Fundamentals of Environment and Sustainability - GERD

Group 13

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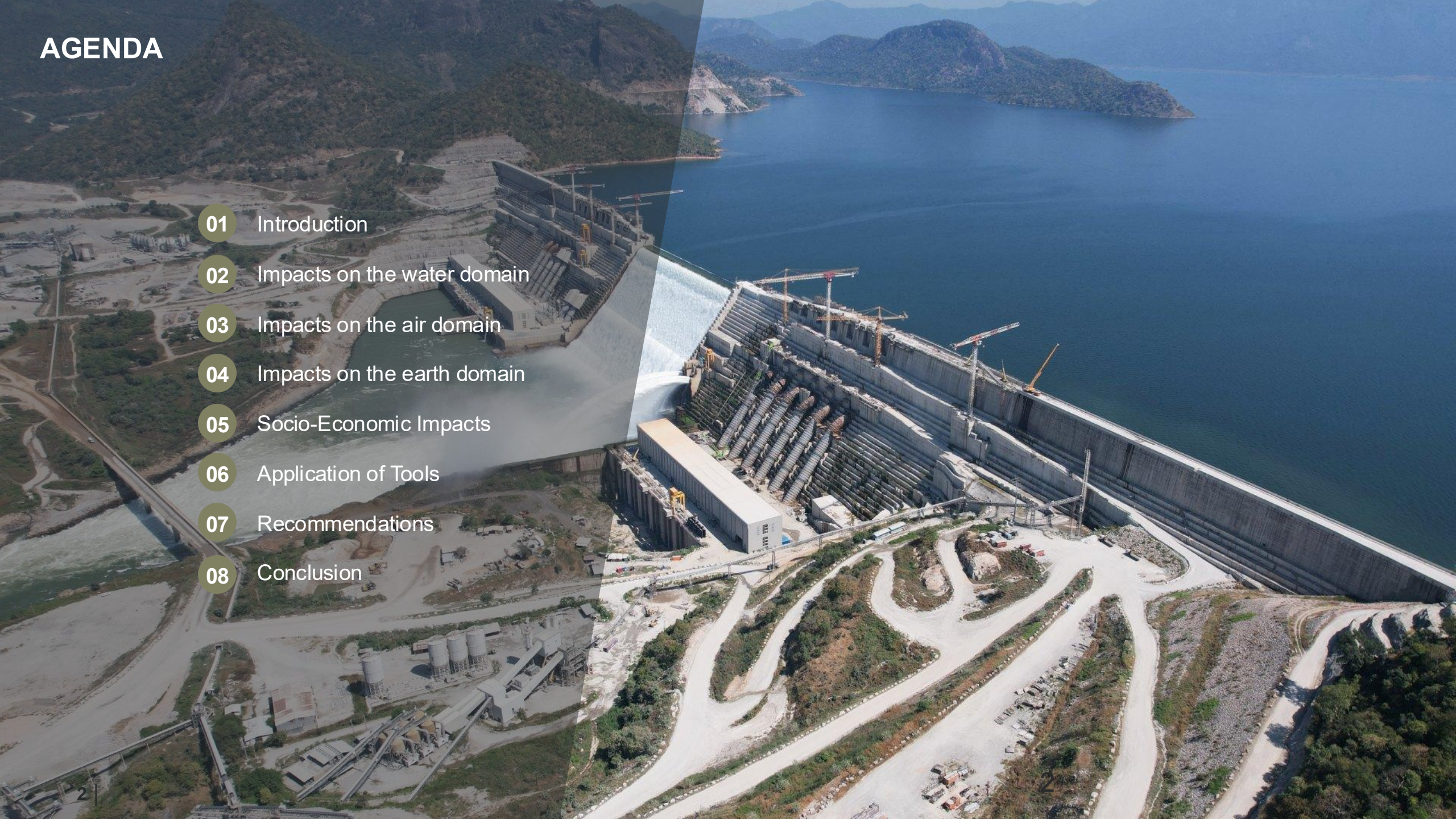
AGENDA



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From blueprint to power: GERD's key milestones (2011-2025)

2011
- Ethiopia initiated the GERD project by awarding a $4.8 billion contract to Salini Impregilo
- The dam was envisioned to be Africa's largest hydroelectric project, aiming to address the country's energy shortages.

