Addis Ababa University

Addis Ababa Institute of Technology

School of Graduate Studies

School of Civil and Environmental Engineering

Evaluation of Transboundary Water Sharing Rules and Principles: The Case of the Nile River Basin

By: Mekdelawit Messay Deribe

Advisor: Dr. Belete Berhanu

Sponsor: Ethiopian Road Authority (ERA)

A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfilment of the Degree of Master of Science in Hydraulic Engineering

December 2020

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Mekdelawit Messay Deribe

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Declaration

I declare that the research work entitled “Evaluation of Transboundary Water Sharing Rules and Principles: The Case of the Nile River Basin” is my own work. The work has not been presented elsewhere for assessment. Where material was used from other sources, it has been appropriately acknowledged and referred.

Mekdelawit Messay Deribe

The undersigned have examined the thesis entitled “Evaluation of Transboundary Water Sharing Rules and Principles: The Case of the Nile River Basin” presented by Mekdelawit Messay Deribe in partial fulfilment for the Degree of Master of Science in Hydraulic Engineering and hereby certify that it is worthy of acceptance.

Dr. Belete Berhanu	……	……
Advisor	Signature	Date
Dr. Daniel Fikreselassie	……	……...
Internal Examiner	Signature	Date
Dr. Fisseha Behulu	…….	…….
External Examiner	Signature	Date

Abstract

The principles and practices of transboundary water sharing have undergone significant evolution throughout the ages. The cardinal principles of equitable and reasonable use and the principle of causing no significant harm and the principle of cooperation form the basis for modern-day transboundary water sharing. While these principles are fundamentally accepted worldwide, translating these principles into workable water-sharing frameworks has been difficult because these principles are law-based. The contextualization and quantification of these principles to tangible water allocation schemes are left to the custodians of each transboundary basin. Recognizing this gap, this study aims to translate and quantify transboundary water sharing principles in the context of the Nile basin and formulate a framework of water allocation for the basin. The study came up with a flexible water allocation tool that stakeholders can use to evaluate basin countries' water shares based on internationally agreed on factors of equitable use. In addition, multiple scenarios that show the range of possible allocation possibilities in the basin were evaluated. The study indicates that the existing water sharing/allocation condition in the basin has no basis under modern-day international water-sharing principles. Under no kind of equitable allocation can the current dominant users of the Nile waters keep their existing claimed share. However, the study also acknowledges a need to supplement these countries' existing needs and underlines the need for innovative, integrated, and sustainable ways of using the Nile waters. To this end, eight recommendations have been outlined as possible ways of moving forward collectively in the basin to satisfy all riparian countries' current and future demands.

Key Words: Transboundary water, Equitable and reasonable use, Nile River basin, International transboundary water sharing principles, Nile, Ethiopia, Egypt, Sudan, Sustainability.

Acknowledgment

First and foremost, I would like to extend my heartfelt thanks and appreciation to Dr. Belete Berhanu, who has been a mentor and guide for me for the past ten years. Thank you for believing in me and putting the seed of this thesis in my mind, guiding me throughout the way, and for your non-stop encouragement. I am forever grateful.

I would like to thank Zerihun Abebe, Fekahmed Negash, Dr. Abdulkerim Seid, Dr. Yohannes Gebretsadik, Dr. Wubalem Fekade, and Azeb Mersha for their continued support and guidance throughout this thesis. My special regards to my friend and colleague Besrat Eshetu; this thesis would not have been possible without you. Mesay Shemsu, thank you for your critical help in times of my need and your constant encouragement and support.

Finally, my heartfelt gratitude to my family and friends for their unwavering support and belief in me. Your faith kept me standing when my legs could not carry me anymore, and for that, I am eternally grateful.

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Acronyms

BCM: Billion Cubic Meters

CFA: Cooperative Framework Agreement

DOP: Declaration of Principles on the GERD

DRC: Democratic Republic of Congo

ENSAP: Eastern Nile Subsidiary Action Program

ENTRO: Eastern Nile Technical Regional Office

ESA: European Space Agency

ET: Evapotranspiration

ETS: Emission Trading System

EU: European Union

FAO: Food and Agriculture Organization

GDP: Gross domestic product

GERD: Grand Ethiopian Renaissance Dam

GRG: Generalized reduced gradient

IIL: Institute of International Law

ILA: International Law Association

IWMI: International Water Management Institute

LP: Linear program

MCA: Multi-Criteria Analysis

NBI: Nile Basin Initiative

OAU: Organization of African Union

PCIJ: Permanent Court of International Justice

RF: Rainfall

SDG: Sustainable Development Goals

UK: United Kingdom

UN: United Nations

UNDP: United Nations Development Program

UNECE: United Nations Economic Commission for Europe

UNESCO: United Nations Educational, Scientific and Cultural Organization

US: United States of America

1. Introduction

1.1 Background

Water is an essential part of life and human development with fundamentally no substitutes. Despite the abundance and renewable nature of the resource, water is unevenly distributed in space and time, making it a rather precious resource (Postel et al., 2003).

Global water demand has been growing at more than twice the population growth rate in the last century (FAO, 2007; McKinney, 2011; Roser et al., 2013). The number of regions that are being (and will be) affected by water scarcity is also steeply rising (Watkins, 2006). Currently, around one-fifth of the world's population suffers from "physical" water scarcity, and roughly the same proportion suffers from economic water scarcity (Petruzzello, 2019). This number is set to rise under the stress of climate change and population growth.

The freshwater supply, which only accounts for less than 3% of the total water available on earth, is not keeping up with the steeply rising demand for water. The global freshwater reserve has stayed constant if not diminished because of pollution and overuse over the centuries (Boretti & Rosa, 2019). Due to the changes in climate and weather patterns worldwide, the amount and distribution of rainfall worldwide are changing. Available water per capita in many areas of the world is continuously decreasing (Lakshmi, Fayne & Bolten, 2018). Due to numerous factors such as climate change, population growth, and environmental degradation, the United Nations (UN) estimated that nearly half of the world population will be living in areas of high water stress by the year 2030 (Watkins, 2006, WWAP, 2018). Without adequate water resource management, freshwater availability will fail to keep up with global water demand by 2040 (Global Water Security, 2012).

A big part of the world's freshwater resources lies in transboundary basins as more than 200 rivers are shared by two or more nations (Mimi & Sawalhi, 2003). With 276 transboundary lakes and river basins covering almost half of the earth's surface, transboundary waters account for a large portion of the global freshwater reserve[1] (UN, 2018). Some 60% of the world's fresh water supply originates from transboundary watersheds (Wolf et al., 1999; USAID, 2019). One hundred forty-

[1] https://www.siwi.org/priority-area/transboundary-water-management/

five sovereign states have part of their territories lying in transboundary river basins, while 30 countries lie entirely within these basins (UN Water, 2018). Around 40% of the global population depends on transboundary rivers as water sources (Munia et al., 2016). As such effective water resource management should ideally have transboundary river water management at its core. This is why the UN Sustainable Development Goals (SDGs) put transboundary water cooperation at the global and regional level in its agenda (SDG 6.5.1 Integrated water resources management and 6.5.2 Transboundary basin area with water cooperation). However, around two-third of the world's transboundary rivers still do not have a cooperative management framework [2] (UN Water, 2018).

Transboundary river water management is often complicated as relationships between riparian countries are usually asymmetric (Brochmann & Gleditsch,2012; Arjoon et al., 2016). Upstream and downstream countries often have conflicting interests when it comes to the use of transboundary river waters. Moreover, countries' claims of shared water are often "larger than their endowments," which complicates water allocation (Ansink & Weikard, 2009). Hence, transboundary waters' utilization and management are often complicated and laced with a layer of tension and conflict. Data from the world water website[3] by the pacific institute, which documents water conflict chronology shows that there have been 926 conflicts related to water counting from 3000 B.C to 2019. The UN world water development report (2009) warns that water scarcity, coupled with the stress of climate change, can produce significant conflicts worldwide. The UN had dubbed this one of the most urgent political issues on the UN national global agenda two decades ago already (El-Fadel et al., 2003).

However, this does not mean that transboundary waters are sources of conflict per se. There are more instances of cooperation than conflicts on transboundary waters. It has been observed and recorded that two-thirds of the time, interactions on transboundary waters lead to cooperation than conflict (Wolf, 2007; UN, 2014; UNESCO, 2015; Zeitoun & Mirumachi, 2008 De Stefano et al., 2010). As the UN also noted in its International Decade for Action "Water for life" 2005-2015 publication, the fact that there have been 150 treaties signed over transboundary waters in the last 50 years compared to 37 "acute" disputes over water involving violence makes this case. Over

[2] https://www.siwi.org/priority-area/transboundary-water-management/-=

[3] http://www2.worldwater.org/conflict/timeline/

3600 treaties have been drawn up related to transboundary water use since 805A.D (UN, 2014). Therefore, even though transboundary waters can be trigger points for conflict, the opportunity for cooperation is also strongly present. If managed well based on agreeable frameworks, transboundary water resources are means of cooperation. It can be safely assumed that both conflicts and cooperation co-exist in transboundary basins. The potential of transboundary waters to be trigger points for conflicts in and of itself offers an opportunity for cooperation.

The case for effective transboundary water management is easy to make; however, the implementation of such a system is often lacking. Three aspects of transboundary water management need to be considered to result in effective water governance and cooperation: the technical aspect, the legal aspect, and the diplomatic/political aspect. Without these three spheres coming to a confluence, reaching a holistic transboundary water utilization and management framework cannot be a reality. However, this overlap/confluence has been mostly lacking in transboundary water governance, the result is that the majority of the transboundary river basins in the world do not have allocation frameworks (UN Water, 2018).

The technical sphere of transboundary water management has so far focused on sub-basin level management and studies. Only a handful of studies such as the 50% rule by Beaumont (2000), the Legal Assessment Model (Wouters et al., 2005), and a study by Mimi & Sawalhi (2003) for the Jordan river basin formulate quantitative water-sharing frameworks. Basin-wide water allocation endeavors that are rooted in legal principles, are largely lacking. The hydro-political/ diplomatic sphere often does not go beyond debates on whether transboundary waters are a source of conflict or cooperation. These conversations further develop into securitization of water, the weaponization of water into a means of war, and stray from the central point of water allocation, sharing, and management. Because of this, it is difficult to form a confluence with the other technical and legal spheres. By its very nature, the legal sphere cannot go beyond general principles of equitable and reasonable sharing of transboundary waters. Owing to this, the contextualization of legal guidelines is left to individual basin States by all the major international principles and guidelines (CFA, 2010; ILA, 1966; UN 1997).

This gap between these three spheres in transboundary water management and governance is a significant pitfall. Unless there is a quantitative framework with strong legal framing, which is practical enough to aid in water diplomacy, we cannot move forward. Bridging the gap between these three spheres and coming up with a framework that can be a starting point for further research is, therefore, a worthy cause to pursue.

The law underscores that international principles are only guidelines and that contextualization is necessary. It is apparent that each transboundary river basin is a special case on its own and should ideally be governed by its own tailor-made rules and treaties (Caflisch,1993). However, clear and tangible guidelines that will address the most common issues and at least provide the basis for water allocation are necessary in every basin (UN, 2014). Such endeavors pave the way for a smooth transboundary river basin management.

1.2 Problem Statement

The history of transboundary water management goes back millennia. As time progressed, numerous doctrines, rules, principles, and treaties have been developed to facilitate transboundary waters' utilization and management. Some of these doctrines aimed to perpetrate the sole advantage of either the upstream or downstream hegemon in a basin or a few riparian countries at best. Such doctrines are biased and short-sighted, and they failed to result in fair, equitable, and sustainable water use in their respective basins. However, modern customary water laws and principles are based on the concepts of equitable and reasonable use of transboundary waters by all riparian countries while stressing that all riparians, in turn, have the responsibility not to cause significant harm on others. However, because these principles are also highly law-based, they do not offer significant assistance regarding providing concrete and implementable guidelines in the quantitative aspect of water allocation. There is still the need to contextualize and quantify what “equitable and reasonable” use means and what constitutes “significant harm” for each transboundary basin.

Modern-day water-sharing laws generally acknowledge that all riparian countries have equally legitimate claim on transboundary river water and are entitled to their fair share (UN, 2012). There is a general consensus worldwide that the principles of reasonable and equitable water use, and the principle of no significant harm, should be the guiding principles in transboundary water sharing.

However, different parties have different interpretations of these principles and varying preferences for which principle takes precedence over the other. Because of this, whenever development endeavors are made on such shared resources, tensions, and conflict still arise.

Despite not developing at the pace required to match transboundary water resource developments and not having universal acceptance, customary international water laws still offer a basis for a common understanding for the utilization and management of shared resources. However, these rules and conventions essentially provide only loose guidelines for transboundary water management. This is mainly because the principles provided in these laws are elastic and open for interpretation and do not give a clear-cut guideline on how to share resources. Hence it is up to riparian states to decide who gets what and how. It is then essential that negotiators and decision-makers have a decision tool based upon objective criteria or standards to reach acceptable entitlements to shared water resources by all parties. The task at hand is to translate water law principles into operating rules and procedures for the equitable apportionment of waters from shared water resources (Mimi & Sawalhi, 2003). Nevertheless, as mentioned above, except for a few attempts, for the most part, such quantitative tools are lacking.

1.3 Research Objectives

This research's main objective is to contextualize and quantitively evaluate widely used transboundary water sharing rules and principles to the Nile basin and come up with the basis for a reasonable and equitable water allocation framework. This will contribute towards filling the gap between legal principles of transboundary water sharing and quantified workable frameworks. Such a framework can later feed into the grand aim of coming up with a tailor-made water-sharing rule for the Nile basin.

This resulting objective framework of water allocation can be used for decision support systems, guidelines for water allocation negotiations and discussions, as well as input for both national and regional water use policies. The countries' respective water shares under multiple scenarios are assessed to identify insights that can help develop a robust, reasonable and equitable water sharing rule for the basin.

1.3.1 Specific Objectives

- Study major historical and modern-day transboundary water allocation laws, rules, and principles used worldwide and in the Nile basin.
- Quantify factors outlined in modern-day water-sharing principles for the Nile Basin.
- Evaluate water-sharing scenarios based on factors for equitable water allocation.

1.4 Research Questions

1. What are the major international principles used in transboundary water sharing worldwide?

    1.1 What are the major historical and currently used transboundary water sharing laws and principles worldwide?

    1.2 Under what context were these rules, principles, and treaties developed, and the guiding principles behind them?

2. What are the major water sharing rules, laws, principles, or treaties in the Nile Basin?

    2.1 What are the major historical and currently used transboundary water-sharing agreements and principles in the Nile basin?

    2.2 Under what context were these agreements and treaties developed and used?

3. What is the implication of the factors outlined in modern transboundary water laws on the Nile riparian countries' water share?

