
Ayres et al 1996

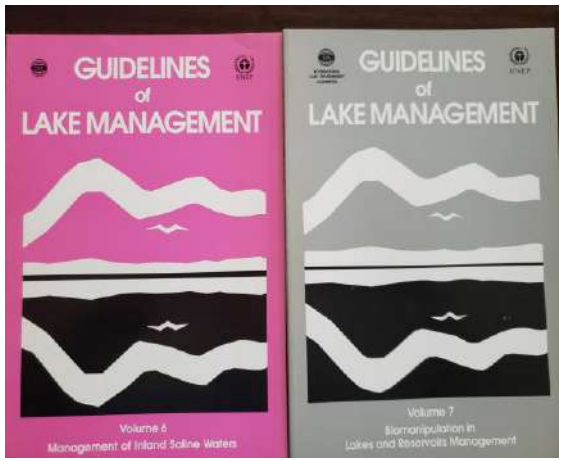


Davis and Hirji (eds) 2003

Early global experience on Lake and Reservoir Management work

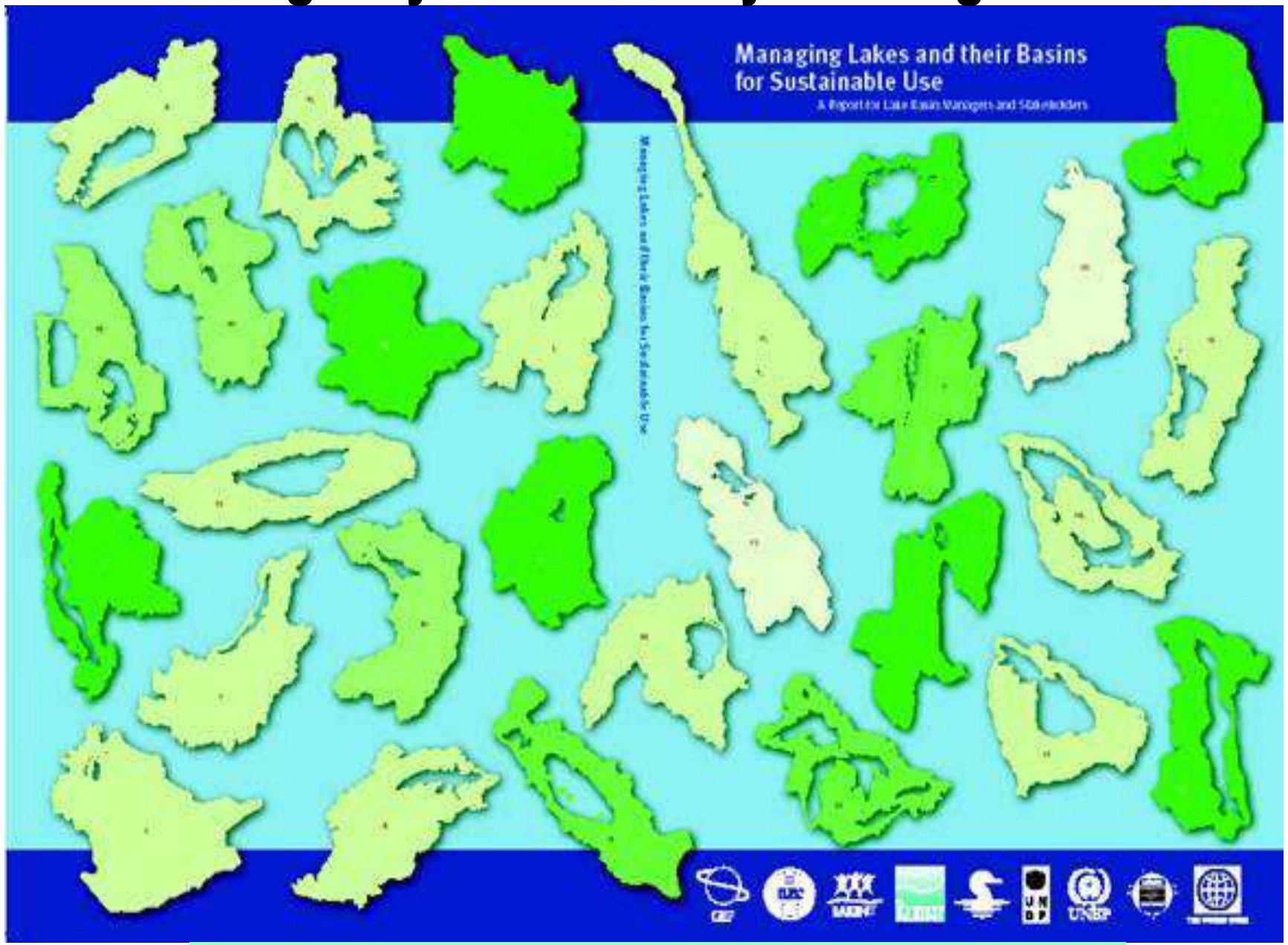






Global best practice: Integrated Lake Basin Management

A Multiagency Global Study on Integrated Lake Basin Management



GEF

ILEC

Ramsar

UNDP

USAID

THE WORLD BANK

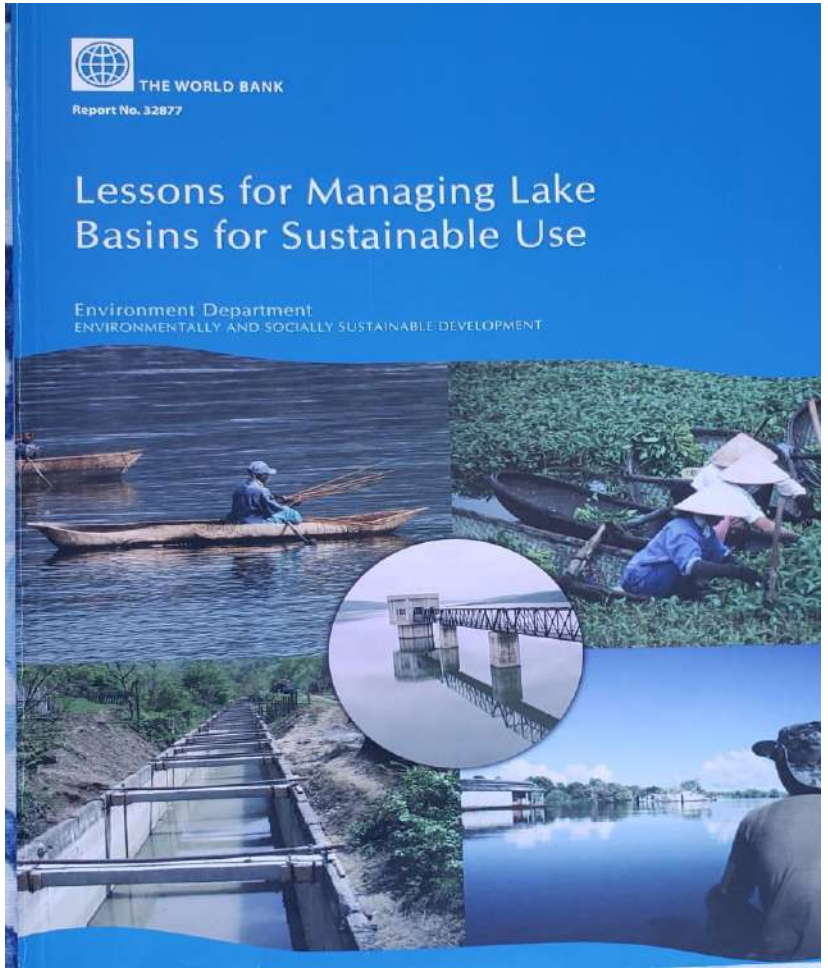
THIS GEF FUNDED MULTIAGENCY PROJECT WAS SUPPORTED BY 288 LAKE BASIN EXPERTS FROM 41 NATIONS FROM 2000 TO 2005

ILEC (2005) Downlodable from ILEC Website

Lessons for Managing Lake Basins for Sustainable Use (World Bank 2005)

- A comparative analysis of (i) water resources problems occurring in river basins and lake basins and (ii) policy and institutional responses associated with river basin management and lake basin management and

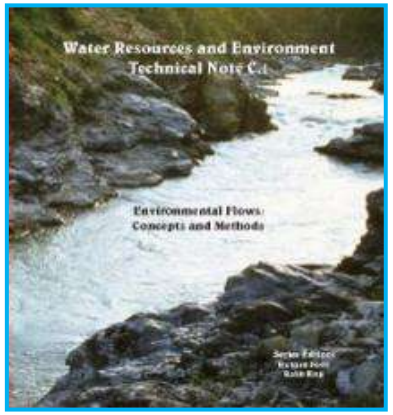
- Extends the monitoring and evaluation (M&E) indicators developed by the GEF for international waters projects.