2013
- In May, Ethiopia diverted the Blue Nile to facilitate dam construction, a move that heightened tensions with downstream countries, particularly Egypt and Sudan.

2015
- Ethiopia, Egypt, and Sudan signed the Declaration of Principles, agreeing to cooperate on the dam's construction and operation, and to conduct joint studies on its impact.

2020
- Ethiopia completed the first phase of filling the dam's reservoir in July, despite objections from Egypt and Sudan, who expressed concerns over water security.

2021
- The second filling phase was completed
- Diplomatic efforts to reach a binding agreement among the involved countries continued without resolution.

2022
- Ethiopia began generating electricity from the dam as the first turbine became operational.

2023
- In September, Ethiopia announced the completion of the fourth and final filling phase of the dam's reservoir, bringing it closer to full operational capacity.

2025
- **GERD is expected to be fully operational**, with all turbines generating electricity, significantly boosting Ethiopia's power generation capacity and enabling electricity exports to neighbouring countries.

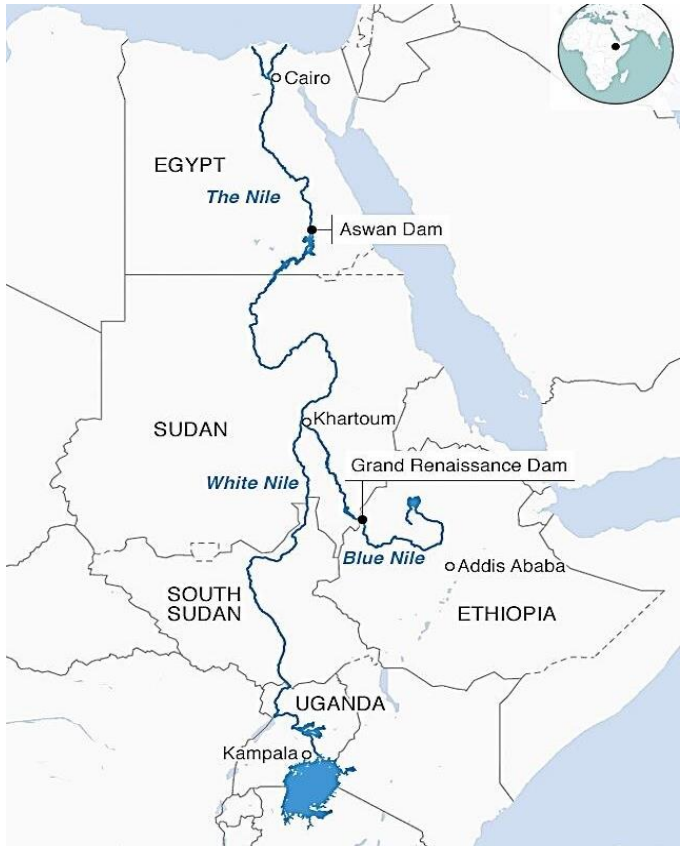
Sources: Kamara et al. (2022), Power Technology (2015), Wikipedia contributors (n.d.)