    3.1 How can the factors to be considered in transboundary water sharing be quantified for Nile basin countries?

    3.2 What are the respective water shares of the countries under multiple scenarios?

1.5. Scope

The spatial scope of this research will be the whole of the Nile basin; hence water shares of all eleven countries are evaluated. The temporal scope spans the history of the basin from the late 19th century until present day while data projections stretching till 2050 were used to determine water shares under multiple scenarios. As this study is a first attempt at quantifying factors determining equitable shares, the interrelationships between the different factors used are out of the scope of the present study, although it is something to be included in future research. Moreover, this study

is limited to assessing surface transboundary water sharing and hence does not deal with transboundary groundwaters in the Nile basin. As the highest authority in the basin, the data from the Nile Basin Initiative (NBI) was most comprehensive, complete, and valid, and as such, much of the data used in this study was justifiably sourced from the NBI and supplemented from other sources where it was lacking or relevant.

1.6. Organization of the Thesis

The thesis is organized into seven chapters. The current chapter, i.e., the first chapter, introduces the study's topic, the objective of the thesis, and the research questions. The second chapter describes the historical development of transboundary water sharing principles and the current state of events in the world. It further focuses on the Nile basin and presents treatises on Nile water use and the context these treaties were developed in going as far back as 1891. The third chapter is the methodology chapter. Here a brief description of the case study area, the data used, and sources of these data, a detail description of factors used in the study, and their respective quantification are given. Finally, the analytical methods and tools used in the study are described. Chapter four presents the results of water shares for all basin countries evaluated based on the basic allocation framework developed. It presents the results of multiple scenarios of water allocation developed for the entire basin on the framework. It also discusses the meanings and implications of the findings compared to the existing allocation scheme present in the basin. Chapter five wraps up the study with conclusions and recommendations on how to collectively move forward as a basin to satisfy all riparian states' water security. Chapter six provides the study references while chapter seven presents supplementary material relevant for the study in the appendix.

2. Literature Review

2.1 Historical development of transboundary water sharing rules and principles

Agreements on the sharing and use of transboundary waters can be traced back to ancient times, as far back as 2500 B.C. The first agreement or treaty of any kind in the world was a treaty on water[4], between the ancient Sumerian city-states of Lagesh and Umma in 2550 B.C over the Tigris river (UN, 2014). This boundary water treaty, called the Mesilim treaty, is inscribed in the ancient Sumerian writing system cuneiform, on a stone pillar (stele) and is often said to be the world's first legal document.

Figure 1. Memorial cone and stele of the Mesilim Treaty displayed at the Louvre Museum in France

(Source: Sand, 2018)

The accord came about because Lagesh and Umma were disputing the use of river Tigris and related border issues due to a contested irrigation canal. The treaty of Mesilim, drafted by the arbitration of King Mesilim of Kish, a prominent kingdom North of Lagesh and Umma, included land-lease, annual tenancy fees, and a crop-sharing scheme for land that was cultivated by Umma in Lagesh territory as part of mechanisms for water allocation. It also proclaimed that boundary stones should confirm the boundary running along the irrigation canal[5]. However, the breach of this treaty by the Umma kingdom, because they were not paying their tenancy debts, resulted in the world's first war that was fought over water, in 2470 B.C. The transgressor, i.e., Umma

[4] https://www.un.org/waterforlifedecade/transboundary_waters.shtml

[5] https://www.themaparchive.com/treaty-of-mesilim-2550-bce.html

kingdom, was defeated twice by the Lagesh kingdom, and the treaty was reinstated. However, this treaty was short-lived because of foreign invasions from the Akkadian warlords resulted in the conquest of both city-states (Sand, 2018). Regardless of this outcome, however, this agreement is rightly hailed as the precursor of international water laws.

This ancient precedent gave rise to modern-day transboundary water agreements. Early modern-day transboundary water agreements were dominated mainly by navigation-related uses (Rahman, 2009; Salman, 2007). The UN states that more than 3600 treaties and agreements have been drawn up since 805 A.D, and the majority of these dealt with navigation and boundary demarcation (UN, 2014). Early navigational agreements and treaties on transboundary watercourses can be traced back to the Roman Civilization, which held that rivers were public resources and that all citizens retained the freedom of navigation (Bannon, 2017). In the late 18th century, Thomas Jefferson extended this Roman principle to transboundary watercourses when he argued that the United States (US) also had the freedom to navigate the lower Mississippi river, which was under Spanish rule. This claim was later formalized in the Treaty of San Lorenzo/ Pickney's Treaty in 1795, granting navigational rights to the US over the Mississippi River, a shared watercourse[6] [7].

Later on, the industrial revolution in Europe necessitated the movement of goods across large distances. With other modes of transport being at their early stages of development, rivers and transboundary watercourses became "international highways" (Salman 2007). Owing to this, rules and treaties governing the use of shared transboundary watercourses for navigation dominated the transboundary water governance arena. Moreover, navigational uses of transboundary waters were exponentially more important than other shared water uses, which would later become dominant, such as irrigation and hydropower use (McCaffrey, 1996). This made navigation the single largest user of rivers in Europe, forcing governments to enforce mechanisms of guiding this use. In 1815 major European powers made the Act of the Congress of Vienna, which instituted the freedom of navigation for all riparian states on a shared watercourse on a reciprocal basis and the priority use of navigational use over other uses (Salman, 2007; Rahman, 2009). The 1868 Mannheim

[6] https://history.state.gov/milestones/1784-1800/pickney-treaty

[7] https://www.britannica.com/event/Pinckneys-Treaty

Convention on navigation on the Rhine river among Belgium, France, Germany, and the Netherlands was another major multilateral treaty (Rahman, 2009). In 1885 the treaty called the General Act of the Congress of Berlin was made to facilitate the movement of colonial powers on the Congo and Niger rivers, extending the freedom of navigation to non-riparian colonial states. The 1919 Peace Treaty of Versailles continued this development and opened all navigable water-ways in Europe to all European countries, liberalizing navigational use of transboundary watercourses (Salman, 2007).

Navigation kept its dominant use of transboundary watercourses, much more than other uses, until the late 19th century and early 20th Century (McCaffrey, 1996). However, with the growing population, demands for irrigation and domestic water use became more pressing. As a response to this pressure, non-navigational uses of shared watercourses were given recognition in the navigational treaty signed in 1921, the Convention and Statute on the Regime of Navigable Water-ways of International Concern, widely known as the Barcelona Convention (Rahman, 2009). The industrial revolution was continually coming up with speedier and more efficient ways of transport while at the same time increasing the demand for water for industries and hydropower plants. This resulted in the gradual decline of the dominance of navigation in transboundary water use. In 1923 the Geneva convention (General Convention Relating to the Development of Hydraulic Power Affecting More than One State), which stated the rights of any riparian state to develop operations to enhance hydraulic power in its territory subject to the limits of international law, was adopted (Salman, 2007). The Second World War had a significant impact on restraining the freedom of navigation and resulted in the limitation of freedom of navigation to riparian countries, which represent the current contemporary state of affairs in the field of navigational law (Caflisch, 1998; Salman, 2007).

After the Second World War, the use of transboundary watercourses for non-navigational uses such as hydropower, irrigation, and domestic use started to gain traction because of the increasing population and the massive rebuilding of Europe after the war (Salman, 2007). The UN also corroborates this by stating that the focus of negotiations and treaties in the last century has shifted away from navigation to other uses, development, protection, and conservation of transboundary watercourses.

However, McCaffrey (1996) notes that since the development of laws on non-navigational water uses was slower than the intensity of development of the uses, there was a reliance on "general" concepts, doctrines, and customary laws. There was no universal treaty in force to guide and regulate the increasing use of international rivers. The established rules on navigational uses could not be adopted to non-navigational uses. The law not being able to catch up with the demand, hence, extreme ideologies such as absolute territorial sovereignty and the polar opposite response to this doctrine, i.e., absolute territorial integrity, started developing.

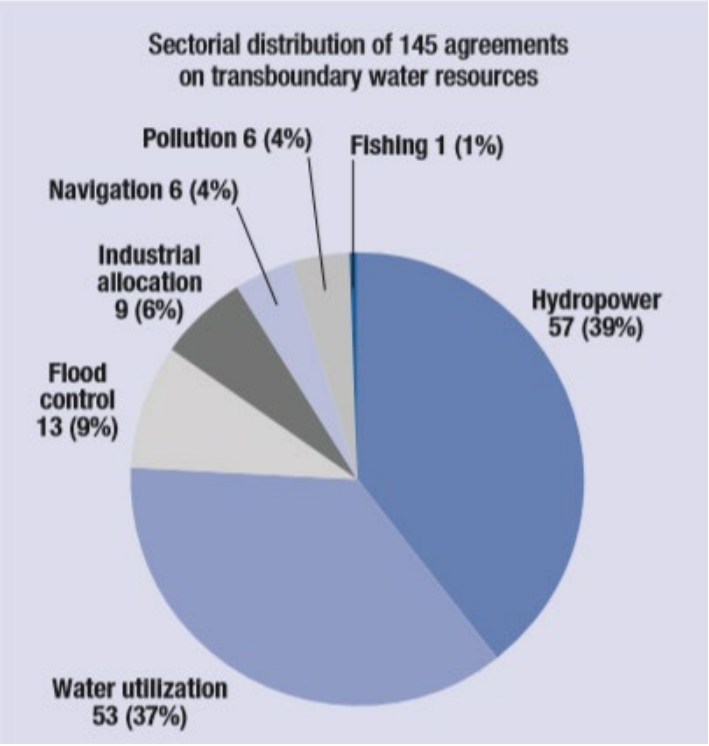


Figure 2. Sectoral distribution of 145 agreements on transboundary water resources signed in the last 50 years

(*Source: UNDP Human development report (2006). Beyond Scarcity: Power, poverty and the global water crisis*)

2.2 The Doctrine of Absolute Territorial Sovereignty

The doctrine of absolute territorial sovereignty hinges on states' absolute sovereignty on their territories and, by extension, on the part of international watercourses within their borders. This doctrine was famously used by the Attorney General of the United States, Judson Harmon, in 1895 in an opinion he gave regarding the use of a transboundary watercourse, the Rio- Grande river, which the US shares with Mexico.

The Rio- Grande river flows from the San Juan mountains in Colorado in the United States down to Mexico, forming some 1995 km of the border between them. The controversy between the two countries started when the government of Mexico made official claims on the increasing amount of water diverted from the Rio- Grande River for irrigation in the state of Colorado in the USA was affecting river levels down in Mexico. The situation was so bad that it was observed that the Rio- Grande had a dry bed for over 800 km (McCaffrey, 1996). In response to this formal request by the government of Mexico for "an examination and decision" of this issue, Attorney General Harmon was asked for an opinion on Mexico's legal claims. The Attorney-general cited that the fundamental principle of international law is the absolute sovereignty of nations within their own territories, stating:

"*'the jurisdiction of the nation within its own territory is necessarily exclusive and absolute. It is susceptible of no limitation not imposed by itself "* and that "*the United States is under no obligation to Mexico to restrain its use of the Rio Grande because its absolute sovereignty within its own territory entitles it to dispose of the water within that territory in any way it wishes, regardless of the consequences in Mexico*." (McCaffrey, 1996).

Harmon was opining that by virtue of a nation's sovereignty on its territory and by extension on shared resources within its borders, it was free to use the resource in any way it deems appropriate and fit, without liability to downstream states (Kuokkanen, 2017). Harmon linked this concept to the principle of self-preservation, stating that a nation within its own territory was allowed to do whatever was necessary for its people's development and comfort. Harmon also mentioned that while the theory of natural international servitude entitles downstream countries to receive water from upstream riparians, the theory of absolute territorial sovereignty triumphed over this. He substantiates this claim by saying, "*It is evident that what is really contended for is a servitude which makes the lower country dominant and subjects the upper country to the burden of arresting its development and denying to its inhabitants the use of a provision which nature has supplied entirely within its own territory.*" He adds, "*Self-preservation is one of the first laws of nations. No believer in the doctrine of natural servitudes has ever suggested one which would interfere with the enjoyment by a nation within its own territory of whatever was necessary to the development of its resources or the comfort of its people,*" clearly showing his preference for the principle of absolute territorial sovereignty over servitude (McCaffrey, 1996).

The Harmon doctrine then became synonymous to the principle of absolute territorial sovereignty, so much so that they have become interchangeable terms. However, owing to the apparent short-sighted nature of the doctrine, even the US did not follow this opinion's suggestions in its later dealings with Mexico. McCaffrey (1996) argues given that the US abandoned this doctrine, it thus becomes questionable if this doctrine was ever a part of international law but rather "*an assertion that there being no rules of international law which governed, states were free to do as they wished*." Regardless, the opinion has become the cornerstone, if not the foundation, of the theory of absolute territorial sovereignty (McCaffrey, 1996).

Opponents of this doctrine point the apparent flaws of this short-sighted doctrine, stating that there are at least two sovereigns, the upstream and the downstream in transboundary dealings, possessing equal rights and equal independence. The theory of natural international servitude also entitles downstream countries to receive water from upstream riparians. They also state that the states' mutual benefit can only be ensured not in isolation but by mutual interaction with each other. This goodwill is shown in the consensual relaxation of the "absolute " nature of states' sovereignty to accommodate others' interests in line with customary laws and the civilized world's obligations. To this end, Chief Justice Marshall of the US stated that "*the realities of international intercourse and interdependence meant that states often did not insist upon that absolute and complete jurisdiction within their respective territories which sovereignty confers.*" (McCaffrey, 1996). Chief justice Marshal went further saying that "*a nation that abruptly changed the manner in which it exercised its territorial powers-as had the United States through the greatly increased diversions in Colorado and New Mexico-would justly be considered as violating its faith*." essentially debunking the premise of absolute territorial sovereignty and Harmon doctrine.

The Harmon Doctrine and, by extension, the Doctrine of Absolute territorial sovereignty has been described as "*merely the caution of the ordinary lawyer who is determined not to concede unnecessarily a single point to the other side*" by Herbert Smith (1931). The Harmon doctrine has little support internationally, as it does not represent the tenants of international law (Rahman, 2009; Birnie and Boyle, 2002, Salman 2007).

2.3 The Doctrine of Absolute Territorial Integrity

The polar opposite of absolute territorial sovereignty is the doctrine of absolute territorial integrity. In a radical deviation from the above, this doctrine states that downstream states are entitled to the "uninterrupted" natural flow of a transboundary watercourse. This essentially means that upstream states can do nothing to interfere with the "natural" flow of a river, stripping them of the right to use the shared water completely (McCaffrey, 1996).

In an interesting turn of events, it was the US again which invoked this principle and applied it to transboundary air pollution by stretching the principle's limits. In a dispute that the US had with a Canadian Smelter company, the US claimed that "*it is a fundamental principle of the law of nations that a sovereign state is supreme within its own territorial domain and that it and its nationals are entitled to use and enjoy their territory and property without interference from an outside source*." The US argued that by polluting the air by emissions coming from upstream Canada, the US was "*being deprived of the free and untrammeled use of its territory in a manner a sovereign state has an inherent and incontestable right to use. Sovereign right as a state of the free and untrammeled use of their territory*" (McCaffrey, 1996).

The US argued that just as an upstream intervention on a transboundary watercourse disrupts the "natural flow" or the natural status quo, so does putting something into another state, which in this case was pollutants. The argument was: if the first was prohibited, so should be the later one. Extending this discussion to water-ways, the US argued that "*Otherwise, not only wholesale diversions of international watercourses but also such activities as weather modification to the detriment of another state would be legitimized-a result that promotes neither the reasonable sharing of common natural resources nor friendly relations between states"* (McCaffrey, 1996).

