

Research article

Challenges and prospects of transboundary river water conservation and watershed protection in Ethiopia: The case of the upper Blue Nile

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ABSTRACT

This article aims to present the challenges and prospects of transboundary river water conservation and watershed protection in the Upper Blue Nile basin. The River Nile Basin embraces eleven countries shaping their diverse environments and playing a vital role in the livelihoods of its inhabitants. Within this context sharing and managing the River Nile water resources has been a persistent challenge and a potential source of conflict. The Blue Nile River is shared by Ethiopia, Sudan and Egypt and for the latter it is the life artery as the majority of the water reaching Egypt comes from the Blue Nile. Only Egypt and Sudan have an agreement to share the water and there is a need to revisit this mode of resource use based on water allocation among the River Nile countries and especially for the Blue Nile. Nevertheless, these issues have not been resolved and have exacerbated by the commencement and near operation of the GERD. Another important aspect dealt with in this article is the conservation and watershed protection. The study used a qualitative research approach, and data were collected through key informant interviews. Different relevant secondary sources are also consulted. The data were analyzed based on a thematic analysis approach. The key finding of this study was that, despite the Ethiopian unilateral intervention inadequacy to deal with the problem of environmental degradation and water conservation in the Blue Nile Basin neither Ethiopia nor regional institutions like ENTRO attempted to shed light on the impacts of this problem if remained unaddressed. Moreover, Ethiopia and regional actors are void of designing a clear road map to overcome the cloud of mistrust and struggle to dominate the Nile water use which undermined hope for joint action against the common problem that jeopardize the interests of all the basin states. On the other hand the Ethiopian effort to safeguard the shared Nile water resource in the Blue Nile basin yield modest results it may encourage the basin countries to cooperate over the use and management of the Nile water. Hence, the inadequacy of Ethiopia's sole effort to conserve and protect the Upper Nile watershed calls for Ethiopian water management policy and water diplomacy to push for the collaboration of the downstream states as the threats to the Nile water supply are common threats to all Nile basin states' national water security.

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1. Introduction

Water resources are crucial for sustaining life, supporting ecosystems, and driving socio-economic development. Sustainable water use and conservation rose as an agenda when water mismanagement and pollution affected most of the major river basins in the developed world. The agenda has emerged among academics, policymakers, and development actors not only within one country but also at the global level since the 1970s [1]. The 2019 United Nations World Water Development Report indicated the growing stress on water resources due to the growing demand for water use [2], underscoring the importance of water conservation. Hence, in the 21st century, one of the major challenges that humanity faces is the conservation and sustainability of freshwater resources, which are very precious and finite. In the context of transboundary river systems, the challenges and prospects of effectively conserving and protecting water resources become even more complex [3].

In the Eastern Nile basin, widespread water mismanagement was reported, sometimes as high as 48% of the total water applied to irrigation fields [4]. The Nile River water conservation is one of the areas that receives less attention, despite the growing risks that the water demand outstrips the supply of water in the basin unless mitigation measures are taken. The 2015 Nile Basin Initiative (NBI) Strategic Water Resources Analysis also indicated that without the intervention and coordination of member states, the water shortfall could go as high as 50% of the current Nile River water supply [5]. On the other hand, this analysis also indicated the water demand for irrigation could increase by more than 160% from where it was in 2015, calling for basin-wide water conservation intervention. The irrigated area in the basin was estimated to increase from 5.4 million hectares in 2015 to 8.7 million hectares by 2050 [6]. A Strategic Water Resource Analysis study was conducted "to develop sustainable options to meet the growing water needs of the Nile riparian countries and subsequently to mitigate current and future water stress" by the NBI [6]. Similarly [7], projected the gap between supply and demand to be around 50 BCM shortly after the current water project plans of the basin countries are implemented. All these studies indicate the need to prioritize water conservation in the Eastern Nile Basin for the welfare of the basin states.

On the other hand the individual states of the Eastern Nile basin made significant effort to conserve the Nile water. They designed different water conservation strategies in the various water using sectors. For instance, the response to conserve the Nile water in the Eastern Nile basin countries through legislation, adoption of new technologies, and water pricing has little to offer in terms of the overall Nile water conservation [8]. The individual states water conservation can hardly address the problem that transcends national boundaries and demands collaboration among the basin countries.

The NBI Strategic Water Resources Analysis estimated the loss of water from the Nile Basin reservoirs to be around 17.2 BCM [6]. This estimation of Nile water loss does not include the extensive losses of water in the irrigation fields of Egypt and Sudan, the sectors that have extensively used Nile water with very backward irrigation practices, where the losses are reportedly very high [9]. In the Eastern Nile Basin, the unilateral effort to conserve and protect the Nile through individual responses remains inadequate.

The Upper Blue Nile, as a vital tributary of the Nile River, plays a pivotal role not only in Ethiopia's water security but also in the downstream countries' water availability, as it contributes 60% of the total Nile flow. The river not only supports the livelihoods of millions of Ethiopians who depend on it for agriculture, domestic use, and hydropower generation but also has far-reaching implications for the downstream countries of Sudan and Egypt [10]. Climate change exacerbates the challenges faced by the region. Changes in precipitation patterns, increased frequency of droughts and floods, and rising temperatures pose significant threats to the water availability and quality of the Upper Blue Nile. These climate-related impacts further strain the delicate balance of water resources in the region and require adaptation strategies to ensure sustainable water management [11,12].

Additionally, land degradation and deforestation pose serious threats to the watershed's health. Unregulated agricultural practices, improper land management, and unchecked deforestation contribute to soil erosion, sedimentation, and water pollution. These factors degrade the river's water quality, reduce its storage capacity, and harm the delicate ecosystems that depend on it [13].

Ethiopia, as an upstream state, has been implementing land and water conservation programs since the 1970s to tackle environmental degradation in the Blue Nile Basin and beyond [14]. Similarly, the other basin countries also have their own program to deal with water mismanagement and wastage in their respective areas [8,15]. To address the issue of unilateral water management, the Nile basin countries and the international community are supporting the basin countries to work together for the use and management of the Nile River water [16,17, and 18]. However, the countries in the Eastern Nile basin have struggled to reach an agreement on the use and management of river water [19], which has negatively affected the hope for collaboration to mitigate these challenges in the Blue Nile [18].

Several previous research studies have been conducted on water management in the upper Blue Nile Basin. These studies have focused on different areas, such as the adoption of strategies to mitigate climate change impacts [12], the prioritization of erosion-risk areas to combat land degradation [20], and the success achieved in reversing land degradation through watershed programs [21]. Additionally, water conservation intervention studies emphasized the identification of suitable locations to store Blue Nile water [22, 23] and the impacts of water development projects on downstream states [24].

However, none of these studies on the Ethiopian government's efforts to manage the upper Blue Nile Basin and its interventions in water conservation have addressed the issue of collaboration to protect the Nile from climate change and environmental degradation. This study aims to investigate the challenges and opportunities in conserving and safeguarding the Upper Blue Nile watershed. It highlights the importance of international collaboration and sustainable water governance in the Upper Blue Nile Basin.

2. Concept of collective action

The subject of "how ostensibly sovereign parties willingly form cooperative procedures to manage and use common pool and common property resources" has remained debatable issue to govern shared resources like international rivers. Community, market,

contract, and hierarchy are the four frameworks proposed to explain collective action or its absence. There is a widely held belief that since the era of John Locke's contractual theory, which states that rational actors can solve collective action issues by negotiating a deal that provides the highest returns to all contract parties [25]. However, the issue with this contracted cooperation is that it is challenging to enforce terms of agreement in the absence of hierarchical authority. To achieve common goals in areas where their interests are aligned, it has proven difficult to coordinate the actions of the parties. The methods used to establish and maintain this coordination present another challenge.

According to Ref. [26] the size of the group is important in determining whether "informal coordination or formal organization to obtain a collective good". He believes that in small groups with few members, "one or more members get such a large fraction of the total benefit that they find it worthwhile to see that the collective good is provided, even if they have to pay the entire cost may get along without any group agreement or organization." In fact, a contract is necessary in such a small group to evenly split costs or boost the provisions of collective goods. In addition, he claimed that in larger groupings, no collective benefit could be realized without some degree of coordination or agreement. Large groupings can produce the best results for the whole under the condition of "coercion or outside incentives".

Those participants in the collective enterprises who stand to gain the most may have an incentive to adhere to the aims of the group [27]. Coercion and imposing rules to enforce compliance are not sustainable and increase monitoring costs. Placing an emphasis on proper institutional architecture is the best method to overcome issues with collective action [28]. The ideal institutional structure includes "far more than rules, fines, and formal organizations ... but also a system of incentives and payoffs that will make the collective action sustainable over time" [25].