GERD's construction and operation reflect Ethiopia's pursuit of energy independence, regional leadership, and long-term development

GERD

Construction

- Began in April 2011 under a $4.8 billion contract (Salini Impregilo, now Webuild)
- Funded mostly through domestic bonds and citizen contributions
- Diverted the Blue Nile in 2013 to enable dam building
- Structure: 145m high concrete gravity dam, 1,874 km² reservoir
- Faced no publicly released Environmental Impact Assessment, raising transparency concerns



Operation

- First turbine began generating power in February 2022, marking the start of energy production
- By early 2025, several turbines are online, with more expected — full generation up to 6,450 MW
- Will more than double Ethiopia's electricity supply and increase access for rural areas
- Enables electricity exports to Sudan, Egypt, and other East African countries
- Designed to regulate Nile flow, potentially reducing floods in Sudan and enhancing dry-season flows

Sources: Power Technology (2015), IHA (2022), Hassaan (2021)

The water domain is severely impacted by altered flow patterns, degraded water quality, and harmed aquatic ecosystems.

Flow Regime & Sediment Management

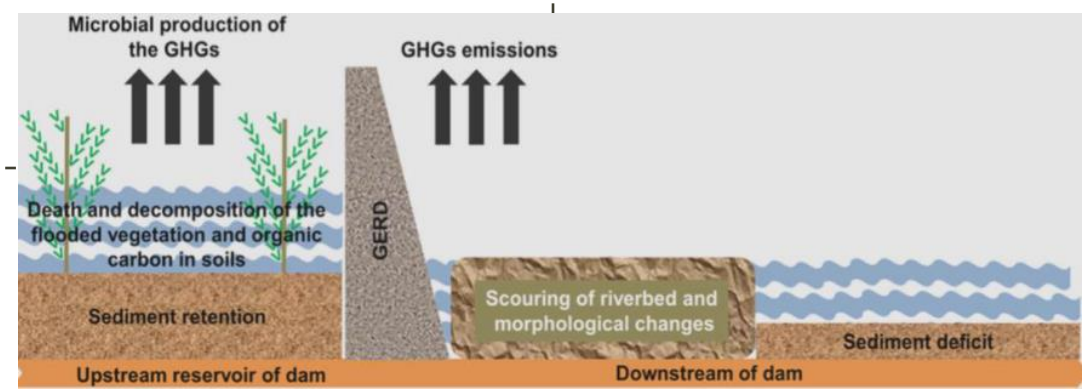
- **Altered Flow Patterns:** GERD regulates the Blue Nile's flow, reducing natural flood pulses and altering seasonal variations.
- **Sediment Trapping:** The dam traps nutrient-rich sediments, leading to decreased soil fertility downstream and increased reliance on chemical fertilizers.
- **Delta Erosion:** Reduced sediment flow contributes to Nile Delta erosion, increasing vulnerability to sea-level rise and saltwater intrusion.

Water Quality & Reservoir Dynamics

- **Stratification:** The reservoir's stagnant waters stratify, with oxygen-poor layers at depth, potentially releasing cold, deoxygenated water downstream.
- **Eutrophication Risk:** Nutrient accumulation can lead to algal blooms, harming aquatic life and water quality.
- **Invasive Species:** Conditions may favour invasive aquatic plants, disrupting ecosystems and water usage.

Ecological Impacts on Aquatic Systems

- **Habitat Transformation:** Conversion from river to reservoir alters habitats, affecting species adapted to flowing waters.
- **Fish Migration Disruption:** The dam blocks migratory routes, impacting fish populations and fisheries downstream.
- **Biodiversity Loss:** Changes in flow and sediment transport can reduce biodiversity and ecosystem services.



Sources: Morsy et al. (2021), IHA (2022), Abdelhady et al. (2015)

Massive Construction and Operational Emissions Undermine GERD's Clean Energy Gains

Atmospheric Emissions

Construction Phase

- **Material Use**: ~10 million m^3 concrete and large steel quantities likely emitted between 8-12 Mt CO_2 during construction
- **Diesel Use**: 10+ years of machinery and transport added CO_2, NO_x, and particulate emissions, likely emitting more than 0,1 Mt of CO_2-eq