To demand un-interrupted natural flow of any shared watercourse is not a reasonable avenue to explore, and hence for the same reasons, the doctrine of absolute territorial sovereignty fails. This approach places duties on the upstream states but calls for no reciprocal action from the downstream states (Beaumont, 2000). It is well understood that states do not live in isolation, and hence one state cannot use its own waters to affect the other injuriously. International law supports the claims of all sovereign riparian countries. That is why these doctrines of absolute sovereignty and integrity need to be capped by the co-extensive rights of the other riparians involved as well.

Prohibiting upstream nations from using water passing through their territory falls under causing injury to other states under international law as international law would recognize the rights of either side to make any use of the waters within its borders in such a manner that does not interfere with the co-extensive rights of the other (McCaffrey, 1996).

The same drawbacks that can be cited against the doctrine of absolute territorial sovereignty also hold on the flip side for absolute territorial integrity. For the same reason that absolute territorial sovereignty is no more accepted, so is absolute territorial integrity. Notable scholars in this field agree that these myopic and narrow doctrines fit the pre-industrial revolution era more rather than the present world, where close economic, social, and political ties increase the reliance of states on each other (McCaffrey, 1996; Rahman, 2009; Salman 2007).

2.4 The Doctrine of Prior Appropriation

This doctrine states that the earliest users of the water have the right to claim their full amounts irrespective of any subsequent users' needs, essentially allowing prior users of a shared watercourse veto right over new claims (Beaumont, 2000). The doctrine of prior appropriation was originally developed not for cross country transboundary waters but waters within the United States in the late 1840s.

In the arid west of the US, during the California Gold Rush[8], gold miners needed to develop a system of mining and related water use and rights because of the limited and seasonal availability of water[9]. This doctrine of "first come first serve" allowed the diversion of water from a watercourse on non-riparian land (i.e. lands that do not have direct access to streams) based on priority use. Later claimants of the water were not allowed to use this scarce resource if it would reduce first users' claims according to this law. "*A senior appropriator can satisfy his or her water needs before a junior appropriator can take water from a river. In a drought year, only a few users may be able to get water*."[10] This doctrine of prior appropriation was later used in other parts of

[8] http://www.waterencyclopedia.com/Po-Re/Prior-Appropriation.html

[9] https://www.e-education.psu.edu/earth111/node/948

[10] http://www.waterencyclopedia.com/Po-Re/Prior-Appropriation.html

the US like Colorado, Alaska, Arizona, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming and is still in use.

In addition to the "first come, first serve rule," another interesting character of the doctrine of prior appropriation is the "use it or lose it" concept, meaning the water claimants must use the water for its claimed purposes or else they lose the right to water. Any new developments on the water use, such as the expansion of irrigation, is treated as a "junior" claim and is treated as such based on the availability of water and existence of "senior" claims. This doctrine stands on two tenant requisites: the "appropriation of the water," which relates to the withdrawal or diversion of the water, and its "beneficial use," which amounted to mining, irrigation, industrial, domestic and municipal uses, including other "non-wasteful" activities.

The doctrine of prior appropriation came out as a winner in the American west after some wrangle with older doctrines such as the riparian doctrine, which states that those who own land next to water have the rights to reasonable use of the water without affecting downstream riparians (downstream waterfront landowners) and limited the use of water to riparian lands. Spin-offs of the doctrine of prior appropriation are in use to this day[11]. The "Colorado doctrine" which rejects the riparian law entirely, and the "California Doctrine" which hoped to combine riparian doctrine and prior appropriation under the umbrella of reasonable use, the "prescriptive rights" which tries to give junior right holders immunity from senior appropriators, especially in times of drought, etc.… are all based on this doctrine which stipulates "first in time, first in right"[12] (Brian, 2015).

Proponents of the doctrine of prior appropriation cite numerous benefits of the doctrine. Gopalakrishnan (1973) elaborated on some of these benefits, especially in domestic water use, with the most notable ones explained below.

1. allows for full utilization of water,
2. permits water to be used where it is needed without tying use to riparian ownership,
3. restricts appropriator to beneficial use, (makes possible the re-appropriations of excess amounts not beneficially used),

[11] http://waterscape.org/pubs/factsheet_waterrights/FS_CaliforniaWaterRights.htm

[12] https://corporate.findlaw.com/business-operations/water-rights-law-prior-appropriation.html

4. allows for the accurate tracking of the amount, purpose, and place of use of appropriated water, adding to the certainty of management, which was missing in the riparian doctrine,
5. management of water resources by a full-time administrative agency staffed by experts rather than by the courts through individual case rulings

This doctrine is different from the first two doctrines mentioned above because it does not visibly favor upstream or downstream countries, but first users. However, as far as accommodating shared interests on a transboundary watercourse goes, it is as narrow and myopic as the two above. This doctrine does not account for future developments or environmental changes in a shared river basin, necessitating previous non-users to make subsequent claims. Owing to this, it is not favored in the international water community (Beaumont, 2000).

The ill-fit of prior appropriation with transboundary water management roots because this concept was aimed at governing waters within a country. The doctrine of prior appropriation has successfully managed water within the confines of a country such as the US, where rigorous administrative structures, controls, rules, and definitions of use are in place. Obviously, it is easier to apply such rules "*under the unified jurisdiction of a single country*" than at international levels, says Beaumont (2000). However, such clarity is mostly lacking in transboundary water basins, and hence the doctrine fails to be of any value in such scale and context.

2.5 The Doctrine of Limited Territorial Sovereignty

Limited territorial sovereignty is a principle based on the Latin motto "*sic utere tuo ut alienum non laedes"* (so use your own property as not to injure your neighbor's) (Beaumont 2000). This doctrine limits the extreme principles explained above and forms the basis of modern transboundary water laws. It asserts the equal rights of all riparians in the use of a shared watercourse. While this principle acknowledges a state's right to use the water within its boundaries (sovereignty), it also highlights the state's responsibility towards other states in not causing significant harm and hence limits sovereignty. However, working with these two principles in parallel is challenging.

The key tenants of this doctrine are (a) the principle of equitable and reasonable use, (b) the principle of causing no significant harm, and (c) the principle of cooperation, also called the three prongs of International Water Law. These ideas developed progressively from older doctrines such

as the California Doctrine, also called the rule of reasonable use and common customary laws of England (Beaumont,2000).

Two scholarly non-governmental organizations established in 1873 contributed the most to the development of modern international transboundary water laws: The Institute of International Law (IIL) and the International Law Association (ILA) (Salman, 2007; Beaumont, 2000).

The IIL was responsible for numerous declarations that favored the obligation not to cause significant harm. Among these, its first resolution, called the Madrid Declaration in 1911, which established "absolute prohibition" against actions that may result in injury to other states, and the milder resolution called the Salzburg resolution adopted in 1961, which tempered the "absolute prohibition of harm" by subjecting it to the right of the states to use shared water by other states, are notable ones (Salman 2007). In addition, the IIL adopted resolutions in 1979 and 1997, which prohibit any acts that may cause pollution to shared watercourses or adversely harm riparian countries.

The ILA, however, favored the principle of the equitable and reasonable use of transboundary waters. The ILA was most notable for developing the Helsinki rules (1966) and the Berlin Rules (2004). Its first resolution, the Dubrovnik statement, adopted in 1956, acknowledged "*the sovereign control each state has over the international river within its own boundaries, but required states to exercise such control with due consideration of its effects on other riparian states*" (Salman, .2007). This statement was refined in the New York resolution, which came out in 1958. It stated that co-riparians are entitled to a reasonable and equitable share in the beneficial uses of the drainage basin's waters. These concepts of equitable and reasonable use by riparian states were further developed in Tokyo in 1964, which led to the adoption of the Helsinki Rules on the Uses of the Waters of International Rivers in 1966.

The Helsinki rules are the first rules on transboundary watercourses to address shared surface watercourse and shared groundwater aquifers. It is also the first legal instrument to cover both navigational and non-navigational uses of an international watercourse (Salman, 2007). The Helsinki rules put the principle of equitable and reasonable use at the center of transboundary water sharing and utilization and subjects the obligation not to cause significant harm to this preceding principle.

The Helsinki rules also specify a number of factors to be considered in determining equitable and reasonable shares of basin States in a transboundary watercourse, details of which are presented in Chapter Four. One drawback of these rules was that they had no binding effect as any ILL or ILA resolution had no formal stand (Beaumont, 2000; Salman, 2007; Rahman, 2009). Regardless of this, however, the Helsinki rules were the "*single most authoritative and widely quoted set of rules*" for governing transboundary watercourses for the next 30 years to come (Bourne, 1996). These rules have been used or adopted by numerous countries and organizations worldwide, with the most notable ones compiled below from numerous sources (Sherk,2000; Salman & Uprety, 2002; Salman 2007).

- 1973 when the Asian-African legal consultative committee on international rivers adopted Article V of the Helsinki rules as factors determining shares in New Delhi,
- 1975 when India and Bangladesh took their dispute over the Ganges river to the United Nations, both countries heavily used the Helsinki rules as a guide,
- 1992 agreement between Namibia and South Africa on the establishment of a Permanent Water Commission on the Lower Orange River,
- 1995 conclusion of the protocol on shared watercourse systems in the Southern African Development Community (SADC) based mainly on the Helsinki rules,
- US supreme court often resolving interstate water disputes based on factors similar to the Helsinki rules,

After the Helsinki rules in 1966, the ILA set out to work on numerous laws:

- 1972 the association issued its Articles on Flood Control;
- 1976 the Rules on Administration of International Watercourses were adopted;
- 1980, the Belgrade Conference of the Association adopted two sets of rules. The first set dealt with the regulation of the flow of the water of international watercourses, and the second dealt with the relationship of international water resources to other natural resources' environmental elements;
- separate Articles on pollution of the waters of an international drainage basin were adopted at the Montreal Conference in 1982;

- in 1986 at its Seoul conference, the ILA adopted the 'Complementary Rules Applicable to International Water Resources' that were intended to clarify some aspects about the application of the Helsinki rules;
- 1999 the Campione Consolidation of the ILA Rules on International Water Resources, 1966–1999 a compilation and consolidation of all the work approved by the ILA since the Helsinki rules were adopted;
- 2004 the Berlin rules on water resources were adopted.

Building on such previous work, the International Law Commission (ILC), an organization created by the United Nations in 1971, drafted the UN Convention on the Law of the Non-Navigational Uses of International Watercourses (the UN Convention) in 1994 following 23 years of preparatory work; and the convention was adopted in 1997 (Salman, 2007). However, Beaumont (2000) writes that the original discussions on the convention date back well before the Helsinki rules to the 1950s.

The convention was open for signatures until May 2000, and before that, only 16 countries had signed the convention. The convention entered into force on August 17th, 2014, following the ratification by the 35th state[13] (UN, 1997; UN, 2014). The convention has 36 ratifications to date, which indicates that the majority of the world is still outside the convention's scope.

The UN 1997 convention primarily drew upon the works of the Helsinki rules. The convention is a framework that aims at ensuring the utilization, development, conservation, management, and protection of international watercourses and promoting optimal and sustainable utilization for present and future generations. As a framework convention, it addresses only fundamental aspects and leaves the details for the riparian states to complement in agreements that would consider the specific characteristics of the watercourse in question (Salman 2007). In line with the Helsinki rules, the UN 1997 convention puts the principle of equitable and reasonable use as the cardinal rule for the governance of transboundary waters. It sets out factors to consider in determining equitable and reasonable use, which are mostly similar with the Helsinki rules and which will be discussed in Chapter 4.

[13] https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-12&chapter=27&lang=en

The UN 1997 convention gives precedence for the principle of equitable and reasonable use over the principle of not causing significant harm (Caflisch, 1998). This is the generally prevailing view based on the reading of the convention. However, the use of a compromise language can be seen so as not to suggest subordination of "no-significant harm" to "equitable and reasonable use" and appease lower riparian countries. Article 7 requires the state that causes significant harm to take measures to eliminate or mitigate such harm "having due regard to Articles 5 and 6," which deal with equitable and reasonable use (Salman, 2007).

After the 1997 UN convention, the ILA went on to revise the Helsinki rules, which led to the development of "The revised ILA rules on equitable and sustainable uses in the management of waters," which was adopted in Berlin in 2004 and later named as "the Berlin rules on water resources" (Salman, 2007). The Berlin rules are praised for being detailed and comprehensive, going beyond both the Helsinki and the UN convention. Unlike its predecessors, the Berlin rules apply for both national and international waters, which solely dealt with international waters (Rahman, 2009). The Berlin rules also deviate from the Helsinki rules and the 1997 UN Convention in dealing with "equitable use" against "no significant harm." While the prior rules put equitable use at the center stating the "rights" of riparian state to use shared water, the Berlin rules "obliges" each basin State to manage the waters of an international drainage basin equitably and reasonably (Salman, 2007; Rahman, 2009). A reading of the Berlin rules is hence said to "*emphasize the obligation to manage the shared watercourse in an equitable and reasonable manner while the Helsinki Rules and the UN Convention establish and emphasize the right of each of the riparian states to a reasonable and equitable share*"(Salman, 2007).

Beyond the endeavors mentioned above, the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes by the United Nations Economic Commission for Europe (UNECE) is a convention worthy of mention. This convention was first adopted between countries of the European Economic Commission and was not a global convention. The UNECE water convention, adopted in 1992 in Helsinki, came into force in 1996. It was later amended in 2003 to allow countries outside of the UNECE region to accede to the convention starting in 2016, making it a worldwide legal framework for transboundary water management. The convention emphasizes transboundary cooperation and "*ecologically sound*

management and protection of transboundary surface waters"[14] in line with the European context rather than equitable and reasonable use or significant harm.

2.6 Community of interest

A community of interest as a governing body in a transboundary watercourse is seen as the next step in the evolution of transboundary water sharing principles and practices. This principle considers the entire river basin as a single economic unit, and the right to use the water is given to a "community of interest" from all basin States (Salman, 2007).

A community of interest in a river basin was defined by the Permanent Council of International Justice (PCIJ) as "*the basis of a common legal right, the essential features of which are the perfect equality of all riparian States in the use of the whole course of the river and the exclusion of any preferential privilege of anyone riparian State in relation to the others*" (River Oder Case, PCIJ, 1929). The concept of a community of interest has its roots in ancient Roman laws, i.e., that a shared watercourse is the common property of the riparian states. It was understood that the natural and physical unity that a watercourse forms as it crosses different communities by default create communities of interest.

The principle of a community of interest is built upon the principle of limited territorial sovereignty. However, it goes beyond that principle and bestows significant rights over the river to a collective body. Although this concept is assumed to be the next step in the evolution of transboundary water sharing principle, it does not enjoy wide acceptance among riparians. Salman (2007) hypothesizes that one reason for this cold reception is that this is an ideal principle beyond the nationalism and competing demands of riparians. On the other hand, some question whether the existence of this notion of a community of interest can give rise to legal obligations in transboundary water use, questioning the applicability of this concept.