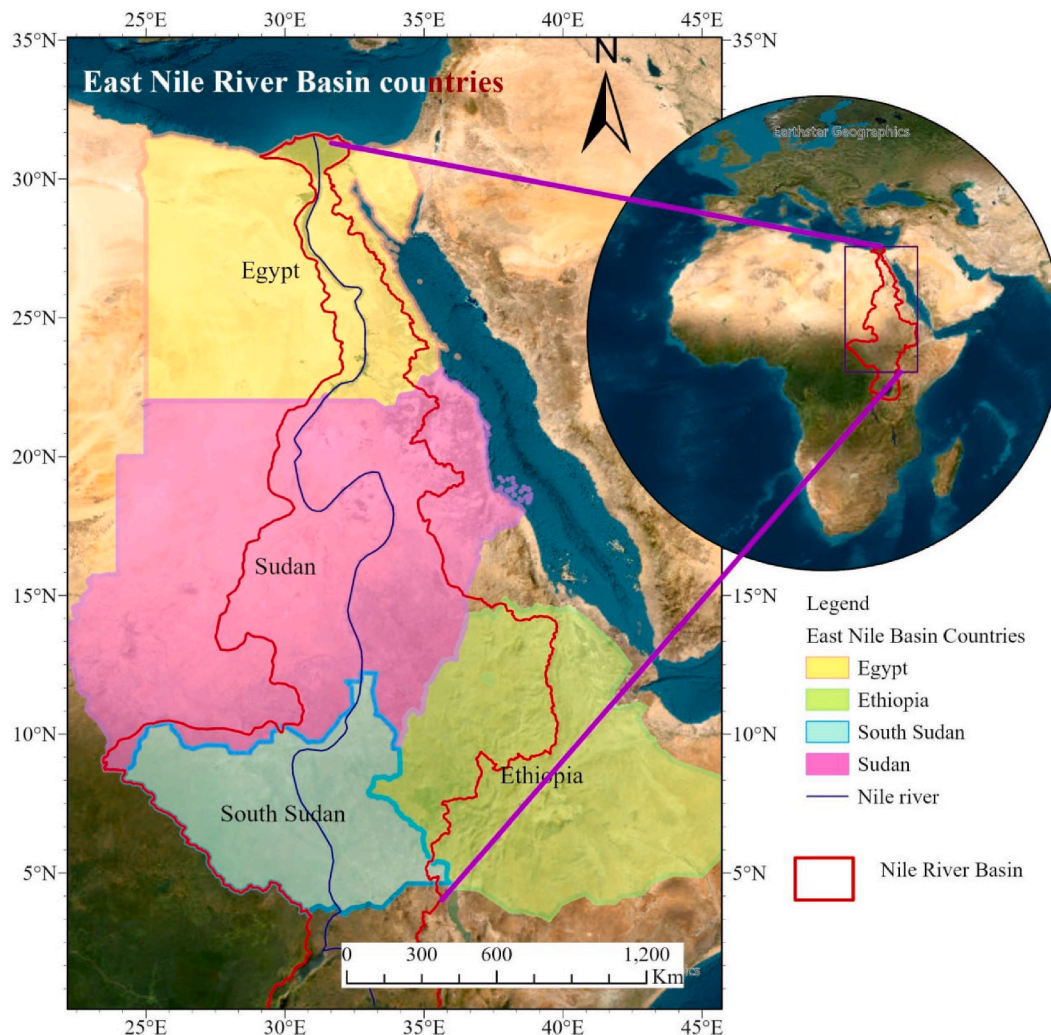


Fig. 1. Map of eastern Nile basin countries.

3. Research methods

3.1. Description of the study area

Geographically speaking, four nations in North East Africa—Egypt, Ethiopia, South Sudan, and Sudan—share the 1,809,606 square kilometer Eastern Nile River Basin (Fig. 1). Egypt makes up only 4% of the whole Eastern Nile Basin area, while Sudan, South Sudan, and Ethiopia account for 13%, 61%, and 22% of it, respectively [29]. The Blue Nile, Baro-Akobo, Atbara, and the main Nile—with the exception of the White Nile—are all included in the eastern portion of the Nile River Basin that it drains. The area undergoes significant seasonal water variations. The weather in the Eastern Nile Basin varies from tropical or subtropical in South Sudan and the highlands of Ethiopia to semiarid and arid [30,31]. According to Ref. [32], the Ethiopian highlands, specifically the Eastern Nile basin, are the source of the majority of the Nile's water, accounting for around 86% of the river's overall flow.

The Ethiopian portion of the Blue Nile, also known as the Abbay basin in Ethiopia, is situated in the northwest of the country between latitudes 8°0'0" and 13°0'0"N and longitudes 33°0'0" and 40°0'0" E (Fig. 2). It borders the Tekeze basin to the north, the Awash Basin to the east and southeast, the Omo-Gibe basin to the south, and the Baro-Akobo basin to the southwest [24].

It has a surface area of roughly 199,812 km² covering parts of Amhara, Oromia, and Benishangul-Gumuz regional states. The principal subbasins of this basin are Anger, Beles, Dabus, Debre Markos, Didesa, Dindir/Rahid, Fincha, Guder, Jemma, Lake Tana, Mota, and Muger. The Blue Nile (Abbay) River, which originates in Lake Tana and flows for around 1450 km before joining the White Nile to form the Nile proper, is the principal river in the basin. The Blue Nile River is the Nile River's most significant tributary, contributing more than 62% of the Nile's flow at Aswan. The lowest and highest elevations in the river basin are 500 and 4261 m, respectively. Estimates place the river basin's total mean annual flow at 54.8 BMC [33].

The Basin experiences a rainy season lasting four months (June–September) and a dry season lasting eight months (October–May). The dry season is longer in duration compared to the shorter rainy season, especially in the southern part of the Basin. In Ethiopia, the Blue Nile contributes approximately 40% of the country's agricultural output, nearly 50% of the average annual runoff from the Ethiopian highlands, and 20% of the country's total land area [24].

3.2. Research design

The study has employed qualitative research. According to Ref. [34] qualitative research helps to determine the significance, emotion, and description of a situation. Therefore, the challenges and prospects of transboundary river water conservation and watershed protection in Ethiopia's Upper Blue Nile Basin are analyzed and interpreted through qualitative research. This study employed a case research design to systematically analyze and interpret the challenges and prospects of transboundary river water conservation and watershed protection in the Upper Blue Nile basin.

3.3. Sources of data

Data for this study were collected from both primary and secondary sources. The primary data were collected from key informants based at academic institutions, government agencies (the Ministry of Water Resources and Energy and the Ministry of Foreign Affairs and Regional Bureau), downstream state embassies (diplomats from Egypt and Sudan), and expats based at a multilateral institution (IWMI). The secondary sources were collected from pertinent books, research articles, working papers, newspapers, proceedings, and reports.

3.4. Primary data

The primary data for this study were collected in two phases, from 2019 to 2021. The combination of factors such as the COVID-19 epidemic and accessing key informants posed challenges for data collection. Due to these challenges, the data were collected twice to address the problem of incomplete data. Moreover, as indicated above key informants from different backgrounds and organizations were incorporated into this study to improve the quality and accuracy of the data.

The study employed both purposive and snowball sampling techniques to select key informants. Initially, we contacted key informants who have research interests and have conducted research related to the Nile water management. The key informants were selected because of their first-hand experience and expertise in Nile water management through research work or working in water-related departments in their respective fields, as well as their educational backgrounds. Before we contacted the key informants based on the objective of the research, we tried to outline a set of questions (checklists) that may help us address the research objectives. We conducted one-on-one interviews with key informants to gain a deep understanding of the topic under investigation. During the interview, we took detailed notes, capturing key points of the interview. Once we contacted the scholars and diplomats we identified as key informants, using the snowballing technique, we contacted and conducted key informant interviews with additional key informants.

Accordingly, we contacted and conducted key informant interviews with key informants based in academic institutions (universities), government agencies (the Ministry of Water Resources and Energy and the Ministry of Foreign Affairs and Regional Bureau), downstream state embassies (diplomats from Egypt and Sudan), and expats based at multilateral institutions (IWMI), as the study aimed to explore the topic in depth. We adopted this interview technique not only to generate a deep understanding of the topic but also to gain additional information we may not incorporate into our research checklist.

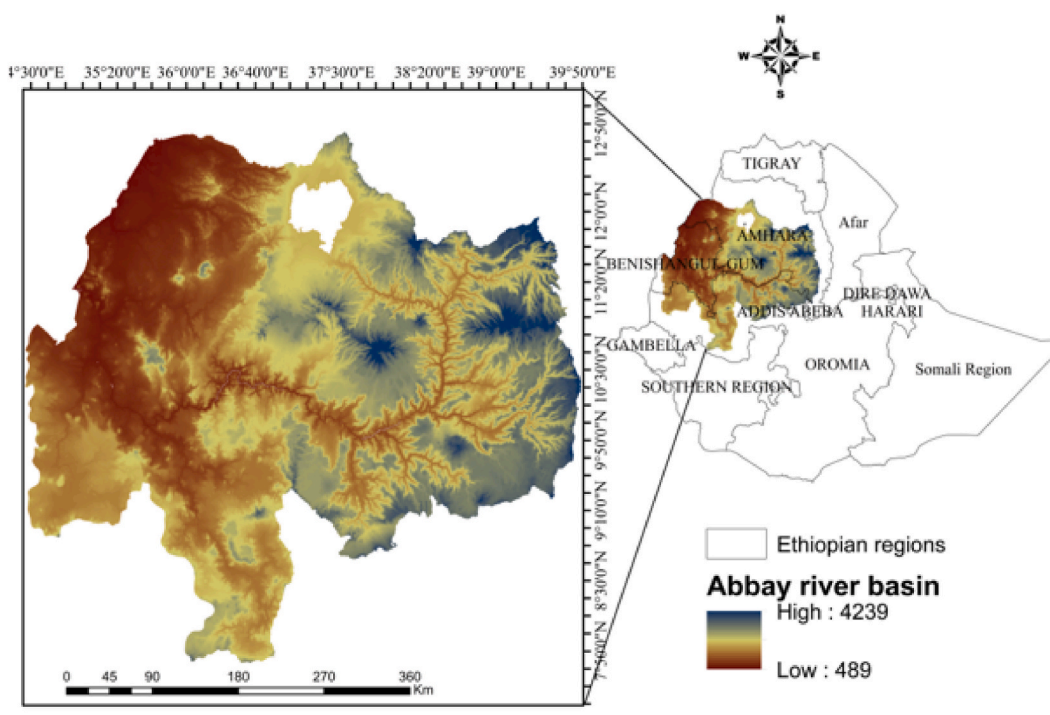


Fig. 2. Map of upper Blue Nile Basin

3.5. Secondary data

In this study, the secondary data were collected from pertinent books, research articles, working papers, reports, and policy and planning documents of government ministries and regional organizations. The authors gathered materials from both library collections and internet sources by using appropriate phrases to search on various internet search engines. We searched for reports, books, and proceedings at the Addis Ababa University Institute of Ethiopian Studies (IES) library, as well as the libraries of the Ethiopian Ministry of Water Resources and Energy, the Ethiopian Ministry of Foreign Affairs, and the Economic Commission of Africa (ECA). We conducted online research to find articles, book chapters, and working papers related to watershed management in the upper Blue Nile Basin by using search phrases such as "watershed management in the upper Blue Nile Basin" and "collaboration on the watershed management of the upper Blue Nile." Accordingly, dozens of materials were downloaded from internet sources. The secondary materials collected were thoroughly reviewed and used in this manuscript.