Operation Phase

- **Vegetation Loss**: Reservoir deforestation released carbon from biomass and soil - up to hundreds of thousands of tonnes
- **Reservoir GHGs**: Decomposing organic matter may emit up to 8 Mt CO_2-eq early on, plus annual emissions of 0,004 Mt of CO_2-eq
- **Energy Shift**: Hydropower replaces fossil fuels, reducing national reliance on biomass and petroleum
- **Regional Exports**: Supplying clean electricity to Sudan, Egypt, and others helps lower regional emissions and move away from fossil fuels

While GERD supports a long-term shift to clean energy, its construction produced high upfront emissions, and reservoir methane keeps operational emissions significant - highlighting hydropower's environmental trade-offs

Air Noise and Vibration

Construction Phase

- Construction caused localized noise and vibration, primarily affecting workers
- Protective gear areas help safeguard workers
- Remote location of GERD minimizes community exposure

Operation Phase

- Operation causes localized noise and vibration, mainly affecting workers
- Protective gear and restricted exposure time in high-noise areas help safeguard workers
- Remote location of GERD minimizes community exposure

Though construction caused local air noise and vibration, impacts were limited due to the site's remoteness and on-site protections

Sources: Wang and Chen (2020), Kamara et al. (2022), Mohammed (2024)

The GERD has caused extensive land transformation, vegetation loss, and biodiversity disruption, with lasting climate and ecological consequences

Land Use Change & Infrastructure Development

- **1,650.9 km² flooded**, incl. 1,300 km² of savannahs, grasslands, and riparian forests
- Extensive **land cleared** for camps, cement plants, and storage areas
- **100+ km of roads** built → fragmentation, erosion, long-term soil degradation

Vegetation Loss & Climate Implications

- Loss of carbon sinks → **18,700–32,500 t CO_2/year** in foregone sequestration
- **Methane emissions** from submerged biomass (CH_4 = 25× CO_2 warming potential)
- Land-use change is a major indirect driver of **climate change**

Biodiversity Loss & Habitat Fragmentation

- Submerged habitats eliminate niches for native flora/fauna → **loss of endemic species**
- **Wildlife corridors cut** → reduced gene flow, migration, increased extinction risk
- No public **ESIA** or **biodiversity offset plan** implemented

These land-based impacts highlight the urgent need for restoration, climate mitigation, and biodiversity offset measures to ensure GERD's sustainability.

Sources: Hassaan (2021), Grace et al. (2006), Devic (2015)

GERD´s Uneven Socio-Economic Impacts: Growth for Ethiopia, Risk for Egypt and Trade-Offs for Sudan

Impact on Ethiopia

- **Energy access & development:** GERD more than doubles electricity output, powering industrial growth and regional exports.
- **Agriculture improvement:** Reliable irrigation supports food production and creates more stable farming jobs.
- **Employment generation:** Many jobs created during construction phase, but also long-term employment opportunities in energy, infrastructure and power-dependent industries.
- **Social Disruption:** Displacement of 20.000+ people, mainly from the Gumuz community, without adequate resettlement support.

Impact on Egypt

- **Threat to agriculture:** Up to 25% water loss could shrink farmland, cut food production and cost Egypt $15.7B annually.
- **Job and livelihood risks:** Agriculture and fisheries could face major job losses, especially among rural and female workers.
- **Strained water security:** GERD adds to Egypt's already existing water challenges alongside climate change and population growth.

Impact on Sudan

- **Initial disruption:** Early reservoir filling affected flood-recession farming and water availability in some regions.
- **Long-term benefits:** Better flow control could reduce flooding, trap sediment and expand irrigation by 500,000 hectares.
- **Severe risk potential:** A dam failure could cause catastrophic flooding, destroying downstream dams and cities, including Khartoum.