[14] https://www.unece.org/env/water/text/text.html

Table 1. Summary of main principles present in transboundary water sharing principles and doctrines

Doctrines and prior experiences	**Guiding Principles**
Mesilim Treaty	Crop sharing and tenancy agreements
Absolute Territorial Sovereignty	Unrestricted use over water in own territory regardless of impact elsewhere
Absolute Territorial Integrity	Entitlement to uninterrupted natural flow from upstream
Prior Appropriation	First come, first serve
Limited Territorial Sovereignty	Equitable and reasonable use, causing no significant harm
Community of Interest	Authority on a shared watercourse is given to a community of interest.

2.7 The Case of the Nile

Although modern water laws acknowledge that all riparian countries have equally legitimate claim on transboundary river water, this alone does not ensure smooth transboundary water sharing when development endeavors are made on such shared resources. The case of the Nile River is an excellent example to illustrate why.

Although the Nile Basin is shared by eleven riparian countries, for thousands of years, Egypt enjoyed unrestricted access to the Nile water (El-Fadel et al., 2003; Laki, 1998). Ancient civilizations were built on the waters of the Nile. To date, it is reported that 90% of Egypt`s population depends on the Nile for their basic water need (Swain, 2011). As such, the country has gone to great length to secure its monopoly over the Nile waters throughout history, oftentimes even threatening to resort to military options (Laki, 1998; Swain, 2011). Colonial powers, in particular, the U.K., had vested interests in ensuring the amount of the Nile water flowing to Egypt and later on to Sudan would not decrease, as the textile industries in the U.K. were fed by cotton plantations in these two downstream countries (Conniff et al., 2012).

The history of water use in the Nile basin does not share the progression and the evolution that international transboundary water sharing has gone through the ages. Historically Egypt and its colonizers and protectorates had a uniform agenda of ensuring Egyptian hegemony over the Nile waters. The prevailing principle on water sharing in the Nile basin has not grown together with the international trend.

To develop an equitable and reasonable water allocation framework for the basin, it is imperative first to know the current state of events in the basin, what is (is not) working, and what needs to change. For this purpose, past and existing allocation practices, treaties, and agreements in the basin are analyzed in light of international transboundary water sharing rules and practices. Below is a list of agreements, treaties, and frameworks made in the Nile basin to illustrate the past and current state of water use and sharing in the basin.

Since 1891 there have been a series of treaties and agreements to ensure the full flow of the Nile to downstream countries (Ferede & Abebe, 2014). These agreements and treaties include not only Nile basin countries, but by virtue of the colonial administrations at the time, colonial powers dominant in the basin, namely the United Kingdom, France, and Italy. It should also be noted that not all the agreements reviewed were exclusively water-related. Some of these agreements relate to border demarcation and agreements on spheres of influence between colonial powers. However, all of these agreements included at least one section which mentions water use on the Nile river and/or its tributaries. Therefore, even though not all the agreements were particularly aimed at governing water use in the Nile basin, they were nevertheless included in the review to give a comprehensive view of the Nile water's far-reaching influence.

2. 7.1 Agreements, treaties and frameworks for water use in Nile Basin

Protocols between Great Britain and Italy on the demarcation of their respective spheres of influence in East Africa: 1891

In this agreement, Italy and the UK agreed to delineate their respective "spheres of influence" in Eastern Africa. As part of this border demarcation agreement, Article 3 states that "*the Italian government shall undertake not to initiate any irrigation works on the Atbara which may alter the rate of flow of the Nile water,*" putting Nile water use squarely at the heart of the agreement.

This Article ensures that a sufficient amount of water reached downstream riparian countries of Sudan and Egypt, which constituted the British "sphere of influence" at the time. By ensuring no works that alter the Nile flow be done on the tributaries of the Nile, in this case the Atbara, the interests of the UK in these downstream countries were secure. Italy, whose sphere of influence at the time was around regions of Atbara and Kassala (border areas of Sudan and Eritrea), in return got free access for travel and duty-free trade in the British sphere of influence in Sudan. However, Kasimbazi (2010) contests that this agreement is quite "puzzling" as Italy, which agreed not to undertake works on the Atbara, was not a colonizing power with a claim on the Atbara river as the area through which the Atbara flowed were under the British rule and the main tributary of the Atbara originating in Ethiopia was not under Italian rule.

Treaty between Ethiopia and Great Britain on the Delineation of the Frontier between Ethiopia and Sudan: 1902

Another border treaty signed between the UK and Ethiopia demarcates the established boundaries of British rule in the frontier between Sudan and Ethiopia. In the same fashion as the above agreement, the 1902 agreement brings Nile water use to the forefront in Article 3 of the treaty.

Article 3 states that "*His Majesty the Emperor Menelek II King of Kings of Ethiopia engages himself towards the Government of his Britannic Majesty not to construct, or allow to be constructed, any works across the Blue Nile, Lake Tsana or the Sobat which would arrest the flow of their waters into the Nile except in the agreement with his Britannic government and the Government of the Soudan*."

This treaty, signed in two copies, i.e., in Amharic and English, shows significant deviations in content and interpretation between the two versions.

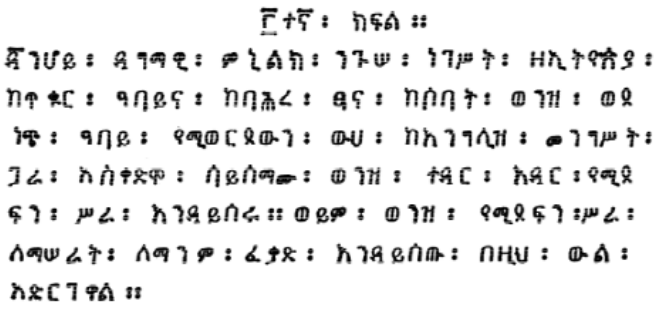


Figure 3. Amharic version of the 1902 treaty

The first and major issue is while the English version talks about refraining from the construction of works that would arrest the flow of water, the Amharic version roughly translates to abstaining from works that would completely block the flow of the water the *White Nile*. While the English version supposedly prohibits Ethiopia from building any kind of dam on Lake Tana without consultation with the UK (as alluded by the British in their letters to Emperor Haile Haileselassie I in 1926), the Amharic version only prohibits complete blockage of the river, which is an impossibility then, now and in the future (Woldetsadik, 2015). By virtue of this play on words, the 1902 agreement aimed to put Ethiopia's developments endeavours at the mercy of the British government and ensure uninterrupted water flow to downstream colonies. However, some scholars disagree with this interpretation of the word “arrest,” arguing that both the Amharic and English versions do not prohibit Ethiopia from using the water, and that the difference is more a question of emphasis rather than content.

The second deviation in the two versions relates to the fact that while the English version ties development on lake Tana with prior agreement with the Government of Britain and Sudan, the Amharic version only mentions the British government. Also, while the English version talks about the reduction of the flow of the tributaries to the Nile, the Amharic version strictly talks about waters flowing into the White Nile alone.

This treaty is often mentioned in debates about water use in the Nile basin as one of the agreements prohibiting Ethiopia from developing infrastructures over tributaries of the Nile. The main debate point for this argument is that this treaty was signed by Ethiopia as a sovereign nation with another Sovereign nation, the UK, and hence is still a valid piece of legal document. This is in sharp contrast to colonial agreements presented next, signed by the UK on behalf of nations under British control; and which the now free sovereign nations categorically denounce as not binding on them.

However, a major criticism against this argument is that the UK breached this agreement it made with sovereign Ethiopia when it recognized Ethiopia's annexation by Italy in 1935. This act invalidates all prior agreements made with the sovereign Ethiopia including the 1902 agreement in question. Ethiopia did not ask for a renewal of the 1902 agreement afterward when the UK recognized Ethiopia's sovereignty again in 1944 and actually rejected the agreement in the 1950s (Ibrahim, 2011).

The legitimacy and hence the treaty's binding nature is also contested by some historians, as records of the ratified versions could not be found in the British archives nor the Ethiopian crown council (Ibrahim, 2011; Woldetsadik, 2015). In addition, the deviation between the purpose of this Article, which was a border agreement, and the presence of this Article on water use, present a clash in the purpose and content of the Article, which devalues its legitimacy and relevance. There are also claims that the agreement was made under duress and hence is not a valid treaty (Woldetsadik, 2015). Scholars also note a substantial change in circumstances, such as the end of colonization and the drastic change in socio-economic and political circumstances in the region, which can be a basis to invalidate the agreement. It also noted that Egypt is the major proponent of this treaty when, it is not a party to it. This treaty is also unfair as it places obligation on Ethiopia without reciprocal rights or benefits. Such arguments around the 1902 agreement have made it one of the most controversial treaties for Nile water use (Personal interview, FekeAhmed Negash, ENTRO, May 2020).

Agreement between Great Britain, France, and Italy respecting Abyssinia/ Ethiopia: 1906

This agreement comes after news about the ill health of Emperor Menelik II spread in the world following the defeat of Italy by Ethiopia in the iconic Adwa victory of 1896. In this agreement, France, Italy, and the UK agreed to maintain Ethiopia's "integrity" for the common benefit of the three countries in their respective territories bordering Ethiopia. While these countries agreed to respect the sovereignty of Ethiopia, refrain from meddling in its internal affairs and work to preserve the "integrity" of Ethiopia, Article 4 of this treaty states that should changes in the status quo in the country be disturbed (alluding to possible disorder following the death of Emperor Menelik), these three countries would work together to secure interests of the mentioned countries together. Specified under Article 4 a is "*the interest of Great Britain and Egypt in the Nile basin, more especially as regards the regulating of the waters of that river and tributaries (due*

consideration being paid to local interests) without prejudice to Italian interest mentioned in Paragraph b." Here again, one can see the continued trend of ensuring Egypt's interests in the guise of ensuring colonial interest.

Agreement between Great Britain and the independent State of the Congo: 1906

This agreement modifies a previous agreement between the UK and the independent state of Congo in 1884 regarding Britain's spheres of influence and the Congo in East and Central Africa. This agreement deals with the lease of land and infrastructure (ports on the Nile and railway passing through Sudan) and boarder delineation between the UK and the Congo.

Article 3 of this agreement states that "*the government of the independent state of the Congo undertake not to construct, or allow to be constructed, any works on or near the Similki or Isango River, which would diminish the volume of water entering Lake Albert, except in agreement with the Soudanese government*."

Article 3, in the same spirit as the previous agreements, was inserted to ensure that the flow of the Nile reaching Egypt and Sudan was by no means reduced.

Exchange of Notes between Great Britain and Italy respecting concessions for a barrage at Lake Tsana and a railway across Abyssinia from Eritrea to Italian Somali land: 1925

The treaty deals with forging an alliance between Italy and the UK to gain a concession from the Ethiopian government for a railway (connecting Italian territories of Eritrea and Italian Somaliland) and a barrage at lake Tana to store the Blue Nile waters. This alliance came after repeated attempts and failure by both governments to gain a concession from the Ethiopian government.

This treaty explicitly mentions the UK's position as one protecting the hydraulic interests of Egypt and Sudan. The treaty establishes the basis for operation, i.e., respecting each other's sphere of influence, and continues to iterate that Britain will help the Italian government gain concessions from the Ethiopian government on other economic works as well in its region of influence in Ethiopia subject to the condition that "*the Italian government recognizing the prior hydraulic rights of Egypt and the Sudan and engage not construct on the headwater of the blue or white Nile or their tributaries or effluents any works which might sensibly modify their flow into the main*

river." The agreement further states that this statement does not preclude reasonable use of the waters in question by inhabitants for hydropower and domestic purposes and food production, even by building dams for hydropower or small storage reservoir. It also acknowledges that the planned dam on Lake Tana will help increase the amount of water in the Nile river and, therefore, be valuable to Egypt and Sudan.

Exchange of Notes between Her Majesty's Government in the United Kingdom and the Egyptian Government on the use of the waters of the Nile for Irrigation: 1929

This is a treaty that exclusively deals with the use of the Nile waters. The treaty resulted from discussions between the UK and the Egyptian government on expanding irrigation in Sudan (then under the UK rule). Egypt raised concerns with the UK stating that while it understands that Sudan needs to use more water than it currently does from the Nile for its development, it has "*always been anxious of encouraging such developments*" and that it will continue with this policy. Egypt explicitly stated that it would only agree with an increase in the quantity of water use by Sudan as long as it does not infringe on "its historical and natural rights" and the proposed agricultural expansion requirements subject to Egyptian interests' assurances. To this end, in 1925, the Nile commission was tasked to examine and propose the basis on which irrigation can be carried out (in Sudan) with full consideration of the interest of Egypt and without detriment to its natural and historic rights. This study's findings were largely used in this agreement and are attached as an annex to the agreement.

The agreement details water withdrawal by Sudan and Egypt, makes arrangements for plans and completion of projects and amendments related to such projects outlined in the 1925 study, requires that Egypt has full right to measure the discharge of the Nile in Sudan and that no irrigation or power works be done in Sudan or countries under the British Administration without prior agreements with Egypt.

In a similar spirit to the above-mentioned treaty of 1925, this treaty under Article 4 states that should Egypt want to develop water projects in Sudan which would increase the water supply benefit for Egypt, Egypt will agree with local authorities to safeguard local interests. It also states that these investments will be under the direct control of the Egyptian government.

Article 4 b. Save works with the previous agreement of the Egyptian government, no irrigation or power works or measures are to be constructed on the River Nile and its branches or on the lakes from which it flows, so far as all these are in the Sudan or in countries under British administration, which would, in such a manner as to entail any prejudice to the interest of Egypt, either reduce the quantity of water arriving at Egypt, or modify the date of its arrival or lower its level.

Article 4.d. In case the Egyptian government decides to construct in the Sudan any works on the river and its branches, or take any measures with a view to increasing the water supply for the benefits of Egypt, they will agree beforehand with the local authorities on the measures to be taken for safeguarding local interests. The construction, maintenance and administration of the above-mentioned works shall be under the direct control of the Egyptian government.

The 1929 agreement puts water shares by Egypt at 48 Billion Cubic Meters (BCM) and that of Sudan at 4 BCM. The common trend seen in the treaties mentioned above, that of the UK ensuring Egyptian and by extension British interests were secured in water dealings on the Nile, can also be seen in this treaty.

Treaty between Belgium and Great Britain and Northern Ireland regarding the boundary between Tanganyika, Rwanda, Burundi and Belgium 1934

This agreement is another border treaty between colonial powers in the region that required Belgium to return waters from streams originating in areas under its control without substantial reduction of the natural bed before forming a common boundary with British-controlled regions (Brownlie, 1979).

Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the Government of Egypt regarding the construction of the Owen Falls Dam, Uganda: 1949

This treaty details Egypt and the UK's agreement on the construction of Owen dam in Uganda, for electricity production and control of the Nile in the "*spirits of the Nile water Agreements of 1929*". This Article sets the plans and specifications for the dam to be built in Uganda would be prepared and approved by Egypt and Uganda's government. Article 4 of this exchange states that a resident Engineer will ensure Egypt's interest at the dam site. Egypt and Britain had a prior agreement that

"*Uganda would regulate the discharges to be passed through the dam on the instruction of the Egyptian resident engineer be stationed with his staff at the dam*." In addition, Article 5 stipulates that "*the two governments (Egypt and Britain) also recognize that during and after the construction of the dam, the Uganda electricity board may take action at Owen Falls which it may consider desirable provided that the action does not entail any prejudice to the interests of Egypt in accordance with the Nile Water agreements of 1929 and does not adversely affect the discharge of water to be passed through the dam in accordance with the arrangements to be agreed with the two governments (Egypt and UK)".*

In addition to confirming the common trend of the British ensuring the "rights" of Egypt on the Nile waters, this exchange of notes brings another problematic trend in Nile water dealings to the forefront. This exchange of notes between the UK and Egypt on a dam which would be built on a third-party country sets a precedent for breach of national sovereignty in dealings over the Nile waters.