3.6. Data analysis

After we completed the key informant interview, we analyzed the data and looked for themes and insights that emerged. The collected data were analyzed through the thematic analysis method. As part of the thematic analysis processes, once we collected the data, we familiarized ourselves with the data through reading, grouping, and the identification of relevant themes that we thought helped address our research question. The major themes that emerged from the interviews can be categorized into three themes: the Ethiopian water conservation and watershed protection status and role of downstream states, challenges of collaboration over water conservation and watershed protection, and prospects of water conservation and watershed protection for cooperation among the Eastern Nile Basin States. Afterward, the data were analyzed and interpreted using the thematic analysis method.

4. Results and discussion

4.1. Results

The main themes identified through the analysis of qualitative data for this research include water conservation and watershed protection practices in Ethiopia, as well as the implementation of modern water management practices. Additionally, the study examines challenges related to collaboration among Eastern Nile basin states in conserving and protecting the water resources of the Blue Nile, along with the potential for cooperation among states regarding Nile water management and utilization. Accordingly, the following section provides the findings of the study under the themes.

4.2. Ethiopian water conservation practices in the upper Blue Nile Basin and the role of downstream states

In Ethiopia, water conservation practices have existed for centuries. The concept of water conservation has been embedded in Ethiopian society's value system. Despite the belief that water is a natural gift from God, no society in Ethiopia's culture promotes water waste. There are circumstances when water use efficiency can serve as a parameter for choosing a bride, because if the would-be wife can take care of the 'abundant' water, she could wisely handle household affairs, thus demonstrating her good quality for being a wife¹

A water management expert² at the Ethiopian Ministry of Water Resources and Energy suggests that the modern Ethiopian water bureaucracy should reconsider how traditional water management practices can be adapted into its systems. Currently, there is a low level of water use efficiency in Ethiopia due to the top-down water management approach, which ignores traditional water management practices, as well as the lack of water storage infrastructure. Despite the adoption of the water management policy in 1999 and the water management regulation in 2000, there has been little or no improvement in the overall water management in the country. To address the devastating drought that has affected the country since the 1980s, the government has constructed water-storing structures, which have enhanced the water conservation capacity of the country in the Abbay and other basins.

The Ethiopian People's Revolutionary Democratic Force (EPRDF)-led government has continued this policy by extensively expanding water storage structures since 2002. According to a water management expert at the Ethiopian Ministry of Water Resources and Energy,³ it is important to reconsider how the modern Ethiopian water bureaucracy can adapt these traditional codes into its systems. The observation of a low level of water use efficiency in Ethiopia in modern times attributes this to the top-down water management approach that ignores the traditional water management approach in addition to the low level of water storage infrastructure. As a result, the adoption of the water management policy in 1999 and the water management regulation in the subsequent year in 2000 have contributed little or no to improving the overall water management in the country. This expert noted that to deal with the devastating drought that has affected the country since the 1980s, the government embarked on constructing water-storing structures, which in turn enhanced the water conservation capacity of the country in the Abbay (Blue Nile) and other basins. As a policy continuation of the previous government, the EPRDF-led government has extensively embarked on the expansion of water storage structures since 2002.

As a result, water management specialists and scholars alike have argued that the Ethiopian effort alone is inadequate to address the need for water conservation in the basin. For instance, a transboundary river management specialist⁴ at IWIM believes that effective water management, including its conservation, should take place in the Ethiopian highlands through collaborative means. Nevertheless, this requires collaboration among all the Eastern Nile basin states. A scholar⁵ from Ethiopia also agreed that the Nile states must work together to maintain the shared watersheds of the basin states and to promote water conservation. The professor⁶ noted, however, that Ethiopia needs to i) evaluate its water management strategy, particularly its management of transboundary rivers, including the Nile Basin, and ii) advocate for the NBI joint framework's functionality or push for a new framework.

However, a scholar⁷ with knowledge of past negotiations for cooperation in the Nile basin has a pessimistic view of collective actions. He stated that "the reactions of the downstream states to the proposal to undertake multipurpose dam projects in Ethiopia were rejected by downstream states despite its advantage for conservation of the [Nile] river water under the auspices of the NBI environmental facility framework." However, Ethiopia, as a country with a great stake in water conservation and watershed protection activities, has the responsibility to engage the downstream states parallel to the negotiation to secure a fair share of the Nile water resources. In addition to the formal diplomatic engagement, parallel discussion networks among academics and bureaucrats similar to the 'Nile 2002' should be reconstituted again on the importance and urgency of water conservation and watershed protection in the Eastern Nile Basin.⁸

A diplomat⁹ from Sudan emphasized the importance of collaboration in preserving watersheds. He stressed the importance of expanding joint NBI environmental projects to benefit all basin states. He agreed that issues with Nile River water conservation and watershed protection are under serious scrutiny and that the best course of action is to jointly handle these common problems. On the other hand, the Egyptian diplomat¹⁰ stressed the value of collaboration with regard to issues of water conservation and environmental protection in upstream areas, emphasizing Egypt's prior participation in a number of regional initiatives to eradicate invasive weeds, particularly in the equatorial lake region, by providing financial and technical support to upstream countries. He also mentioned the potential for discussing cost sharing when upstream governments, such as Ethiopia, are open to Egyptian specialists participating in water management within Ethiopia and agreements are reached on disagreements over the operation and management of the GERD project.

¹ Interview with local elder on May 2, 2020 at Nekmte.

² Interview with an expert in the Ethiopian Ministry of Water Resources and Energy, transboundary desk, February 2, 2021.

³ Interview with project management expert at Ethiopian Ministry of Water Resources and Energy on June 6, 2020.

⁴ Interview with IWIM transboundary water expert in Addis on 23 March 2020.

⁵ Interview with Ethiopian International Relations Professor in Nekmte on April 4, 2019.

⁶ *ibid.*

⁷ Interview with Ethiopian International Relation Professor at Addis Ababa University, on February 4, 2021.

⁸ *ibid.*

⁹ Interview with Sudanese Diplomat based in Ethiopia, February 13, 2020.

¹⁰ Interview with Egyptian diplomat, May 5, 2020.

According to an experienced Ethiopian diplomat¹¹ who is knowledgeable about transboundary water management, the Ethiopian government has not been effective in addressing the issue of cost-sharing for environmental protection, despite the fact that such practices are common in other international river basins. During negotiations over Nile River water management and development, Ethiopia did not prioritize the agenda of cost sharing for environmental protection, as the fair distribution of Nile River water took precedence over other water management concerns.

The views of Ethiopians, Sudanese, and Egyptian diplomats, as well as Ethiopian scholars and bureaucrats, agree on the need to address collective action problems. Moreover, they all appeared to agree on the need to negotiate a deal with collective action problems. Moreover, diplomats from Egypt and Ethiopia raised the possibility of maintaining compliance through the formation of supranational institutions, including the provision of incentives for the production of public goods. However, the view expressed by Ethiopian scholars with the knowledge of past negotiation track records on multipurpose projects proposed by the World Bank and other donors implied that there were circumstances in which negotiation and external imposition seemed unable to resolve collective action problems.

According to Ethiopian academia,¹² Ethiopia views its projects on the Nile, such as the GERD, not only as a means to enhance water supply for energy production but also as a way to conserve Nile water (Table 1). The dam helps to reduce water loss due to evaporation, which is relatively low, in addition to regulating and mitigate the siltation problems for lower riparian states. Perhaps that is the reason behind the suggestions of the late Ethiopian Prime Minister Meles Zenawi during the inauguration of the GERD project. He proposed cost-sharing between the basin states. He suggested that downstream states cover half of the project cost, while Egypt should cover 20% and Sudan should cover 30% of the cost based on the benefits they would receive from the project [37].

It appears that Egypt's suspicion and hostility towards the dam may stem from Ethiopia's lack of diplomacy in negotiating its intention to begin the project. Ethiopia did not properly notify or communicate the potential benefits of the dam to downstream states, including Egypt. These benefits include the storage of Nile water in a cool place with low water loss due to evaporation and the assurance that Ethiopia intends only to produce energy with no impact on the quantity of water flowing downstream.¹³ Nevertheless, the Ethiopian diplomat¹⁴ has a different opinion on the prior notification of the project to the downstream states, particularly Egypt, as the country would have obstructed the project since Egypt sees itself as the only legitimate user of the Nile. He further noted that there are also issues of sovereignty, and above all, prior notification holds security risks for Ethiopia and appears to attract unnecessary pressure from the international community before the commencement of the project.