Sources: Kamara et al. (2022), Minority Rights Group International (2023), Elbelasy et al. (2024)

The GERD Project Lacks Comprehensive Environmental and Sustainability Assessments

Environmental Impact Assessment

- An EIA is legally required in Ethiopia (Proclamation No. 299/2002), but enforcement is weak due to limited capacity and political influence
- GERD moved forward without a public EIA, raising concerns over transparency and accountability
- **Challenges**: Lack of public consultation, exclusion of regional stakeholders, and insufficient assessment of (cross-border) ecological and social impacts
- **Recommendation**: Conduct a rigorous retroactive EIA with stakeholder input to assess cumulative environmental and social effects

Enhances governance through transparent, inclusive, and accountable environmental oversight

Life Cycle Assessment

- No LCA has been conducted despite GERD's scale and environmental impact
- Major emissions result from materials (concrete, steel), diesel use and biomass flooding throughout different stages of the life cycle
- **Challenges**: Renewable energy offsets expected, but carbon payback timeline unclear due to absence of baseline data
- **Recommendation**: Carry out a post-construction LCA to quantify emissions and plan for sustainability and eventual decommissioning

Provides a full picture of GERD's footprint and helps track and reduce emissions over time

Strategic Sustainability Assessment

- GERD supports SDGs 7, 8, 9, and 13 through clean energy and infrastructure development

- **Challenges**: No SSA published, limiting analysis of the project's alignment with national and international sustainability goals
- **Recommendation**: Use SSA to evaluate cumulative, intergenerational impacts and ensure the project supports sustainable growth and cooperation in the Nile Basin

Supports SDG alignment and long-term cooperation in the Nile Basin

Sources: Ebissa et al. (2022), Dejenie and Kakiso (2023)

To ensure the projects long-term responsibility, we recommend four forward-looking and feasible measures

Mandate and Publish a Full Environmental and Social Impact Assessment (ESIA)

- Commission a comprehensive and transparent ESIA to evaluate GERD's environmental and social impacts
- Include biodiversity impacts, methane emissions, community displacement, and water quality changes
- Conduct the process in collaboration with neutral international institutions (e.g., UNEP, AU) for credibility
- Creates a scientific basis for adaptive dam management and fulfills international norms

Develop a Biodiversity Offset and Ecosystem Reforestation Program

- Establish and legally protect new conservation areas to compensate for the 1,300 km^2 of flooded ecosystems
- Prioritize ecologically equivalent areas (e.g., savannahs, riparian forests) and design wildlife corridors to maintain connectivity
- Involve local communities in restoration through jobs, agroforestry, and land stewardship programs
- Secure long-term funding through a dedicated environmental trust funded by GERD revenues

Implement Sediment Management and Watershed Conservation Programs

- Introduce sediment flushing mechanisms at GERD to prevent reservoir siltation and extend operational life
- Launch upstream watershed restoration projects, including reforestation and erosion control in the Ethiopian Highlands
- Helps preserve downstream soil fertility in Sudan and Egypt, which depends on sediment-rich seasonal flows
- Builds environmental resilience while supporting local livelihoods in degraded catchments

Establish a Cooperative Transboundary Water Management Framework

- Develop a legally binding, trilateral water management agreement among Ethiopia, Sudan, and Egypt
- Establish guaranteed minimum flows and drought-sharing protocols to protect downstream agriculture and human security
- Set up a basin-wide real-time data-sharing and early warning system to build transparency and operational trust
- Reinforces long-term regional stability while ensuring equitable access to Nile waters

Sources: BBOP (2012), Global Infrastructure Hub (2020), Right for Education (2023)

The Grand Ethiopian Renaissance Dams Future: Balancing Progress, Sustainability and Cooperation

GERD is a transformative project with vast energy and development potential for Ethiopia, but its impacts are regionally complex.

Environmental costs are significant, including habitat loss, altered river flow and greenhouse gas emissions from the reservoir.

Socio-economic gains come with trade-offs, such as displacement in Ethiopia and water insecurity in Egypt and Sudan.

Sustainability tools like EIA and LCA remain essential to assess and manage the dam´s long-term effects, even without a formal ESIA at the current point in time.

Regional cooperation is key to turning GERD into a model of shared progress, peace and ecological responsibility in the Nile basin.


Thank you!

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