Agreement between the Republic of Sudan and the United Arab Republic on the full utilization of the waters of the Nile: 1959

This treaty starts off by acknowledging the importance of implementing projects that enable full control of the river and, echoing what was highlighted in the treaties that came before, increase the water supply available to ensure Egypt and Sudan's present and future requirements. It states that the 1929 agreement was directed only towards the partial use and regulation of the Nile water and did not cover the "*future conditions of fully controlled river supply*."

To this end, the treaty explicitly states that the shares of water by Egypt were 48 Billion Cubic Meters (BCM), and that of Sudan was 4 BCM under "present established rights" according to the 1929 agreement. It proposes projects to increase the amount of available water and how the benefits should be shared accordingly. This treaty proposes building the *Sudd el Aali reservoir* at Aswan as the first of a series of over-year storage schemes on the Nile. In addition, to allow Sudan to exploit their share, the construction of the Rosaries dam on the Blue Nile and any work deemed necessary by Sudan for the same purpose. The net benefit from the *Sud el Alli* which was calculated to be 22 BCM assuming 84 BCM average Nile water flow and 10 BCM annual storage (evaporation) loss was then distributed in a ratio of 14.5 BCM to Sudan and 7.5 BCM to Egypt,

which raises their share 55.5 BCM to Egypt and 18.5 BCM for Sudan. In addition, the treaty also has arrangements for:

- sharing any excess benefits that might come if the Nile has more than average flow (i.e., greater than 84 BCM),
- cost-sharing for projects,
- compensation schemes for affected land and relocated people because of hydraulic projects suggested in the treaty,
- as well as water loan schemes between these two countries.

Under the general provisions of the treaty, Egypt and Sudan have agreed that should questions on Nile water use arise from the other riparian countries, then the two countries shall agree beforehand and present a united view which shall inform the negotiations with the governments that present with such claims. In addition, the 1959 agreement goes further to stipulate if the negotiations with other riparian countries result in an agreement to construct works on the Nile outside Egypt or Sudan then the "permanent joint committee" shall assume the responsibility to lay down technical details for the projects while construction and afterward during operation and maintenance, and shall supervise the execution of such agreements.

The treaty under the general provision also acknowledges that "*since other riparian countries on the Nile basin besides Egypt and Sudan claim a share in the Nile waters, both countries agree to study these claims and adopt a unified view there on."* If such studies result in the possibility of allotting an amount of the Nile water to one or the other of these territories, then the value of this amount as at Aswan shall be deducted in equal shares from the share of each of the two republics.

This treaty, doubling down on previous precedents, completely divides the Nile waters between the two countries, Egypt and Sudan. Not only that, it strips the fair share of other Nile riparian countries and ties any claims to the water by these countries to the jurisdiction of the "permanent commission". It strips the natural rights of other riparian countries completely and ensures any water other riparian countries might get is only from Sudan and Egypt's shares. This gives a massive incentive to Sudan and Egypt to deny any claims by upper riparian countries on the Nile as any "share" of these countries would come out of their assumed shares of the water.

Following this agreement, several responses have been issued by upper riparian countries, notably Ethiopia, stating the illegitimacy of this agreement and asserting each country's right to the Nile waters. The 1956 communiqué released by the Ministry of foreign affairs of Ethiopia, the 1957 Aide Memoir of the Imperial Ethiopian government, are most notable ones. In addition, when Egypt went on to construct the Al Salam canals diverting the Nile waters to the Sinai through six tunnels, the Memorandum released by the Ministry of Foreign affairs of the socialist Ethiopia and the speech by Lt. Col. Addis Tedla to the extraordinary session of the heads of states and governments at Organization of African Union (OAU) in Lagos in 1980 were also written in the same spirit. The releases mentioned above from the Ethiopian government uniformly assert (1) Ethiopia as the source of more than 85% of the Nile waters, (2) Ethiopia's Sovereign right to use the Nile waters, (3) Ethiopia's rejection of these bilateral treaties and unilateral moves of development on the Nile water by Egypt and Sudan while acknowledging that the Nile is a transboundary water shared with other riparians and (4) its willingness to collaborate.

The Nyerere doctrine of 1962, issued by the Government of Tanganyika, i.e., present-day Tanzania, sent to the UK, Sudan, and Egypt, stated that the 1929 agreement was not binding on the independent state of Tanganyika. This doctrine asserts the relevance of Lake Victoria to the Nile waters and acknowledges the dependence of all riparian states on the Nile water declaring its willingness to go into discussions with a view of formulating a just, equitable use of the water by all riparian states. This doctrine was later adopted by most upstream riparian countries as well.

Framework for General Cooperation between Ethiopia and the Arab Republic of Egypt: 1993

A general framework of understanding was signed between Ethiopia and Egypt in 1993, as two geopolitically important countries for the region's political and economic stability. In this agreement, the two countries agreed on basic issues such as principles of good neighborliness and non- interference in internal affairs, mutual trust and understanding and the importance of cooperation. In addition, this agreement states that the Nile issue should be worked out through discussions with experts from both sides by taking international law into account and refraining from actions that cause significant harm. It also emphasized the necessity of conservation and protection of Nile waters and the need for a mechanism of periodic consultation on matters of mutual interest, and the need for a framework of effective cooperation among the Nile basin countries.

While this cooperation framework is very general and did not mention specific operation mechanisms, it included one aspect of modern transboundary water law, i.e., the obligation not to cause significant harm. It is rather odd that this principle alone was mentioned without the adjoining and arguably preceding principle of reasonable, equitable utilization, showing the continuation of the trend of Egypt securing its interests on the Nile water.

Agreement on the Nile River Basin Cooperative Framework (CFA): 2010

This is the first agreement in the Nile basin that brings forth the internationally accepted principles of equitable and reasonable use and causes no significant harm to the Nile water use discussion. The CFA is a comprehensive framework developed by all riparian countries' participation for the first time in the basin's history. It gives coverage for all the basin countries' water security, unlike the previously mentioned agreements that solely focused on ensuring Egypt's historical and natural rights and later on Sudan.

The CFA largely draws on international water laws and customary transboundary water management principles and sharing and highlights the factors to be considered to achieve equitable and reasonable use. In a radical deviation from established norms in the region, the CFA was inclusive in its process and comprehensive in its coverage. After being negotiated by all member states for thirteen years (since 1997), it is expected to be the law of the land pending the ratification by six member states. The CFA so far has been signed by six riparian states (Ethiopia, Rwanda, Uganda, Burundi, Kenya, and Tanzania) and ratified by four (Ethiopia, Rwanda, Tanzania, and Uganda). Currently, Sudan and Egypt have not signed the agreement along with Congo and Eritrea. The disagreements on Article 14 b of the framework, regarding debates over maintaining current uses and rights (alluding to shares of Egypt and Sudan according to the 1959 agreement) against not adversely affecting water security of any Nile basin country seem to be a sticking point in the framework.

The Declaration of Principles (DOP) between the Arab Republic of Egypt, the Federal Democratic Republic of Ethiopia and the Republic of Sudan on the Grand Ethiopian Renaissance Dam Project: 2015

The DOP is a document signed as a sign of good faith by the three countries to guide discussions pertaining only to the Grand Ethiopian Renaissance Dam (GERD) and the discussions around the

GERD. The DOP covered issues such as (1) collaboration towards equitable and reasonable use and the causing of no significant harm, (2) the value of GERD as a tool for regional integration and sustainability as well as economic development, (3) principles on the first filling and annual operation of the dam as well as (4) confidence building, exchange of information and principle of dam safety. The DOP largely draws on the CFA and the UN 1997 watercourses convention on when dealing with the GERD issues.

2.7.2 Commonalities Between Past Treaties and Agreements

With the CFA's sole exception, most of the agreements reviewed above have commonalities between them that put them sharply against internationally accepted principles of transboundary water sharing and management. Listed below are some of the major flaws past treaties and agreements share in common.

Un-inclusive

Apart from the CFA, all of the above-mentioned agreements, frameworks, and treaties were made either between a sub-set of countries in the basin or between colonial countries with interests in the Nile basin seeking to protect those interests. All of these treaties and agreements were bilateral or trilateral at best, with the major exception of the CFA. There has never been an inclusive treaty or agreement, including all the basin countries and working towards the benefit of the basin countries as a whole instead of a few until the CFA. The CFA was the first framework in the basin to be drafted by the involvement and deliberation of all basin countries, following all international procedures for treaty-making.

Unfair and un-equitable

In addition to these agreements being un-inclusive, all the agreements above were extremely unfair to the interests of countries not included in the agreements. The common trend seen in all of these agreements was the consistent effort by Egypt and/or protectorates of Egypt to ensure the so-called "historical and natural rights" of Egypt and by proxy, the interest of foreign interests in the region. The British wanted to secure adequate water for their cotton plantations in Egypt, and so most of these agreements were geared at ensuring Egypt's interests on the Nile. It was only when the British wanted to expand irrigation in Sudan that water use in Sudan regarding the Nile was renegotiated. The 1906 agreement to protect the integrity of Ethiopia, the agreement between Italy and UK to

get concessions from the Ethiopian government to build a barrage on lake Tana, and even the agreement to build a dam on Lake Albert were all geared at making sure there was more water in the basin by storing water upstream and ensuring that Egypt has enough water. This precedent to ensure Egypt's "rights" on the Nile while disregarding the other riparian countries is unfair in any measure.

Infringement on National Sovereignty

Many of the treaties above infringed on the national sovereignty of the other riparian nations to ensure the benefits of Egypt and Sudan and/or colonial interests. The 1929 agreement is one show of this disregard for the sovereignty, as the British signed the agreement with Egypt on behalf of the upper riparian countries under its control.

The agreement to build the Albert Dam in Uganda was another treaty between Egypt and the UK, disregarding the country where the dam was supposed to be built. All the major decisions were decided between these two countries and then communicated to Uganda. While this might not have been an issue at the time as Uganda was under the British administration, it is this precedent of disregard for national sovereignty that we see reflected in current requests of Egypt to have a say in the management and operation of the Grand Ethiopian Renaissance Dam (GERD).

The 1959 agreement, which tied the water shares of other riparian countries to Egypt and Sudan's judgment, disregards their shares of the river. It dictates that other countries' shares, if at all any, would come out of the shares of Egypt and Sudan, disregarding the inherent shares of upper riparian countries. With Ethiopia being the only independent nation in the region and the other riparian countries under British rule (either as a colony or a protectorate), this was a non-issue at the time. This infringement on sovereignty was "justified" by the colonial administrative system then. However, it would not be wide of the mark to suggest that hanging on to these treaties now would be, in essence, hanging on to colonial times. The precedent set by these prior agreements and treaties can be seen now, in dealings over the GERD and Nile water use at large.

Unsustainable

None of the agreements above, except for the CFA and (to some extent) the 1993 framework agreement between Egypt and Ethiopia, had any mechanism to protect and bolster the capacity of the basin taking the future into account. Except for a few measures of implementing storage dams

to enhance the waters for the benefit of Egypt and Sudan, sustainability was a non-issue and was over-looked in all of these agreements. This short-sighted thinking and lack of integration with upstream countries to engage in large scale environmental conservation in the river basin, especially in upstream countries will cost the basin very dearly in the coming decades, where climate change is expected to make upstream rain, which the basin highly depends on, scarce and erratic, as well as deforestation and environmental degradation reducing the amount of water holding capacity of the land.

Even though they have been in place for quite some time, such rules and treaties can hardly result in an equitable water-sharing framework between countries. However, due to multiple reasons of economic and political nature, these treaties were claimed by Egypt and Sudan as "existing water-sharing agreements" in the Nile basin for long (El Fadel et al., 2003). However, recent political stability in the region has accelerated growth and economic development in most upstream countries. The increasing demand from their growing economy and increasing population has been forcing nations to utilize their natural resources more efficiently (Swain, 2011). Sharing the water in the basin without an inclusive and fair allocation scheme is an obvious source of tension in the region as the countries involved continue to be heavily reliant on the Nile's water for basic sustenance.

Owing to this economic development and political stability in the region, the power dynamics in the Nile basin have started to shift. One such show of this shift came in 2011 when Ethiopia announced that it would build five mega-dams on the Blue Nile, starting with the GERD (Obengo, 2016). The GERD is the largest possible dam that can be built on the Blue Nile, ranking as the largest hydropower plant in Africa and the 7th largest in the world. It is expected to produce more than 6000MW of electricity, satisfying Ethiopia's rising demand for electricity and providing electricity for export in the region. The GERD will also serve as a flow regulator and sediment trap, minimizing flooding and dam siltation for downstream countries (Obeng, 2016; Tesfa, 2013).

Ethiopia is deemed as the "source" of the Nile as it contributes more than 86 % of the Nile waters (Lawson, 2016; Naser and Neef, 2016; Obengo, 2016; Yohannes & Yohannes, 2012; Zeitoun & Mirumachi, 2008). For centuries, however, the country has not been able to benefit from this resource. In Ethiopia, songs and folklore ruefully tell how the Nile does not have a home in Ethiopia and loots its own to build others. Hence, when the GERD project was announced in 2011

it was considered sign of a significant shift in the region's status quo. This has already caused substantial tension in the region, with Egypt even threatening to resort to military options (Arjoon et al., 2016; Obengo, 2016). Negotiations and talks on the project have been continuously going on since 2011, resulting in the DOP signing. Ongoing talks on the dam's filling and operation as well have been and are still underway to come to a reasonable arrangement. While there are some encouraging developments, the overall negotiations are not progressing. Because a fair, equitable, and reasonable water use framework that binds all the basin countries does not exist in the basin, lower riparian countries insist on using the contested 1959 agreement as a guiding rule, which inevitably becomes a sticking point in most discussions resulting in stalemates. Such situations underline the need for a revised water use framework based on modern water-sharing laws.

It is also worth noting that negotiations so far are focusing on the dam, which is a single project and only concerns non-consumptive water uses. However, the Nile basin's real challenge comes not from non-consumptive uses such as hydropower but consumptive uses such as irrigation and domestic water use. Ethiopia and many upstream countries have plans to use portions of the Nile water for irrigation to support their growing food demand (Swain, 2011; ENSAP, 2017). It is principally agreed that all countries have the right to a fair share of the Nile water. However, without a framework to guide the water sharing in the basin, any endeavors to develop the Nile water resource might lead to conflict. Despite it being negotiated by all the riparian countries in the Nile Basin, the CFA so far is not in force because it does not have enough ratifications. The agreement is also opposed by Egypt, claiming the "*agreement does not recognize its current use*".