4.2.1. Ethiopia watershed protection intervention and the role of downstream states

The Ethiopian government has learned the impacts of the lack of well-planned environmental protection programs on water projects. As a result, Ethiopian planners have mobilized the masses to undertake environmental protection programs alongside the construction of the GERD project to prevent such issues from occurring again in the future. Accordingly, following the commencement of the Grand Ethiopian Renaissance Dam (GERD) project in 2011, the Ethiopian government mobilized the masses for environmental protection in the Nile catchment areas to protect the dam under construction from the challenge of siltation. Since 2011, the Ethiopian government has implemented environmental protection programs by designing a community-based participatory watershed protection program, which has been implemented every year since then [38]. Unlike previous water projects, the Ethiopian government mobilized the public for watershed protection in tandem with the commencement of the project.¹⁵

Even before the commencement of the GERD and other water development projects in the Blue Nile Basin, Ethiopia has undertaken soil and water conservation (SWC) practices in the Ethiopian highlands since the 1970s, with an impact on sediment yield reduction and the increment of agricultural productivity [39,40]. Table 2 provides a glimpse of the impacts of such an intervention on the Blue Nile Basin.

Similarly, recent research in the Upper Blue Nile Basin's watersheds has shown that soil and water conservation efforts play a critical role in decreasing sediment yield in the Ethiopian highlands (Table 3). This underscores the significance of these interventions in reducing sediment accumulation in the reservoirs of the Blue Nile within Ethiopia and in downstream states.

On the other hand, despite the lack of aggregate data on the total cost Ethiopia has incurred for soil and water conservation practices since the 1970s in the Upper Blue Nile Basin, the Ethiopian Ministry of Water Resources (MOWR) [45] and later Hailesellasiye et al. [46] and the expert at the Ethiopian Ministry of Water and Energy also estimated the average cost of rehabilitation of degraded lands. Accordingly, the [45] estimated the average cost at about 760 USD/ha, and Hailesellasiye et al. [46] adjusted considering inflation rates reported at 1365 USD/ha. Based on the MOWR [45] baseline estimation, the expert at the Ethiopian Ministry of Water Resources and Energy estimated the cost of rehabilitation at about 2500 USD/ha (Table 4). Again, this also varies with the watershed management technology adopted and geographical feature considerations like the slope of the land and land characteristics [40].

As a result of the restoration efforts, vast expanses of degraded land have been successfully rehabilitated and are now covered with vegetation. Mountains and hillsides have been protected from human and animal reach. Moreover, the river ecology in most of the areas visited by the researcher was protected, and wetland areas were restored, although additional work needs to be done. The dried springs and streams were revived, and they began to flow. The cumulative effect of all these local interventions not only contributed to

¹¹ Interview with an Ethiopian diplomat familiar with Nile diplomacy, March 23, 2020.

¹² See note 5.

¹³ *ibid.*

¹⁴ See note 11.

¹⁵ See note 3.

Table 1
Reservoirs storage capacity and rate of evaporation losses in Blue/main Nile basins.

Dams	Storage capacity (BCM) ^a	evaporation losses (BCM/year)
GERD	74	1.57 ^c
High Aswan Dam	169	10–12 ^b
Merowe	12	1.68 ^c
Sennar	0.5	0.32 ^c
Roseires	6	1.6 ^c

Adapted from.

^a Cascão, 2019 [35].

^b Khairy et al., 2019 [36].

^c Jeuland et al., 2017 [19].

Table 2
Sediment yield ton per year (tyr-1) with/without soil and water conservation (SWC) measures in the Upper Blue Nile Basin.

Basin	Sediment yield in tyr ⁻¹ without SWC	Sediment yield in tyr ⁻¹ with SWC	Sediment reduction, %
Upper Blue Nile	131x10 ⁶ tyr ⁻¹	66 × 10 ⁶	44

Adapted from Betrie et al., 2011 [41]

Table 3
Shows sediment yield ton per hectare per year (t ha-1yr-1) with/without Soil and Water Conservation (SWC) measure in selected watersheds of the Upper Blue Nile Basin.

Selected Watersheds	sediment yield t ha ⁻¹ yr ⁻¹ without SWC	Sediment yield t ha ⁻¹ yr ⁻¹ with SWC	% sediment Reduction
Gerda^a	37	17	54
Gumara-Maksegnit^b	44.8	33.5	25
Kecha and Laguna^c	79.38	39.26	49
Akesity and Kasiry Guder sub-basin^d	71.	27.2	38

Adapted from.

^a (Lemann et al., 2016) [42].

^b (Melaku et al., 2018) [43].

^c (Berihun et al., 2020) [40].

^d (Ebabu et al., 2018) [44].

Table 4
Shows the average cost of rehabilitating degraded land per hectare over the years in the Ethiopian Upper Blue Nile Basin.

Year	Average cost (USD/ha)	sources
2002	760	MOWR (2002)
2008	1365	Hailesellase et al. (2008)
2022	2500	Ministry of Water Resources and Energy Expert (see endnote 2)

the reduction of the silt taken to the GERD but also contributed to the health and sustainability of the ecology of the Nile River basin. Given the dwindling number of landholdings per household, prohibiting the local community from utilizing their natural environment responsibly and in an environmentally friendly manner would undermine the sustainability of environmental protection activities.¹⁶

Nevertheless, in the Nile basin of the Ethiopian portion, no matter how much investment is made for the environmental protection of the Nile environment in comparison to the complexity and extent of the degradation, the intervention is still inadequate, calling for further resource commitment. Despite the Ethiopian government's intent and efforts, the growing population and economy, combined with poor land use practices, have undoubtedly continued to cause widespread land degradation.¹⁷ This inevitably has the potential to increase the frequency and intensity of drought and the expansion of desertification, with implications for the flow regime of Abbay (Blue Nile) water to downstream states. Unfortunately, the downstream states hardly recognized the looming threats to Nile River water and never valued Ethiopian farmers' efforts to protect the Nile River basin. The intensity of the intervention to protect the watershed has increased since the commencement of GERD in 2011.¹⁸

¹⁶ *ibid.*

¹⁷ Interview with hydraulic Engineer lecturer at Ambo University on April 1, 2019 at Ambo.

¹⁸ Interview conducted with staff of Wollega University, Department of Political Science and International Relations on 23 June 2020 at Nekmte.

4.2.2. *The challenges of collective action in water conservation and protection of the Abbay (Blue Nile) basin*

Ethiopian state water policy expounds the relevance of governing shared water resources cordially. Beyond that, it has not clearly outlined how to manage water usage in basin states. Even though the Ethiopian water policy discusses the issues of equitable use and benefit sharing as indicated in the NBI document, it rarely discusses the issue of sharing responsibility to rehabilitate the Nile environment and thus the efforts to contribute toward the Nile 'water making'. According to an Ethiopian academic,¹⁹ "advocating for such cost-sharing may be crucial for the river's sustainability and to prevent the perception of "free riding," but policymakers in Ethiopia "shy away for fear that such assertions could invite the criticism of Ethiopia commoditizing the river water".

An IWIMI transboundary river expert²⁰ stated that the fact that the basin countries have limited financial resources to allocate for cost-sharing may be one reason that potentially prevents the basin countries from negotiating on issues that involve financial commitments, but if the basin countries act jointly, they could raise funds for such projects by working with donor agencies that are interested in mitigating climate change impacts. According to Ethiopian academia,²¹ Ethiopia, during the different rounds of GERD negotiation and before, has rarely brought the agenda of the overall Nile basin management from the Ethiopian highlands where the Nile originates to where it ends. He noted that:

Surprisingly, I never heard Ethiopia utter a word about its effort to rehabilitate the Abbay (Blue Nile) basin and other tributaries of the Nile, at least for the last four decades, despite the enormous amount of resources committed to the program. The Ethiopian public, in fact, doubled its efforts since 2011, following the commencement of GERD. This shows the loophole in Ethiopian water management policy that lacks a clear strategy to govern transnational rivers, and the loophole in its foreign policy to guide diplomatic engagement on the subject.

On the other hand, the foreign policy of the country about shared resources like the Nile needs a revisit as it lacks the issues of joint management of water infrastructures to conserve the Nile water, Nile watershed protection for ensuring the Nile water and its environmental sustainability, and fair allocation of the Nile River water. Ethiopia has invested billions in protecting the Nile River watershed, ensuring that it remains safe from the impacts of climate change and desertification. As a result, Ethiopia has every right to reap the benefits of its efforts to safeguard the Nile ecosystem. To this end, all other basin states have a responsibility to join hands with Ethiopia in the environmental rehabilitation and protection of the Nile environment for the common good of all.²²

The environmental rehabilitation program of Ethiopia has been challenged as it lacks resources to enhance agricultural intensification or create off-farm income streams to prevent farmers from encroaching on rehabilitated marginal areas or expansion of farmland, as these actions have the potential to reverse the achievement of the watershed protection programs implemented so far. Moreover, Ethiopia lacks institutional and financial resources to ensure the sustainability of the rehabilitated environment and prevent encroaching on additional marginal lands, such as hillsides. Despite these challenges, Ethiopian water management policy and regulation have not addressed the loophole of engaging basin states to address these problems collaboratively in the Eastern Nile basin.²³

4.2.3. *Prospects of water conservation and watershed protection in the Upper Blue Nile Basin for sub basin cooperation*

According to an international relations scholar,²⁴ British engineers proposed constructing water reservoirs in the Ethiopian highlands during British colonial rule in the Nile basin. This plan was based on the understanding that constructing water reservoirs in the Ethiopian highlands would conserve the Nile by reducing the significant amount of water lost due to the high evaporation rate. The reservoirs would not only help reduce water loss but would also encourage interdependence, communication, and mutual understanding, laying the foundation for better cooperation and sustainability in the Nile basin.