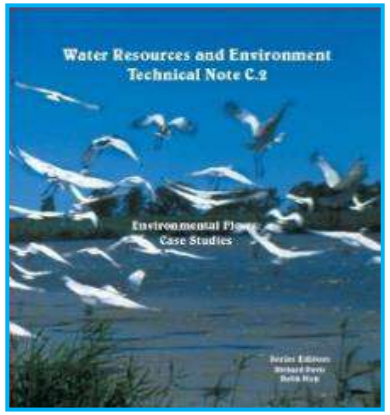


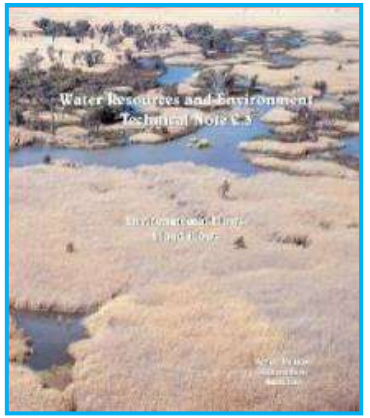
Avoid re-inventing the wheel, use relevant, available, accessible knowledge, supporting IWRM and ILBM

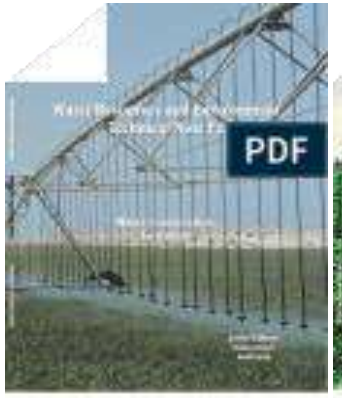
World Bank Water Resources and Environment Technical Note Series, Davis and Hirji (eds) 2003

- **Environmental Flows**
  - Environmental Flow Assessment: Concepts and Methods
  - Environmental flow Assessment: Selected Cases
  - Environmental Flow Assessment: Flood Flows
- **Water Quality Management**
  - Water Quality Management: Assessment and Protection
  - Water Quality Management: Wastewater Treatment
  - Water Quality Management: Nonpoint Source Pollution
- **Irrigation and Drainage**
  - Irrigation and Drainage: Development
  - Irrigation and Drainage: Rehabilitation
- **Water Conservation**
  - Water Conservation: Urban Utilities
  - Water Conservation: Irrigation
  - Water Conservation: Wastewater Reuse
- **Waterbody Management**
  - Water Body Management: Lake Management
  - Water Body Management: Wetlands Management
  - Water Body Management: Management of Aquatic Plants.









Hot of the Press

Hirji, R. & A. Duda. 2025. “Integrated Management of Lakes, Reservoirs and Their Basins is essential for a Climate resilient Planet: A crucial wake-up call from collective amnesia” in *Water Policy*.

Duda, A. & R. Hirji. In the press. “Mainstreaming Integrated Approaches to Sustain Lake and Reservoir Basin Benefits in a Changing Climate” in *Water Policy*.

Natural lakes and built reservoirs are essential for ensuring a stable global water supply and increasing resilience to climate change (Hirji & Duda, 2025).

"Water is central to human life. It is also crucial for social well-being, economic development, and national productivity. Water acts as a catalyst and driver for human development, dignity, food, energy security, and ecosystem and environmental integrity."

H.E. Dr. Samia Suluhu Hassan
The President of the United Republic of Tanzania

“it is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change”.

Charles Darwin

VII. Recommended Actions

To build climate resilience, let's respond to our President's call for action towards human development. We should:

1. Adopt and mainstream best practices in integrated lake basin management (ILBM).
2. Submit a bid to host the World Lakes Conference in Tanzania in 2027.
3. Celebrate World Lakes Day on August 27 each year.
4. Establish a center in Tanzania to enhance Africa's capacity for ILBM.

Asanteni sana!