This goes to show that the vague terms of the universally accepted principles of "equitable and reasonable" water use as well as the principle of "no significant harm" to other riparian countries in the use of transboundary river waters are not enough to secure smooth water sharing. The colonial or bilateral treaties in the Nile basin can hardly result in equitable water sharing between countries. These treaties are clearly un-inclusive, unfair, and unsustainable. They fail to result in a robust and equitable water sharing scheme. Hence there is a need to re-evaluate the situation and come up with a robust, equitable, and sustainable transboundary water sharing rule for the region.

This is especially urgent for the basin as the Nile is projected to be under "very high" environmental water stress by 2030[15].

3. Methodology

3.1 Study Area Description

The Nile basin is a transboundary watershed in the north-eastern part of Africa. It extends from 4^0 South to 31^0 North latitude and spreads across 11 countries. It is estimated to be around 3.2 million $km^{2,}$ which amounts to about 10% of the African landmass. According to the population count of 2012, the basin has a population of about 257 Million directly living in it, while the total population of the countries in the basin amounts to 460 million, which is more than 40% of the African population (NBI, 2016).

The Nile River traverses 6695 km while flowing across Burundi, Democratic Republic of Congo, Tanzania, Kenya, Uganda, Rwanda, South Sudan, Ethiopia, Eritrea, Sudan, and Egypt, emptying into the Mediterranean Sea. The Nile River is the only river in the world that flows from south to north, covering diverse topographic and climatic zones. It has two main tributaries, the White Nile, which is fed by rivers originating in Burundi and Rwanda, and the Blue Nile, which originates from Ethiopia. Other notable tributaries include the Baro-Akobo -Sobat and the Tekeze- Atbara, both of which originate in Ethiopia. The Blue Nile or Abay, together with the Baro-Akobo-Sobat, Mereb river, and the Tekeze-Atabra River, contribute more than 86 billion cubic meters (BCM) of water to the annual Nile flow (Kidanewold et al., 2014). The White Nile and the Blue Nile join in Sudan's capital city and are further up joined by the Atbara river to form the main Nile (NBI, 2016).

The Nile basin contains two major sub-systems: the Eastern Nile Sub-basin and the Equatorial Nile sub-basin. The Eastern Nile sub-basin has the Main Nile sub-basin, the Tekeze- Atbara sub-basin, the Blue Nile sub-basin, and the Baro-Akobo Sobat sub-basin. The Equatorial Nile sub-basin includes the Lake Victoria Sub-basin, the Albert Nile Sub-basin, the Victoria Nile Sub-basin, the Baher el Jebel Sub-basin the White Nile sub-basin, and the Bahr el Ghazal sub-basin, in total

15http://twap-rivers.org

ten sub-basins (NBI, 2016). Out of these, the Blue Nile, Baro- Akobo Sobat, and Tekeze Atbara contribute the lion's share of the Nile waters amounting to 74 BCM. The White Nile contributes 25-26 BCM annually however, a large amount of this water is lost in the Sudd swamps. The flow in the main Nile measured at Aswan amounts to 84 BCM (NBI, 2016).

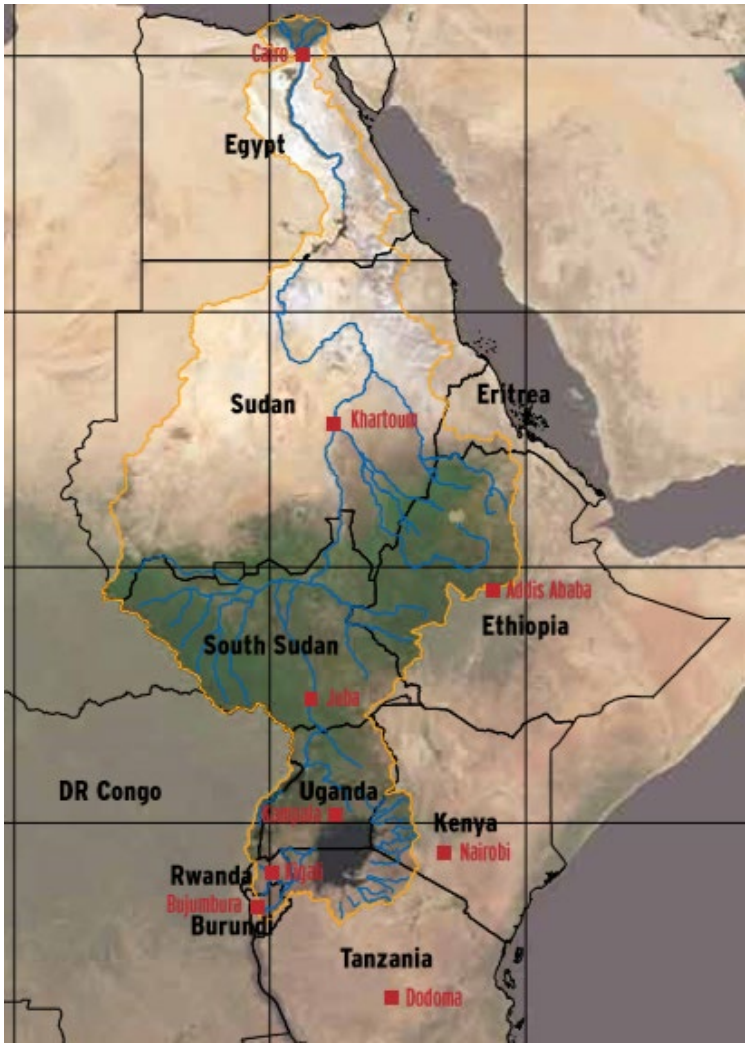


Figure 4. Nile river basin

(Source: NBI, water resource Atlas, 2016)

The Nile basin has various topographic reliefs across its stretch, with mountain ranges, grasslands, plateaus, and flood plains. The slope gradient in the basin also largely varies, ranging anywhere between 0 and 33 degrees, massively affecting the surface runoff and soil erosion conditions across the basin (NBI, 2016). The basin is divided into sixteen terrestrial ecoregions, with a variety of plant and animal life, exemplifying its great expanse.

Land use in the Nile basin is rapidly changing because of human activities. A study done by the European Space Agency (ESA) GlobCover estimated 31 % of the basin as bare areas, 29% as shrublands, 23% cultivated lands, 7% forests, and 6 % grassland. However, since 2009 significant changes in landcover have been observed. Figure 5 below indicates the changes observed in various land covers in the basin.

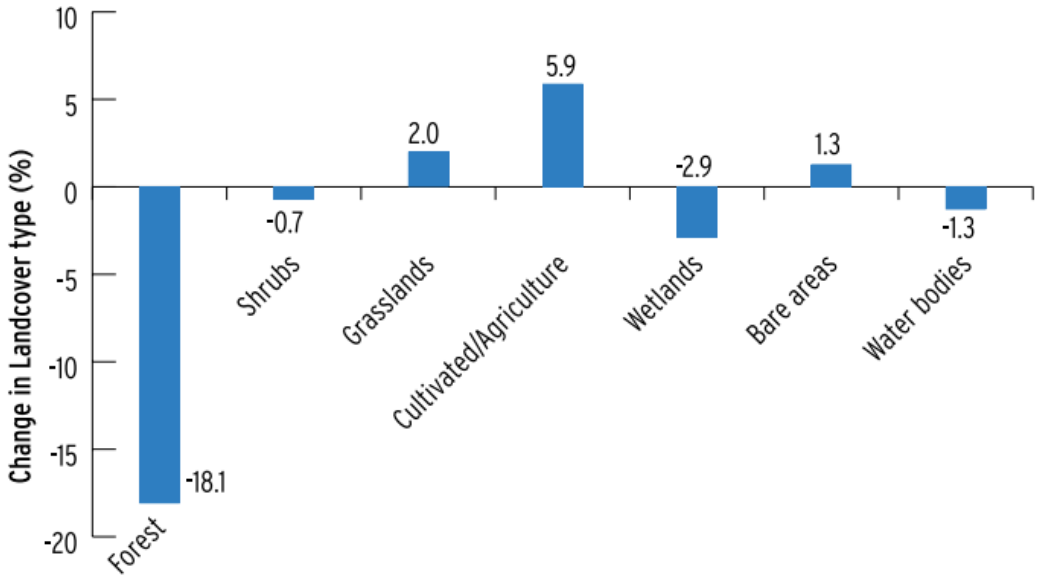


Figure 5. Change in land use in the Nile basin

(Source: NBI, 2016)

Even though the Nile River is the longest river in the world, the discharge of the river is quite small, especially compared with other transboundary rivers around the world. Extreme dependency on the water coupled with climate change and population growth has made the Nile basin one of the world's most water-scarce river basins. The Nile basin is marked by an uneven distribution of resources and huge disparity in socio-economic development among countries. Five out of the eleven basin riparian countries are documented to be among the world's poorest countries (FAO, 2011). Access to basic necessities such as food, water, sanitation and energy are still low in the basin, with the marked exception of Egypt.

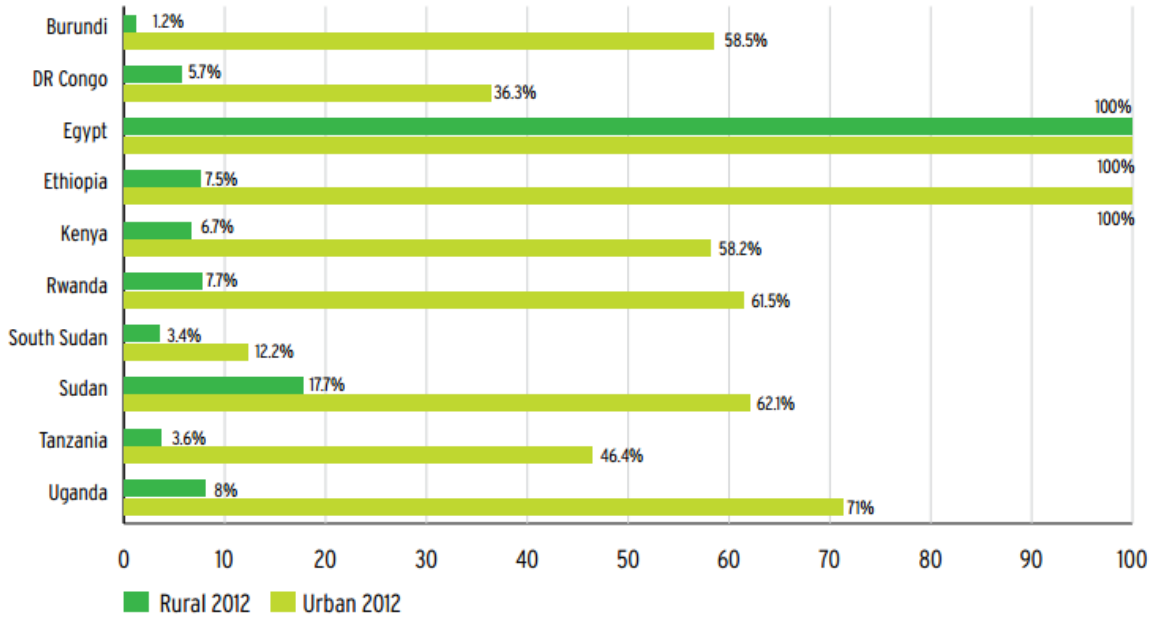


Figure 6. Access to electricity in the Nile basin.

(Source: NBI, 2016)

The basin shows similar trends in population growth and urbanization, albeit at different rates (see Figures 7 and 8). While there is a significant amount of unmet water demand in the basin, the water demand is also expected to increase.

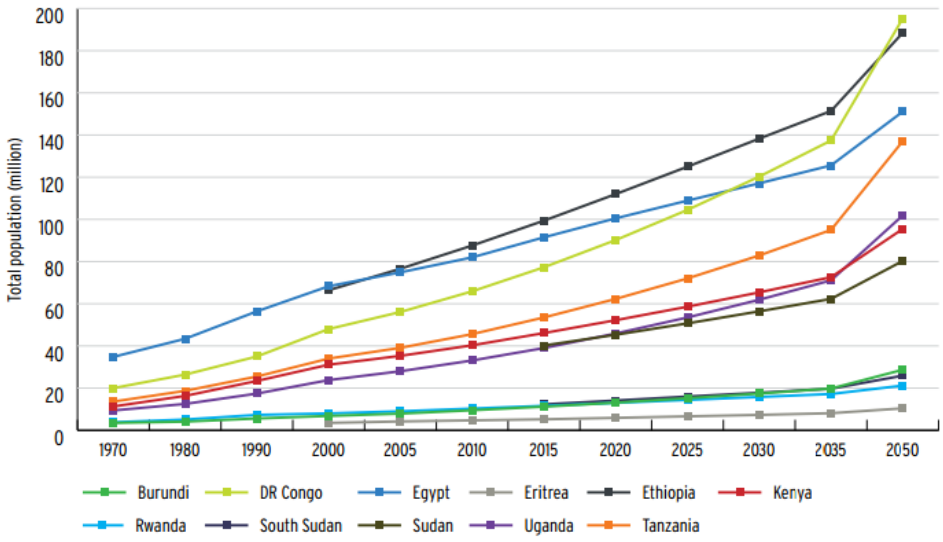


Figure 7. Population projection for the Nile basin

(Source: NBI, 2016)

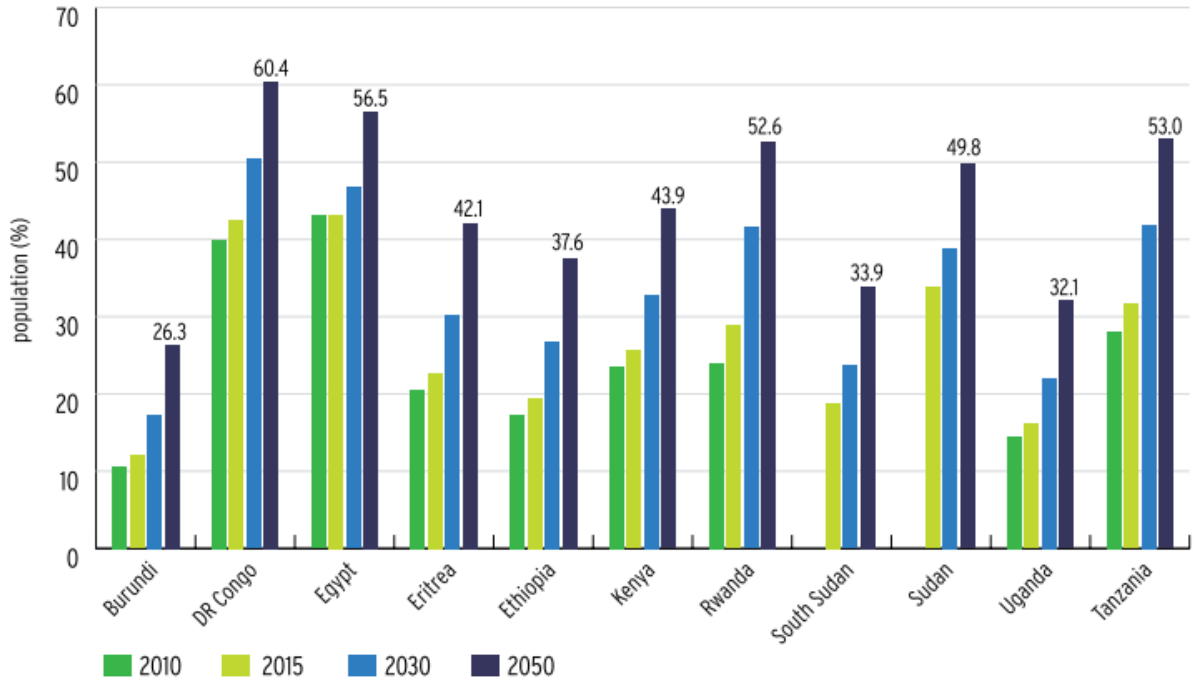


Figure 8. Urbanization trend for the Nile basin

(Source: NBI, 2016)

Again, with the marked exception of Egypt, the gross domestic product (GDP) of all the Nile basin countries is among the lowest globally, with less than 4000 dollars per capita. All the Nile basin countries have a significant amount of their population living under the poverty line with large income inequality across the basin, except Egypt. Access to electricity, drinking water and sanitation also shows the same trend, with the basin countries significantly lagging behind the world, with the sole exception of Egypt. This puts immense pressure on countries to utilize their resources and lift their population out of poverty. As the scarce resources in the region, the Nile water becomes a focal point in many development endeavors. However, the existing skewed water-sharing framework in the basin which allocates all of the Nile water to Egypt and Sudan without considering the other basin States, is a significant impendent.