Even though the unilateral actions of Ethiopia are inadequate to safeguard the Nile environment and conserve the Blue Nile water, the Ethiopian action partially mitigates the threats. An expert²⁵ on the transboundary river at the Ethiopian Ministry of Water Resources and Energy stated that with the commencement of the GERD project, the Ethiopian government made a concerted watershed protection movement by mobilizing the local population throughout the country, unlike the previous watershed protection movements, which were limited to selected areas. The commencement of the GERD induced a new impetus for watershed programs throughout the country in general and the Upper Blue Nile Basin in particular. The Ethiopian effort not only reduces the siltation of Ethiopian hydraulic structures like GERD but also reduces the siltation of Sudanese reservoirs and irrigation canals, which reduces the potential of the Sudanese energy production and irrigation sectors.

Moreover, the practical benefit in the long term may motivate not only better cooperation and the contribution to watershed protection and water conservation efforts from their national coffers but also the search for additional financial resources from donors as environmental rehabilitation programs in the Ethiopian highlands also mitigate the extreme climate change impacts in addition to their role in protecting and safeguarding the Eastern Nile Basin from environmental degradation effects. An Ethiopian International

¹⁹ Interview with International Law professor at Addis Ababa university on May 7, 2020.

²⁰ See note 4.

²¹ See note 7.

²² See note 19.

²³ See note 3.

²⁴ See note 7.

²⁵ See note 3.

Relations professor²⁶ has the view that such understanding and collaboration have the potential to pave the way for non-water cooperation among the Eastern Nile Basin countries, strengthening regional integration in North East Africa with far more economic, security, and geostrategic repercussions. He further noted that this understanding and cooperation also enhance the idea of NBI's benefit-sharing idea from the Nile water resources, as the countries could be interconnected through the power grid for power trade and the trade of commodities, making every country participate as a beneficiary of the engagement.

The expert²⁷ from IWIM expressed optimism that the protection and conservation of Ethiopian watersheds could lead to beneficial outcomes for downstream states. This positive development has the potential to reduce current tensions surrounding the use of the Nile, particularly regarding the GERD. It could also foster a gradual understanding among riparian states and encourage them to resume negotiations. By addressing the issues related to Article 14(b) of the Cooperative Framework Agreement (CFA), basin-wide institutions can be created. Ultimately, this could result in the establishment of supranational institutions that effectively govern the Nile, ensuring sustainability and tranquility for all countries in the basin.

The Egyptian diplomat²⁸ stationed in Addis Ababa, however, holds the opinion that while Ethiopia's environmental protection initiatives are beneficial for protecting the country's water control structures from silt, they are insufficient on their own to address Egypt's water security concerns because no legally binding agreement that protects Egyptian interests is in place. He emphasized that although Egypt is aware of the advantages of Ethiopia's environmental intervention, the issue of managing the Nile's water is far more complicated than water management operations. Without a legally enforceable agreement regarding Egypt's concerns, it is challenging to predict the next step by Ethiopia or another upstream state. He suggested that supporting this Ethiopian action with concrete legal documents would promote confidence and understanding. A Cairo University professor also expressed similar concerns to the Egyptian diplomat, even further expressing his fear that without such legal agreements, Ethiopia could go with a plan to build an additional four dams with negative impacts on downstream states [47].

4.3. Discussions

4.3.1. Ethiopian water conservation practices in the upper Blue Nile Basin and the role of downstream states

In line with the findings of this study, previous studies by Ref. [48] documented the existence of water conservation value systems among the various Ethiopian societies. Despite the existence of water conservation traditions in Ethiopia, this study found widespread water use inefficiency in modern times. The findings of this study, which indicated widespread water use inefficiency during the Ethiopian military junta that ruled Ethiopia (Derg)²⁹ and EPRDF regimes, agreed with the previous studies, which reported a low level of water use efficiency as low as 20–30% [49]. Similarly, the study by Ref. [50] reported the low level of water use efficiency, attributing the factors to low water-use charges and the fact that users are required to pay based on hectares cultivated rather than the volume of water used. Other studies on water use efficiency have indicated similar challenges in Ethiopia [51,52].

This study found that though the Ethiopian water policy document underlined the importance of water conservation when it comes to transboundary rivers, Ethiopian water policy and diplomacy have not clearly stated how to engage the downstream states since this document also recognizes international rivers as shared rivers. As a result, no serious study or discussion has been conducted on the water conservation issue, regardless of the importance of water conservation in the context of climate change, population growth, and widespread mismanagement of water resources. In this regard, it is worth mentioning the [5] Strategic Water Resources Analysis, which underscores the need for conserving Nile water in general at a basin scale.

Moreover, despite the recognition of water conservation, Ethiopia, as a country with a high stake in the matter of water conservation, has rarely raised the water conservation issue, as witnessed during the GERD inaugural speech. This low level of water conservation practice in Ethiopia, coupled with the lack of collaboration among the Eastern Nile states, sustains the status quo, which helps prevent the loss of Nile water from evaporation. Previous studies by Refs. [33,48] also found the priority given to water allocation issues over its sustainable management by Eastern Nile Basin countries.

It was found in this study that regional organizations like the Nile Basin Initiative (NBI) have not encouraged the countries of the region to work together in building and managing water conservation facilities. This is concerning, as it is important to construct water reservoirs in the Ethiopian highlands, where the rate of evaporation is relatively low [19]. Without joint efforts, it will be hard to use the Nile water sustainably, as individual actions are not enough to conserve the river's water, given the need for basin-wide planning. The Eastern Nile Basin countries have been reluctant to collaborate for Blue Nile water conservation, which is in line with collective action theorists' assumption that the existence of common interests is not enough to bring about cooperation when dealing with common challenges like water conservation [25].

This weakness of the regional institution to coordinate and resolve common problems in the Eastern Nile basin raises the question of why some regional institutions are successful and others are not. In this regard, it is worth looking at the experience of the Organization for the Development of the Senegal River Basin (OMVS), which successfully managed the Senegal River on a basin scale. This organization coordinated the joint construction and operation of the reservoirs at a location where such water infrastructure offers optimal benefit to all the basin states, with the commitment of member states to such projects that promote the welfare of society and the sustainability of river water. In the Senegal River basin, water allocation is rarely an issue among the riparian countries, as they

²⁶ See note 7.

²⁷ See note 4.

²⁸ See note 10.

²⁹ The Ethiopian military junta that ruled the country from 1974 to 1991, commonly known as the Derg.

harmonize and coordinate the benefits accrued according to the country's needs [53]. Even though this idea of benefit sharing has been expounded in the NBI document [33], it has yet to materialize in the Eastern Nile basin. Moreover, no member country of the OMVS has refused to make an annual contribution as the eastern Nile basin countries have done [6]. To effectively manage transnational water resources, the countries must analyze why they were able to collaborate successfully in the Senegal River basin but not in the Eastern Nile basin. The crucial step is to learn from this experience and apply the lessons learned to overcome past failures and work together effectively.

It is not only the lack of strategy to manage the Ethiopian international rivers and the weakness of Ethiopian diplomacy to engage the downstream states that affected joint water conservation in Ethiopian highlands but also the reluctance of the downstream states like Egypt, which vehemently opposed the construction of water reservoirs in Ethiopian highlands for fear such projects might affect the 1959 agreement Egyptian water quota despite the importance of such projects for all the basin states [54]. In addition, the study also found that despite the importance of water conservation structures like GERD for Sudan, they hardly support the Ethiopian initiative, though they refrained from outright opposing such projects in Ethiopia.

The construction of such water reservoirs in Ethiopia helps mitigate the country's devastating floods and the siltation of the Sudanese dams. The country hoped that the new dam over the Blue Nile would replace the role of the Sudanese dams as "siltation basins," which would save millions of dollars for Sudan [55,11,and56]. Moreover, they also saw the advantage of the project, as it provides another opportunity to expand irrigation fields [57] and increase the energy generation capacity of the Sudanese reservoirs [18].

Therefore, the findings of this study showed that material benefit alone is not adequate to entice states to cooperate, even to collaboration schemes that ease the financial burden of states that become members of a cooperation, as the Sudanese case witnessed in this study. Perhaps a combination of factors—both material and non-material considerations—influence the behavior of states to cooperate over a given issue area, like the management of transboundary rivers. These non-material considerations may include the level of communication and diplomatic engagement, the opportunity for free riding, and the existence or absence of regional institutions that coordinate the member states towards such collaboration.

4.3.2. Ethiopia watershed protection intervention and the role of downstream states

This study found that, regardless of all its limitations, the Ethiopian government and society have undertaken watershed protection in the Blue Nile basin and beyond for the last few decades. The study also found that the watershed protection measure in Ethiopia significantly reduced the sediments that affected the water reservoirs of Ethiopia and downstream states. Efforts to tackle environmental degradation, especially after the launch of GERD on the Blue Nile in 2011, have not been enough to address the challenges of siltation and desertification. Unfortunately, this study has found that the progress made in rehabilitating degraded lands has been limited. The Ethiopian effort alone is inadequate given the scale of land degradation in the Blue Nile basin portion of the Ethiopian highlands. Unfortunately, the downstream states have never recognized and considered this Ethiopian effort [58]. long noticed and stated that downstream states have "zero value" for the Ethiopian effort to rehabilitate and protect the Nile River Basin.