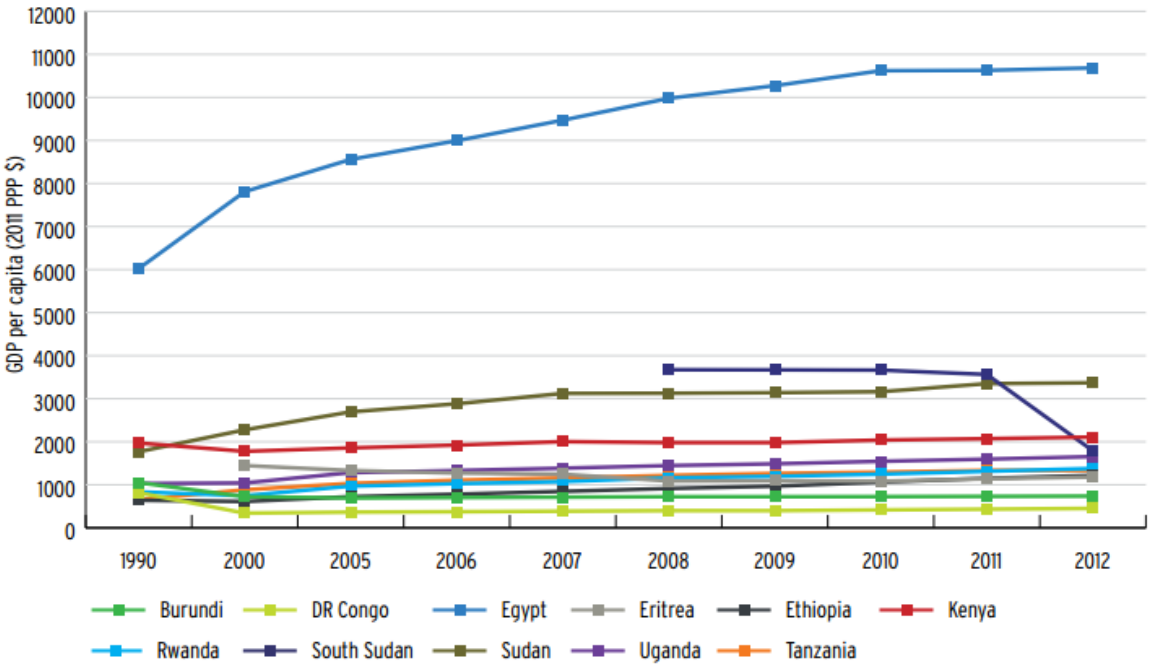


Figure 9. Trends in GDP per capita of Nile basin countries

(Source: NBI, 2016)

3.2 Data use and Sources

3.2.1 Factors used in modern water allocation doctrines, rules, and principles

Modern-day customary water laws have overlapping factors that they outline as determining factors for reasonable and equitable use in a transboundary basin. The Helsinki rules were the first to outline a thorough list of factors to determine transboundary water shares. Later on, the UN 1997 Convention, based on the Helsinki rules, came up with a compressed version of these factors with some amendments. The Berlin rules did not so much change the factors but rather presented a different reading from its predecessors on the precedence of the principle of equitable and reasonable use over the principle of causing no significant harm. The CFA had a set of factors that were primarily borrowed from the UN 1997 convention with two additional factors.

To be exhaustive, the factors outlined in the three major principles, i.e., the Helsinki Rules, the UN 1997 Convention, and the CFA, were combined to come up with a comprehensive list. Below are the factors outlined by each rule.

The Helsinki rules

In Article V, the Helsinki (1966) rules state that "*a reasonable and equitable share within the meaning of Article IV is to be determined in the light of all relevant factors in each particular case*." (ILA, 1966) It then lists the relevant factors to be considered in the determination of reasonable equitable share, stressing that the list is non-exhaustive. Below are the factors as written in the ILA (1966).

(a) Geography of the basin, including in particular the extent of the drainage area in the territory of each basin State;

(b) Hydrology of the basin, including in particular the contribution of water by each basin State;

(c) Climate affecting the basin;

(d) Past utilization of the waters of the basin, including in particular existing utilization;

(e) Economic and social needs of each basin State;

(f) Population dependent on the waters of the basin in each basin State;

(g) Comparative costs of alternative means of satisfying the economic and social needs of each basin State;

(h) Availability of other resources in the basin States;

(i) Avoidance of unnecessary waste in the utilization of waters of the basin;

(j) Practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses; and

(k) Degree to which the needs of a basin state may be satisfied, without causing substantial injury to a co-basin State.

After outlining the factors, it dictates that the weight to be given to each factor is to be determined by its importance compared with that of other relevant factors. In determining what a reasonable and equitable share is, all relevant factors are to be considered together, and a conclusion reached based on the whole (ILA, 1966).

The Helsinki rules also state that no factor has a fixed weight or inherently possesses priority or precedence over others. It also underlines that for a factor to be relevant, it should aid in the satisfaction of the social and economic needs of co-basin States, narrowing the chance of intrinsically self-serving factors being included in the list.

UN Watercourses Convention (1997)

The UN 1997 convention also lists a non-exhaustive list of factors to be considered in determining reasonable and equitable use in sub Article 1 of Article 6.

(a) Geographic, hydrographic, hydrological, climatic, ecological, and other factors of a natural character;

(b) The social and economic needs of the watercourse States concerned;

(c) The population dependent on the watercourse in each watercourse State;

(d) The effects of the use or uses of the watercourses in one watercourse State on other watercourse States;

(e) Existing and potential uses of the watercourse;

(f) Conservation, protection, development, and economy of use of the water resources of the watercourse and the costs of measures taken to that effect;

(g) The availability of alternatives, of comparable value, to a particular planned or existing use.

Then it goes on to say that concerned states of an international watercourse shall enter into consultation with a spirit of cooperation in sub-Article II and highlights that "*the weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable use, all relevant factors are to be considered together and a conclusion reached on the basis of the whole*." (UN, 1997).

The factors outlined in the UN 1997 convention were largely based on the Helsinki rules with a few exceptions.

- The UN 1997 factors have included more "natural factors" such as hydrography, ecology of the region, and basin States even though these factors' exact meaning is not described.

- While the Helsinki principle dictates that "*the past utilization of the waters of the basin, including in particular existing utilization,*" be considered, the UN 1997 convention strictly focuses on current and future uses i.e., present and potential uses of the watercourse.
- The UN 1997 convention drops the factor of compensation as a means of conflict resolution outlined in the Helsinki rules.
- The UN 1997 convention brings the issue of protection and conservation of a basin and the cost of these measures into the picture.

There are other slight discrepancies in phrasing between the factors outlined between the Helsinki rules and the UN convention, which can be easily married if there is consensus in the reading of the terms. For example, the effect of the use(s) of the watercourses in one state on another (from the UN convention) can be interpreted to mean the degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State in the Helsinki rules. Avoidance of unnecessary waste outlined in the Helsinki rules can also be included under the economy of use in the UN 1997 convention. The Helsinki rules also put "*the comparative costs of alternative means of satisfying the economic and social needs of each basin State" and "the availability of other resources*" as separate factors while the UN convention just has "*the availability of alternatives, of comparable value, to a particular planned or existing use*."

The CFA adopted the UN 1997 convention fully and then added two more factors: one on the contribution of each basin State to the waters of the Nile river system and second on the extent and proportion of the drainage area in the territory of each basin State, upon the insistence of Ethiopia and Sudan respectively. In Article 4 sub-article 2, the CFA states that "*in ensuring that their utilization of Nile River System water resources is equitable and reasonable, Nile Basin States shall take into account all relevant factors and circumstances, including but not limited to the following*":

(a) Geographic, hydrographic, hydrological, climatic, ecological, and other factors of a natural character;

(b) The social and economic needs of the Basin States concerned;

(c) The population dependent on the water resources in each Basin State;

(d) The effects of the use or uses of the water resources in one Basin State on the other Basin States;

(e) Existing and potential uses of the water resources;

(f) Conservation, protection, development, and economy of use of the water resources and the costs of measures taken to that effect;

(g) The availability of alternatives, of comparable value, to a particular planned or existing use;

(h) The contribution of each Basin State to the waters of the Nile River system;

(i) The extent and proportion of the drainage area in the territory of each basin State."

As can be seen, the CFA factors are identical to the UN 1997 convention with redundant factors of the extent of the drainage area and water contribution by each state being the exception. The last two additions would have been covered by geography and hydrology of the basin States outlined in the Helsinki 1966 rules and UN 1997 convention. The CFA also follows the UN 1997 convention in stating that all factors need to be considered in determining reasonable and equitable use.

For this thesis's purpose, the CFA and UN 1997 convention will be the guiding frameworks to evaluate equitable and reasonable use, with the Helsinki rules used to provide readings and simplifications of some factors. The only factor that was dropped entirely was the factor on compensation as a mechanism of conflict resolution in the basin since no other factor in the CFA, or the UN convention could be related to it. A summary of the variation of factors between different rules, principles, and conventions can be found in the appendix. A description of the factors used in this thesis along with their respective quantification and data for each country is presented below.

Table 2. Summary of factors for equitable and reasonable use

Factors	Helsinki 1966	U.N. 1997	CFA 2015
F1	Geography of the basin including, in particular, the extent of the drainage area in the territory of each basin State;	Geographic, hydrographic, hydrological, climatic, ecological, and other factors of a natural character;	Geographic, hydrographic, hydrological, climatic, ecological, and other factors of a natural character;
F2	Hydrology of the basin, including in particular the contribution of water by each basin State;	The social and economic needs of the watercourse States concerned;	The social and economic needs of the watercourse States concerned;
F3	Climate affecting the basin	The population dependent on the watercourse in each watercourse State;	The population dependent on the watercourse in each watercourse State;
F4	Past utilization of the waters of the basin, including in particular existing utilization;	The effects of the use or uses of the watercourses in one watercourse State on other watercourse States;	The effects of the use or uses of the watercourses in one watercourse State on other watercourse States;
F5	Economic and social needs of each basin state	Existing and potential uses of the watercourse;	Existing and potential uses of the watercourse;
F6	The population dependent on the waters of the basin in each basin State;	Conservation, protection, development, and economy of use of the water resources of the watercourse and the costs of measures taken to that effect;	Conservation, protection, development, and economy of use of the water resources of the watercourse and the costs of measures taken to that effect;
F7	Comparative costs of alternative means of satisfying the economic and social needs of each basin State;	The availability of alternatives, of comparable value, to a particular planned or existing use	The availability of alternatives, of comparable value, to a particular planned or existing use
F8	Availability of other resources in the basin States;		The contribution of each Basin State to the waters of the Nile River system;
F9	Avoidance of unnecessary waste in the utilization of waters of the basin;		The extent and proportion of the drainage area in the territory of each basin State."
F10	The practicability of compensation to one or more of the co-basin States as a means of adjusting conflicts among uses;		
F11	The degree to which a basin state's needs may be satisfied without causing substantial injury to a co-basin State.		

3.2.2. Data Sources

As explained above, this study's data are based on the factors outlined in international water-sharing principles. The majority of these data came from unofficial NBI studies and official NBI publications, mainly the Nile basin water resource atlas published in 2016. For data that could not be found in these sources, websites and scientific publications were used to supplement and complete the data. The data sources for each factor used in this study can be found together with the summaries of the data in the next section below.

3.2.3 Definition and quantification of factors used in this study in the determination of equitable and reasonable use

1. Geography (F1)

The Nile Basin Initiative (NBI) defines geography and natural factors of the Nile basin in terms of topography, slope, geology, soil types, ecoregions, land cover, and sub-basins characteristics in the basin. However, to limit the scope of the definition to the limits of this thesis, geography refers to the extent of the drainage area of a basin in each basin State (also as outlined in the Helsinki rules). This is characterized by the percentage of the basin present in each riparian state. A distinction is made here between the percentage of the basin in the country versus the percentage of the country in the basin. Following the phrasing used in the UN 1997 convention and the CFA, the prior i.e. % of basin in the countries is used in this study. The total area of the Nile basin is estimated to be 3,176,550 km^2. The percentage of a country is hence evaluated according to Equation 1 and the summary of the data for all basin States is summarized in Table 2.

$$\%\ of\ country\ in\ the\ basin = \left(\frac{Area\ of\ country\ in\ the\ basin}{total\ area\ of the\ basin}\right) * 100\%$$

Equation 1. Equation for the geographic contribution of countries calculation.

Table 3. Geography data of basin States

Countries	Total area (km^2)	Area in basin (km^2)	% of basin in country	% of country in basin
Burundi	27834	13869	0.44	49.3
DRC	2345410	21796	0.69	0.91
Egypt	996960	302452	9.52	30.34
Eritrea	121722	25697	0.81	21.11
Ethiopia	1144035	365318	11.50	31.93
Kenya	593116	51363	1.62	8.66
Rwanda	26338	20625	0.65	84.01
South Sudan	644329	620626	19.54	97.71
Sudan	1864049	1396230	43.95	74.90
Tanzania	945000	118507	3.73	12.69
Uganda	241248	240067	7.56	99.51

(Source: Nile Basin Water Resource Atlas, 2016)

2. Hydrology (F2)

Hydrology of the Nile basin is described in terms of annual and seasonal flow patterns of significant rivers in the basin, hydrological extremes, and groundwater in the Nile basin (Nile basin water resource Atlas, 2016). However, in this thesis, the definition of hydrology is limited to the contribution of water by each basin State to the waters of a transboundary water (as described in the Helsinki rules and the CFA). The table below summarizes this data for the Nile basin States.

It was rather challenging to identify the amount of water contribution from each basin State as most studies done in the basin were not at the scale of countries but sub-basins. Each basin State's contribution is calculated from a water use schematic provided by NBI, by deducting natural losses and overlaps between countries. The resulting total flow of the basin was found to be around 96 BCM (See flow accounting schematic in the appendix). The summary of the break down by country is shown in Table 4 below.