Similar to the findings of this study, scholars have long warned of the consequences of the inability to act or collaborate on environmental recovery in the Blue Nile basin, with devastating consequences for the Nile and the livelihood of people who relied on the Nile water. According to Ref. [59], the recurrent drought that affected Ethiopia could worsen and recreate the 1980s situation, with implications for the Nile flow regime, which reportedly significantly reduced the volume of Nile water that reached the Egyptian Aswan High Dam in the mid-1980s. Similarly, reports by Ref. [60] indicated the possible impacts of drought on the Nile flow regime. On the other hand [61], warned that if the Nile River environment is not well protected in the Ethiopian highlands from desertification and droughts, the volume of water flowing to downstream states will be reduced significantly.

According to Ref. [61], Ethiopians experience the phenomenon of drought "every 3–8 years in the northern part of the country [Ethiopia] and every 8–10 years in the more humid regions." Furthermore, their study also indicated that reports from more than 40 meteorological stations implied that the minimum and maximum temperatures increased between 1952 and 1997, indicating the impacts of global climate change on Ethiopia. Even though the availability of accurate data is a problem regarding the impacts of climate change on water availability [61], indicated that "a 10% reduction in rainfall would produce a 30% reduction in catchment runoff and a 1.5 °C increase in air temperature, a 15% reduction in simulated discharge." Thus, a lack of joint action would affect every state in the Eastern Nile basin, with significant ramifications for the economy and livelihood of the Nile population.

Even though the findings of this study underscored the need for collaboration and cost-sharing, the previous studies by Refs. [62, 63], which underlined the importance and necessity of providing incentives for upper-riparian countries, found that even their cooperation in 'reasonable and equitable' utilization of shared water is a bit controversial and would not help the spirit of solidarity. Such an approach would rather sow further mistrust and discord among the basin countries and reinforce the status quo of Nile water management, which again in no way helps the sustainable utilization of Nile river water. However, the weakness of institutional mechanisms prohibits meaningful negotiation to arrange compensation mechanisms for those who contribute to the health of the Nile ecosystem [64].

4.3.3. The challenges of collective action in water conservation and protection of the Abbay (Blue Nile) basin

This study found poor communication and weak diplomacy on the part of Ethiopia to be factors that challenge collaboration in the Eastern Nile Basin. The research also found a lack of a coherent policy approach, and methods for involving the downstream states have been highlighted. Moreover, there is a fear of a negative response from the downstream states for trying to commoditize the river if Ethiopia claims cost sharing for the Nile 'water making' [65] through its intervention to conserve the Nile water through the construction of reservoirs and intervention to rehabilitate the Blue Nile environment.

The findings of this study agreed with those of previous studies, which identified historical mistrust and asymmetrical benefits from cooperation as factors that prevent cooperation among states [66]. Recent studies by Refs. [18,67] identified risk perception as a factor holding collaboration back in international river basins. The risk perception identified by Ref. [67] discusses the issue from a downstream perspective. However, upstream states like Ethiopia feel the risks to call for collaboration or compensation for the services they provided in rehabilitating the Nile environment.

The Ethiopian water policy acknowledged the importance of regional cooperation for the efficient utilization of the Nile River [68]. However, it did not delve much into the topic of cost sharing. Instead, it mainly focused on the issue of how the benefits of the Nile could be shared among the involved parties. This Ethiopian water policy document also underlined the vulnerability of Ethiopian transboundary river basins to natural disasters. This has a far greater impact on the quantity and quality of water that reaches the downstream states, justifying the need for engaging the downstream states in Nile 'water making' by rehabilitating the Nile environment.

This study found that weak supranational institutions were a challenge that undermined joint efforts in Blue Nile water conservation and environmental rehabilitation. No matter how active states are in diplomacy and engagement with their neighbors, supranational organizations are responsible for coordinating cooperation, as it is impossible to force sovereign states to contribute towards public goods. However, the collective action model suggests that negotiation and presentation of the matter can ensure the compliance of sovereign actors to act [25]. Ethiopia has not made any efforts to negotiate sharing the costs of water conservation and environmental rehabilitation in the Abbay (Blue Nile) Basin, despite being the country most affected by the lack of intervention. Moreover, Ethiopia has made little or no diplomatic move to shed light on the inadequacy of its efforts due to the sheer magnitude of the problem. As indicated in the above section, Ethiopian farmers have contributed towards what [65] called 'water making' at least for the last four decades through environmental rehabilitation programs [14]. Neither Ethiopia nor the downstream states have recognized the cost-sharing of Nile water making [58] and compensated the Ethiopian farmers for their contribution to it for the last four decades.

The experiences in other transboundary river basins, such as the Mekong [69], Columbia [70], and Rhine Rivers [71], have shown that upstream states design and implement policy regimes that benefit downstream states. This, in turn, has helped upstream states receive compensation from downstream states to encourage upstream states. In the Mekong River Basin, when China decided to release water from its cascade of reservoirs to alleviate the critical droughts the downstream states of the Mekong faced in 2016, the downstream states agreed to provide both tangible and intangible benefits in the form of diplomatic support and trade concessions. Similarly, in the Colombian River Basin, Canada demanded more compensation for its efforts in environmental and flood protection activities from the United States, and the latter offered a package of compensation for the former [71].

Unlike the trends in these major river basins, in the Eastern Nile Basin, the upstream state like Ethiopia rarely pushes for compensation, and the downstream states on their side are also unwilling to recognize and appreciate the Ethiopian effort that helps to conserve the Nile water and environmental protection programs that safeguard the basin from the impacts of climate change. Besides, the Ethiopian effort alone is inadequate to rehabilitate the Upper Blue Nile Basin, which could potentially compromise the sustainability of the Nile basin in the era of climate change-induced uncertainty. Research conducted by Basheer et al. [71,72] corroborates the importance of Ethiopian action for the downstream states. According to Ref. [72], the lack of cooperation in the Eastern Nile Basin is attributed to the lack of mechanisms to share benefits and the weak attempt made to build confidence.

Olson [26] argued that collaboration among sovereign states can be challenging to achieve through "coercion," but "outside incentives" may aid in fostering cooperation among the Nile states concerning water conservation issues. The experience in the Nile basin supports the notion that outside incentives played a significant role in promoting collaboration among the basin states. Key actors like the World Bank, Canadian Development Cooperation, and other donor agencies were instrumental in establishing the NBI in the past. These findings align with the perspective of collective action theorists, emphasizing the importance of regional institutions in facilitating regional collaboration. The absence of such institutions hampers collaborative efforts and increases the likelihood of unilateral decision-making.

4.3.4. Prospects of water conservation and watershed protection in the Upper Blue Nile Basin for sub basin cooperation

Undertaking water conservation and water protection in the Ethiopian highlands holds greater opportunity for the sustainable use of Nile water and the enhancement of cooperation in the Eastern Nile basin as well as in other international river basins. The interdependence created to jointly manage and operate the water reservoirs enhances understanding and communication, which also helps to enhance cooperation among the Eastern Nile basin states. In line with this, previous studies argued that in spite of Egypt's opposition to water control structures on the Blue Nile for fear that they affect the quantity of water that reaches the country or are manipulated by Ethiopia for political reasons [18], Ethiopian intervention in the form of watershed protection and the construction of water storage structures is predicted to help "mitigate both the considerable inter-year and intra-year variations in the flow of the Blue Nile [73], which could motivate the downstream state, Egypt, to abandon its opposition towards the water infrastructure development in Ethiopia after observing its practical benefits. This also helps to gradually lessen the current tension and come to terms with better cooperation over the management and sustainable utilization of the river's water.

Regarding watershed protection programs by Ethiopia, this study found that this Ethiopian intervention not only benefits Ethiopian water reservoirs but also downstream states, especially Sudan. This in turn helps in enhancing cooperation among the basin states. Similar to the findings of this study, research by Ref. [11] indicated that Ethiopian efforts in the upper catchment of the Blue Nile and the GERD itself relieve Sudan of the costs of removing silt from its reservoirs and irrigation canals. Moreover, the findings of this study implied that the Ethiopian effort to safeguard the Blue Nile from climate change impacts and the effort to save the Nile could also help to ease tension, as work by Ref. [56] also implied in its findings, which in turn strengthens collaboration among the basin states.

5. Conclusion

This study provides insights into the obstacles and potential of conserving transboundary river water and protecting the watershed in the Upper Blue Nile basin. The results emphasize that although the countries within the basin have made progress in collaborating on Nile River management, they still face significant barriers to effectively addressing shared challenges like water conservation and environmental degradation. Insufficient transboundary water management systems, limited financial resources, and ongoing disputes over Nile water allocation impede cooperative efforts. Moreover, the research reveals the shortcomings of Ethiopia's unilateral approach to tackling these issues. Ethiopia's diplomacy has struggled to involve downstream countries in addressing environmental degradation and water conservation concerns, missing an opportunity for regional cooperation.

Additionally, the failure to consider cost sharing or compensation during Nile water negotiations underscores the necessity for a more inclusive approach. Considering that the threats to the Nile water supply endanger the national water security of all Nile basin states, Ethiopia needs to revise its water management policy and adopt a proactive water diplomacy approach. Collaborative efforts among all basin countries are crucial for effectively conserving and safeguarding the upper Nile watershed. Through shared responsibility, addressing these common challenges will contribute to the long-term sustainability of water resources in the region.

The need for a change in the current water management system is imperative. Ethiopia's efforts alone are insufficient, and the Eastern Nile faces new risks and uncertainties due to climate change, environmental degradation, and the demand for managing large-scale projects. To ensure sustainable use of the Nile, cooperation and change are necessary among the basin countries. In the past, basin countries in the Rhine, Elbe, and Aral Sea areas successfully collaborated to overcome shared challenges. In Sub-Saharan Africa, too, the riparian states along the Senegal River collaborated and successfully dealt with common water management challenges in the basin. It is time for the Nile basin countries, or at least the Eastern Nile basin states, to contemplate a new transboundary water management model or else risk the threats to the basin environment and people. However, the question remains: in an anarchic system lacking coordination institutions, which riparian state or multilateral organization should be responsible for fostering collaboration among the basin countries?

Ethical statement

The research study was carried out in accordance with ethical principles and with the informed consent of the participants.

CRediT authorship contribution statement

Emiru Gemechu Kedida: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Yacob Arzano:** Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- [1] S.M.A. Salman, *The Missing Pillar* in Nile: Water Catching Fire? *Discourse*, Volume II. March –May, 2018. Addis Ababa: EFRSSI, 2018.
- [2] WWAP (UNESCO World Water Assessment Programme), *The United Nations World Water Development Report 2019: Leaving No One behind*, UNESCO, Paris, 2019.
- [3] N. Salim, M. Anziani-Vente, D. Madsen, *Water Security: A Dynamic Multidisciplinary Vision from Theory to Practice* in UNESCO and UNESCO I-WSSM. 2019. *Water Security and the Sustainable Development Goals (Series L)*. Global Water Security, 2019.
- [4] T. Tafese, የናይል ተፋሰስ ተለዋዋጭ የውኃ ፖለቲካና ተቋማዊ ገፅታዎች, in: NED (National Endowment for Democracy) Proceedings, ዲሞክራሲያዊ የለውጥ እርምጃዎች እንደምታዎች እና አማራጮቻቸው በኢትዮጵያ: ኢትዮጵያ ከአካባቢ አገራት ጋር ያላት ግንኙነት እና የዓለይ ውኃ ጉዳይ (ቅፅ ሦስት). Forum for Social Studies: Addis Ababa, Ethiopia, 2020.
- [5] Nile Basin Initiative, *Briefing Note 8: Restoring the Nile Basin*, 2015. <https://nilebasin.org/index.php/documents-publications/59-restoring-the-nile-basin-digital/file>.
- [6] NBI (Nile Basin Initiative), *NBI Technical Reports- WRM-2020-03 Irrigation Development Projection in the Nile Basin Countries: Scenario-Based Methodology Technical Report - 2a*, 2020.
- [7] X. Wu, M. Jeuland, D. Whittington, "Does political uncertainty affect water resources development? The case of the Eastern Nile" *Policy and Society* 35 (2) (2016) 151–163.
- [8] S.F. Sherif, *Environmental reform in Egypt: the past mistakes, present situation, and future perspectives*, *J. Environ. Earth Sci.* 4 (23) (2014). www.iiste.org.
- [9] F. Mahgoub, *Current Status of Agriculture and Future Challenges in Sudan*. *Current African Issues*, vol. 57, Nordiska Afrikainstitutet, Uppsala, 2014.
- [10] V. Roth, T. Lemann, G. Zeleke, A.T. Subhatu, T.K. Nigusie, H. Hurni, *Effects of climate change on water resources in the upper Blue Nile Basin of Ethiopia*, *Heliyon* 4 (9) (2018).
- [11] S. Thuo, P. Riddell, *Political Economy versus Comparative Advantage in the Nile Basin: Short-Term Advantages or Long-Term Gain? River Basin Management in the Twenty-First Century: Understanding People and Place*, CRC Press, Boca Raton, 2015, pp. 216–243.
- [12] G. Worku, E. Teferi, A. Bantider, Y.T. Dile, *Prioritization of watershed management scenarios under climate change in the Jemma sub-basin of the Upper Blue Nile Basin, Ethiopia*, *J. Hydrol.: Reg. Stud.* 31 (2020) 100714.
- [13] S.B. Awlahew, V. Smakhtin, D. Molden, D. Peden, *The Nile River Basin: Water, Agriculture, Governance and Livelihoods*, 2012.
- [14] F. Mengistu, E. Assefa, *Farmers' decision to adopt watershed management practices in Gibe basin, southwest Ethiopia*, *International soil and water conservation research* 7 (4) (2019) 376–387.
- [15] O.M.M. Ali, *From vision to action: towards a national policy for integrated water management in Sudan*, *Dev. Water Sci.* 50 (2003) 237–244. Elsevier.
- [16] J. Brunnée, S.J. Toope, *The changing Nile basin regime: does law matter*, *Harv. Int'l LJ* 43 (2002) 105.

- [17] M. Zeitoun, M. Goulden, D. Tickner, Current and Future Challenges facing transboundary river basin management, *WIREs Clim Change* (2013), <https://doi.org/10.1002/wcc.22>, 2013. (Accessed 2 June 2023).
- [18] K.G. Wheeler, M. Jeuland, J.W. Hall, E. Zagana, D. Whittington, Understanding and managing new risks on the Nile with the grand Ethiopian renaissance dam, *Nat. Commun.* 11 (1) (2020) 5222.
- [19] M. Jeuland, X. Wu, D. Whittington, Infrastructure development and the economics of cooperation in the Eastern Nile, *Water Int.* 42 (2) (2017) 121–141, <https://doi.org/10.1080/02508060.2017.1278577>.
- [20] T. Gashaw, T. Tulu, M. Argaw, A.W. Worqlul, Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia, *Environmental Systems Research* 6 (1) (2017) 1–15.
- [21] N. Haregeweyn, A. Berhe, A. Tsunekawa, M. Tsubo, D.T. Meshesha, Integrated watershed management as an effective approach to curb land degradation: a case study of the Enabered watershed in northern Ethiopia, *Environ. Manag.* 50 (2012) 1219–1233.
- [22] A. Amdihun, E. Gebremariam, L.M. Rebelo, G. Zeleke, Suitability and scenario modeling to support soil and water conservation interventions in the Blue Nile Basin, Ethiopia, *Environmental Systems Research* 3 (2014) 1–13.
- [23] Y.T. Dile, J. Rockström, L. Karlberg, Suitability of water harvesting in the Upper Blue Nile Basin, Ethiopia: a first step towards a mesoscale hydrological modeling framework, *Adv. Meteorol.* 2016 (2016).
- [24] M.P. McCartney, M. Menker Girma, Evaluating the downstream implications of planned water resource development in the Ethiopian portion of the Blue Nile River, *Water Int.* 37 (4) (2012) 362–379.
- [25] J. Waterbury, *The Nile Basin: National Determinants of Collective Action*, Yale University Press, 2008.
- [26] M. Olson Jr., *The Logic of Collective Action: Public Goods and the Theory of Groups*, with a New Preface and Appendix, vol. 124, Harvard University Press, 1971.
- [27] R. Hardin, *Collective Action*, Johns Hopkins University Press, Baltimore, 1982.
- [28] E. Ostrom, Institutions and common-pool resources, *J. Theor. Polit.* 4 (3) (1992) 243–245, <https://doi.org/10.1177/0951692892004003001>.
- [29] M. Abdelwareh, J. Lelieveld, P. Hadjinicolaou, G. Zittis, A. Wagdy, M. Haggag, Evaluation of a regional climate model for the Eastern Nile Basin: terrestrial and atmospheric water balance, *Atmosphere* 10 (12) (2019) 736, <https://doi.org/10.3390/atmos10120736>.
- [30] A. Tilmant, G. Marques, Y. Mohamed, A dynamic water accounting framework based on marginal resource opportunity cost, *Hydrol. Earth Syst. Sci.* 19 (3) (2015) 1457–1467, <https://doi.org/10.5194/hess-19-1457-2015>. <http://www.hydrol-earth-syst-sci.net/19/1457/2015/>.
- [31] R.K. Paisley, T.W. Henshaw, *Transboundary Governance of the Nile River Basin: Past, Present and Future*, vol. 7, Environmental Development, 2013, pp. 59–71, <https://doi.org/10.1016/j.envdev.2013.05.003>.
- [32] A. Swain, Challenges for water sharing in the Nile basin: changing geo-politics and changing climate, *Hydrol. Sci. J.* 56 (4) (2011) 687–702.
- [33] S.B. Awulachew, A.D. Yilma, M. Loulseged, W. Loiskandl, M. Ayana, T. Alamirew, *Water Resources and Irrigation Development in Ethiopia*, vol. 123, Iwmi, 2007.
- [34] A.J. Cropley, *Qualitative Research Methods: A Practice-Oriented Introduction for Students of Psychology and Education*. Riga, Zinātne, Latvia, 2019.
- [35] A.E. Cascao, 10 to Change, or Not to Change? the Transboundary Water Question in the Nile Basin, *Natural Resource Conflicts and Sustainable Development*, 2019, pp. 128–144.
- [36] W.M. Khairy, M. El-Motasem, A. Mehanna, K. Hefny, Estimation of evaporation losses from water bodies in the Sudan and Ethiopia, *International Journal of Energy and Water Resources* 3 (2019) 233–246.
- [37] *The Ethiopian Reporter* (Amharic), ታላቁ ግድብና የግብይት ችግሮች፡፡ 16 (2011), 28/1140.
- [38] Oromia Regional National State, Bureau of Agriculture and Natural Resources, *Effort of Integrated Watershed Management towards Reversing Land Degradation*, 2017. <https://roadsforwater.org/wp-content/uploads/2017/04/Ethiopia-Oromia-Region.pdf>.
- [39] N. Haregeweyn, A. Tsunekawa, M. Tsubo, A.A. Fenta, K. Ebabu, M. Vanmaercke, P. Borrelli, P. Panagos, M.L. Berihun, E.J. Langendoen, Z. Nigusie, Progress and challenges in sustainable land management initiatives: a global review, *Sci. Total Environ.* 858 (2023) 160027.
- [40] M.L. Berihun, A. Tsunekawa, N. Haregeweyn, Y.T. Dile, M. Tsubo, A.A. Fenta, D.T. Meshesha, K. Ebabu, D. Sultan, R. Srinivasan, Evaluating runoff and sediment responses to soil and water conservation practices by employing alternative modeling approaches, *Sci. Total Environ.* 747 (2020) 141118.
- [41] G.D. Betrie, Y.A. Mohamed, A. Van Griensven, R. Srinivasan, Sediment management modelling in the Blue Nile Basin using SWAT model, *Hydrol. Earth Syst. Sci.* 15 (2011) 807–818.
- [42] T. Lemann, G. Zeleke, C. Amsler, L. Giovanoli, H. Suter, V. Roth, Modelling the effect of soil and water conservation on discharge and sediment yield in the upper Blue Nile basin, Ethiopia, *Appl. Geogr.* 73 (2016) 89–101, <https://doi.org/10.1016/j.apgeog.2016.06.008>.
- [43] N.D. Melaku, C.S. Renschler, H. Holzmann, S. Strohmeier, W. Bayu, C. Zucca, F. Ziadat, A. Klik, Prediction of soil and water conservation structure impacts on runoff and erosion processes using SWAT model in the northern Ethiopian highlands, *J. Soils Sediments* 18 (4) (2018) 1743–1755, <https://doi.org/10.1007/s11368-017-1901-3>.
- [44] K. Ebabu, A. Tsunekawa, N. Haregeweyn, E. Adgo, D.T. Meshesha, D. Aklog, T. Masunaga, M. Tsubo, D. Sultan, A.A. Fenta, Analyzing the variability of sediment yield: a case study from paired watersheds in the Upper Blue Nile basin, Ethiopia, *Geomorphology* 303 (2018) 446–455, <https://doi.org/10.1016/j.geomorph.2017.12.020>.
- [45] MoWR (Ethiopian Ministry of Water Resources), *Assessment and Monitoring of Erosion and Sedimentation Problems in Ethiopia*. Final Report, vol. V, MoWR/Hydrology Department, Addis Ababa, Ethiopia, 2002.
- [46] A. Hailelassie, F. Hagos, S.B. Awulachew, D. Peden, S. Gebreselassie, F. Negash, Indicators of Environmental Degradation in the Blue Nile Basin: Exploring Prospects for Payment for Environmental Services, *Second Nile Development Forum*, Khartoum, Sudan, 2008, November, pp. 17–19.
- [47] Egypt Independent, Expert warns Ethiopia may cause ‘first of many’ water wars. <https://www.egyptindependent.com/>, 2023. (Accessed 29 December 2023).
- [48] Y. Arsano, *Ethiopia and the Nile: Dilemmas of National and Regional Hydro Politics*, Swiss Federal Institute of Technology, Centre for Security Studies (PhD Dissertation), Zurich, 2007.
- [49] S. Natea, Ch Tefera, H. Kloos, “Rainwater harvesting” in helmut kloos and worku legesse, in: *Water Resources Management in Ethiopia: Implications for the Nile Basin*, Cambria Press, NY, 2010.
- [50] Z. Abate, *Water Resources Development in Ethiopia: an Evaluation of Present Experience and Future Planning*, Itacha Press, Reading, 1994.
- [51] M. Behailu, M. Abdulkadir, A. Mezgebu, M. Yasin, Preliminary Report on Community-Based Irrigation Management in the Tekeze Basin: Impact Assessment. A Case Study of Three Small-Scale Schemes (Micro Dams), Report Prepared for Mekelle University and the International Livestock Research Institute, Addis Ababa, 2004.
- [52] D. Tolossa, R. Hailu, G. Alemu, Integrated water resources management as a system approach for water security: evidence from the Awash River Basin of Ethiopia, *Ethiop. J. Soc. Sci. Humanit.* 14 (1) (2018) 53–82, <https://doi.org/10.4314/ejossah.v14i1.3>.
- [53] K. Komara, Setting the example for cooperative management of transboundary water resources in west Africa. <https://blogs.worldbank.org/nasikiliza/setting-example-cooperative-management-transboundary-water-resources>, 2014. (Accessed 24 September 2023).
- [54] R. Tawfik, The grand Ethiopian renaissance dam: a benefit-sharing project in the Eastern Nile? *Water Int.* 41 (4) (2016) 574–592.
- [55] A. Swain, Mission not yet accomplished: managing water resources in the Nile River Basin, *J. Int. Aff.* 61 (2) (2008). Spring/Summer 2008.
- [56] S.M.A. Salman, The grand Ethiopian renaissance dam: the road to the declaration of principles and the khartoum document, *Water International* 41 (4) (2016) 512–527, <https://doi.org/10.1080/02508060.2016.1170374> (Accessed 21 December 2022).
- [57] K.G. Wheeler, J.W. Hall, G.M. Abdo, S.J. Dadson, J.R. Kasprzyk, R. Smith, E.A. Zagana, Exploring cooperative transboundary river management strategies for eastern Nile Basin, *Water Resour. Res.* 54 (2018) 9224–9254, <https://doi.org/10.1029/2017WR022149>.
- [58] D. Whittington, E. McClelland, Opportunities for regional and international cooperation in the Nile Basin, *Water Int.* 17 (3) (1992) 144–154, <https://doi.org/10.1080/02508069208686134>, 10.1080/02508069208686134. (Accessed 6 May 2021).
- [59] R. Stoner, *Future Irrigation Planning in Northern Africa*, 1994.
- [60] Sahel and Sahara Observatory (Oss), *Climate Change in the OSS Zone of Action: Vulnerability and Adaption*, 2017. www.oss-online.org.

- [61] S. Moges, H. Kloos, S. McFeeters, W. Legesse, "The water resources of Ethiopia and large-scale hydropower and irrigation development" in helmut kloos and worku legesse, in: *Water Resources Management in Ethiopia: Implications for the Nile Basin*, Cambria Press, NY, 2010.
- [62] A. Okoth-Owiro, *State Succession and International Treaty Commitments: A Case Study of the Nile Water Treaties*. Nairobi, Konrad Adenauer Stiftung and Law and Policy Research Foundation, Occasional Papers, 2004.
- [63] Y. Lupu, *International law and the waters of the euphrates and tigris*, *The Georgetown Int'l Env'tl Law Review* 14 (2) (2002) 349.
- [64] S. Luiz, *Water policy networks in Egypt and Ethiopia*, *J. Environ. Dev.* 17 (3) (2008) 238–268, <https://doi.org/10.1177/1070496508320205>. <http://jed.sagepub.comhostedat>. <http://online.sagepub.com>.
- [65] J. Barnes, *Cultivating the Nile: the Everyday Politics of Water in Egypt*, Duke University Press, Durham and London, 2014.
- [66] J. Waterbury, *Between unilateralism and comprehensive accords: modest step toward cooperation in international river basins*, *Int. J. Water Resour. Dev.* 13 (3) (1997) 279–290, <https://doi.org/10.1080/07900629749692>. (Accessed 28 March 2023).
- [67] A. Subramanian, B. Brown, A.T. Wolf, *Understanding and overcoming risks to cooperation along transboundary rivers*, *Water Pol.* 16 (5) (2014) 824–843.
- [68] T. Tafesse, *A Review of Ethiopia's Water Sector Policy, Strategy and Program*. Digest of Ethiopia's National Policies, Strategies and Programs, Addis Abeba, 2010, p. 313.
- [69] Y. Zhao, F. Wu, F. Li, X. Chen, X. Xu, Z. Shao, *Ecological compensation standard of trans-boundary River Basin based on ecological spillover value: a case study for the Lancang-Mekong River Basin*, *International Journal of Environmental and Public Health* (2021), <https://doi.org/10.3390/ijerph18031251>. (Accessed 15 December 2022).
- [70] J.V. Krutilla, *The Columbia River Treaty: the Economics of an International River Basin Development*, RFF Press, Washington, DC, 2019.
- [71] Y. Yu, P. Tang, J. Zhao, B. Liu, D. McLaughlin, *Evolutionary cooperation in transboundary river basins*, *Water Resour. Res.* 55 (2019), <https://doi.org/10.1029/2019WR025608>. (Accessed 28 November 2022).
- [72] M. Basheer, K.G. Wheeler, L. Ribbe, M. Majdalawi, G. Abdo, E.A. Zagona, *Quantifying and evaluating the impacts of cooperation in transboundary river basins on the water-energy-food nexus: the Blue Nile Basin*, *Sci. Total Environ.* 630 (2018) 1309–1323, <https://doi.org/10.1016/j.scitotenv.2018.02.249>.
- [73] D. Whittington, X. Wu, C. Sadoff, *Water resources management in the Nile Basin: the economic value of cooperation*, *Water Pol.* 7 (2005) (2005) 227–252. <https://www.researchgate.net/publication/279566283EndNotes>.