The significant loss in the basin at the Sudd wetlands in South Sudan was deducted as a natural loss from the whole basin. This spreads this natural loss over the whole basin rather than reducing the country contribution of South Sudan. Data for the exact water contribution of Eritrea to the Nile could not be found. To address this, the whole flow of the Mereb river, which is shared between Eritrea and Ethiopia is taken as the contribution of Eritrea. This assumption will not significantly skew the analysis as the flow of the Mereb River is very small (0.72 BCM).

Table 4. Water contribution of countries to the Nile basin

Countries	Flow (BCM)	% Contribution
Burundi	3.88	4.03%
DRC	4.13	4.29%
Egypt	0	0%
Eritrea	0.72	0.75%
Ethiopia	79.59	82.74%
Kenya	6.74	7.01%
Rwanda	4.7	4.94%
South Sudan	8.29	8.62%
Sudan	5.61	5.83%
Tanzania	4.49	4.67%
Uganda	4.39	4.56%

3. Climate affecting the basin (F3)

Climate is a vast subject to pin down and quantify. The Nile Water Resource Atlas (2016) describes the basin's climate by dividing the basin into climatic zones and describing the rainfall, temperature, evapotranspiration, humidity, and wind speed. Nevertheless, as far as "climate affecting the basin" is concerned, the main aspects of climate that significantly affect the Nile basin's water are rainfall and evapotranspiration.

The Nile basin is mainly affected by changes in the Blue Nile region, which is highly affected by rainfall, and changes in the equatorial lake region, whose water balance is highly susceptible to evapotranspiration. Therefore, for this thesis, climate affecting the basin will be limited to rainfall and evapotranspiration. Table 5 below summarizes the annual average rainfall and evapotranspiration of the basin States.

Table 5. Climate data of basin States

Countries	Country average rainfall (mm/yr)	Rainfall received in the Nile basin portion of the countries (mm/yr)	% contribution of rainfall	Potential Evapotranspiration (mm/day)	% contribution of Evapotranspiration
Burundi	1275	1202	13.36%	3.1	6.87%
DRC	1543	1146	13.01%	3.2	7.1%
Egypt	51	19	0.45%	5.6	12.42%
Eritrea	300	300	3.41%	5.0	11.09%
Ethiopia	848	1184	11.49%	3.9	8.65%
Kenya	630	1149	8.1%	4.5	9.98%
Rwanda	1212	1137	11.32%	2.7	5.99%
South Sudan	900	900	11.21%	4.1	9.09%
Sudan	250	487	3.01%	5.7	12.64%
Tanzania	1071	1043	10.82%	3.5	7.76%
Uganda	1180	1193	13.84	3.8	8.43%

(Source: Nile Basin Water Resource Atlas, 2016 for rainfall and NBI data for evapotranspiration)

Rainfall data for Eritrea and the Congo, as well as evapotranspiration data for the Congo, could not be found from the NBI, so they had to be supplemented from external sources. The country average rainfall and rainfall received in the basin were given the same values because of this lack

of data. Evapotranspiration for the Congo was supplemented from the website linked in the footnote[16].

The percentage contribution of rainfall and evapotranspiration in the basin was calculated in the same manner as the percentage of area in the basin. The total sum of rainfall and evapotranspiration in the basin was evaluated and the percentage contribution of each country to this total was evaluated for use in the water allocation framework.

$$\%\ RF/ET\ contribution\ of a\ country = \left(\frac{RF/ETof\ country}{Total\ RF/ET\ in\ the\ basin}\right) * 100\%$$

Where RF: rainfall,

ET: Evapotranspiration,

Total RF/ ET: Total rainfall and evapotranspiration in the basin, which is the sum of rainfall and evapotranspiration by each country.

Equation 2. Rainfall and Evapotranspiration contribution by country

The influence of rainfall and evapotranspiration on the factor "climate affecting the basin" is assumed to be even and hence an equal factor of 0.5 is assigned to these entities in the water allocation calculation as will be shown in the allocation equation. These weights are subjective and are only meant to show the relatively even importance of rainfall and evaporation in the basin. They can be changed upon consensus by stakeholders.

4. Population dependent on the water resource (F4)

Population dependent on the water resource can be extended to mean population directly living and dependent on the basin or population whose existence indirectly depends on the basin. This is a broad and a rather contentious definition as a country can claim that its whole population is indirectly dependent on the water resource of the basin if the basin accounts for a significant amount of the water resource of the country as in the case of Ethiopia, or if the basin is a major water source for the country as in the case of Egypt.

[16] https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016RG000517

To cater for this rationale and to limit the complexity for this thesis, population dependent on the water resource is classified into two classes, population directly dependent i.e., living in the basin and population indirectly dependent on the water resource, which will be the total population of countries minus population directly dependent/living on the water. While the total population directly dependent in the basin is estimated to be around 248 million according to 2015 population data, the population which is indirectly dependent on the basin amounts to 211 million, totalling 460 million directly and indirectly dependent on the basin. The sets of equations given below show the evaluation for population dependent on the basin and Table 6 below summarizes the following data.

$$\%\ of\ population\ by\ country\ (in) directly\ dependent\ on\ the\ basin = \left(\frac{Population\ of\ a\ country\ (in) directly\ dependent\ in\ the\ basin}{Total\ number\ of\ people\ (in) directly\ dependent\ in\ the\ basin}\right) * 100\%$$

$$Total\ population\ directly\ dependent\ on\ the\ basin = sum\ of\ population\ directly\ living\ in\ the\ basin\ in\ each\ basin\ state$$

$$Total\ population\ indirectly\ dependent\ in\ the\ basin = sum\ of\ population\ of\ countries\ living\ outside\ of\ the\ the\ basin\ in\ each\ basin\ state$$

Equation 3. Calculation of population dependent on the basin

A country with a larger population directly living in the basin has more dependency on the basin than the population indirectly living in the basin. To account for this rationale, a factor of 0.7 is given to the population directly dependent on the basin and 0.3 for the population indirectly dependent on the basin in the water allocation framework. These factors are only indicators of the relative importance of the factors. A factor of 0.7 is given to the population directly dependent population as the rationale behind distinguishing between direct and indirectly dependent population necessitates a factor greater than 0.5 to be assigned for direct population dependency. As such, the proportion can be changed upon consensus of stakeholders if the weights' relative importance is reflected in the values.

Table 6. Population dependent on the Nile basin (based on population data of 2012)

Countries	Total population (Millions)	Population directly dependent /living in the basin (Millions)	% population directly dependent compared to the basin	Population indirectly dependent in the basin (Millions)	% population indirectly dependent Compared to the basin
Burundi	11.2	5.7	2.30%	5.5	2.60%
Egypt	91.5	85.8	34.55%	5.7	2.69%
Eritrea	5.2	2.2	0.89%	3	1.42%
Ethiopia	99.4	37.6	15.14%	61.8	29.21%
Kenya	43	17.2	6.93%	25.8	12.19%
Rwanda	10.5	8.7	3.50%	1.8	0.85%
South Sudan	12	11.9	4.79%	0.1	0.05%
Sudan	36.1	31.4	12.65%	4.7	2.22%
Tanzania	44.9	11.3	4.55%	33.6	15.88%
Uganda	34	33.6	13.53%	0.4	0.19%

(Source: Nile Basin Water Resource Atlas, 2016).

5. Existing and potential uses of the water resources (F5)

In this thesis, existing and potential water use of the resources is limited to the existing and future uses of major key sectors in the basin, namely irrigation, domestic/municipal use, and industrial use. A major sector not included in this list is hydropower. However, data on hydropower potential is not complete for all the basin countries so hydropower was not included in the existing and potential use. Regardless, since hydropower does not constitute consumptive use of water (except for the evaporation loss from dams, which is minimal compared to other consumptive uses), it will not have a significant impact on allocation.

The data summarized below has current use of countries and projected use according to scenarios developed for 2050. These scenarios were developed by the NBI, taking into account expected

developments in the basin by 2050 and the high projection scenario was used for this thesis's purposes to indicate future potential uses. Future irrigation water demand for basin States is calculated based on water that the countries might use, assuming countries would utilize 100% of their irrigation potential. Table 7 below summarizes the current and future water demand per country by summing up the three sectors' total demand. The detailed breakdown of demand by sector can be found in the appendix.

Table 7. Existing and potential water use of countries

	Current use (MCM)	% of current use	Expected use High Projection 2050 (MCM)	% of projected use
Burundi	43.15	0.05%	82.12	0.05%
DRC	9.06	0.01%	34.24	0.02%
Egypt	68902.86	79.07%	88032.90	57.9%
Ethiopia	1593.92	1.83%	23677.37	15.57%
Kenya	1455.00	1.67%	5095.67	3.35%
Rwanda	242.68	0.28%	620.50	0.41%
South Sudan	96.85	0.11%	4967.08	3.27%
Sudan	14249.94	16.35%	27245.33	17.92%
Tanzania	76.75	0.09%	1143.71	0.75%
Uganda	471.05	0.54%	1142.47	0.75%
Total	82197.00		152041.38	

(Source: NBI data)

The percentage share that a country demands out of the total basin's current and projected demand is evaluated and used in the water allocation framework.

$$\%\ of\ water\ demand\ by\ country = \frac{Amount\ of\ current\ or\ projected\ use\ of\ the\ country}{Current\ or\ projected\ demand\ in\ the\ basin} * 100\%$$

Equation 4. Evaluation of existing and potential water demand of basin States

6.Social and economic needs (F6)

The socio-economic needs of a country can mean a wide range of things, and various indicators can be developed to quantify this factor. For this study, countries' social and economic needs are reflected through the expected water needs of countries in the foreseeable future. Quantifying a country's socio-economic needs through its projected water demand was also the practice used in a similar study done for the Jordan river by Mimi & Sawalhi (2003). This is not to say projected water use is the only proper indicator for this factor; instead, it is a simplification chosen for this research as it fits the factor's purpose. To this end, the water needs for basin countries evaluated by NBI considering the projected municipal, industrial and irrigation demands for 2050 were used to quantify socio-economic needs. See Table 7 above for the summarized data. Detailed projected demand of multiple sectors for all basin countries, according to the scenario developed by NBI for 2050, can be found in the appendix.

7.The availability of alternatives, of comparable value, to a particular planned or existing use (F7)

While the UN 1997 convention and the CFA use the above phrasing, the Helsinki rules say, "the availability of other resources". In either phrasing however, it is unclear what kind of alternatives or other resources are being referred to. It is not clear whether these resources are limited to other water resources such as surface and groundwater resources that the basin States are endowed with other than the transboundary water in question or considering non-water resources like oil and natural minerals etc. that the basin States might rely on.

For this research, alternative resources will mean alternative water resources limited to groundwater and desalinated water. Groundwater resources (both renewable and non-renewable) and desalination potential expressed in terms of coastlines of countries in km are considered as indicators for alternative sources. Groundwater data was obtained from a study done by Macdonald et.al., (2012) while the length of coastline was obtained from a website linked in the footnote[17].

Since the study used for groundwater potential (Macdonald et al., 2012) was done in 2012, immediately after the independence of South Sudan, the data for South Sudan is not available separately but together with Sudan. The groundwater potential of Sudan was divided equally

[17] https://www.citypopulation.de/en/world/bymap/Coastlines.html

between the two countries, after the same proportion as observed in their surface water shares. This is an explicit limitation because of lack of data; however, the effort to overcome this limitation through informed assumptions is expected to reduce its impact on the allocation scheme. The summary of values for this factor is presented in Table 8.

The availability of "other" surface water resources available in the basin States, besides the Nile, can possibly be considered as alternatives. Also, no distinction was made between groundwater systems that feed the Nile system versus separate ones. This distinction is necessary to avoid double counting of water resources contributing to the basin. These nuances were, however, beyond the current scope of the study because of time constraints. However, these factors need to be addressed in future studies.

Table 8. Availability of alternative resources

	Groundwater reserve (BCM)	% Groundwater reserve	Coastline in Km	% of coastline
Burundi	47	0.03%	0	0%
DRC	38300	20.79%	37	0.49 %
Egypt	55,000	29.96%	2450	32.52%
Ethiopia	12700	6.89%	0	0%
Eritrea	333	0.18%	2234	29.65%
Kenya	8840	4.8%	536	7.11%
Rwanda	49	0.03%	0	0%
South Sudan	31600	17.15%	0	0%
Sudan	31600	17.15%	853	11.32%
Tanzania	5250	2.85%	1424	18.9%
Uganda	339	0.18%	0	0%

(Source: https://www.citypopulation.de/en/world/bymap/Coastlines.html and Macdonald et al., 2012)

The percentage share of alternative resources for each country is evaluated in the same way as explained for the other factors by taking the country's share compared to the whole basin. The effect of groundwater and desalination potential is considered to be even under the factor of

alternative resources, and hence a factor of 0.5 is given to both of them in the water allocation evaluation.

$$\%\ share\ of\ alternative\ resource\ of\ a\ country = \frac{Amount\ of\ ground\ water\ or\ Shore\ line\ of\ a\ country}{Total\ amount\ of\ ground\ water\ or\ shore\ line\ in\ the\ basin} * 100\%$$

Equation 5. Evaluation of alternative resource contribution

8. The effects of the use or uses of the water resources in one basin State on other basin States (F8)

The effect of use by one basin State on others is evaluated in terms of the extent of countries' consumptive water use. The majority of the water in the basin goes to irrigation use. Therefore, it makes sense to evaluate the potential of harm on other basin States by the basin States' expected irrigation water use. To this end, each country's irrigation potential and the expected water demands were evaluated to serve as an indicator for this factor. The logic behind this being the greater the irrigation water demand of a country, the more it would consumptively use water from the basin and the more likely it will affect the use by other countries. The percentage share of irrigation demand per country was evaluated in the same fashion as above and results are summarized in Table 9.

$$\%\ share\ of\ irrigation\ demand = \frac{Irrgation\ demand\ of\ a\ country\ for\ 2050}{total\ irrigation\ demand\ in\ the\ basin} * 100\%$$

Equation 6. Evaluation of the effect of use on others

Data for Eritrea and Congo was not available for this factor and could not be supplemented from other sources as well and hence was taken to be zero. However, this assumption is not expected to skew the allocation significantly as both of these countries do not have a significant irrigation potential and water demand.

Table 9. Effect of use on other basins as a function of irrigation potential and forecast water use.

Countries	Total Suitable area for irrigation (ha)	Expected requirement (MCM)	% of expected requirement
Burundi	162,909	28.9	0.02%
DRC	487,817	-	-
Egypt	3,377,971	80,861.7	58.47%
Eritrea	154,632	-	-
Ethiopia	7,969,455	23,407.8	16.93%
Kenya	1,927,607	1,589.2	1.15%
Rwanda	464,665	92.5	0.07%
South Sudan	3,580,578	4,669.4	3.38%
Sudan	20,086,802	26,226.5	18.96%
Tanzania	4,273,263	1,093.3	0.79%
Uganda	7,308,534	329.0	0.24%

(Source: NBI data)

9. Conservation, protection, development and economy of use of the water resources and the costs of measures taken to that effect; (including the avoidance of unnecessary waste in the utilization of waters of the basin) (F9)

This factor is rather broad, covering several aspects such as:

- conservation and protection of the basin,
- development and economy of use of the water resource
- cost of measures
- avoidance of unnecessary waste in the utilization of water.

The first two facets can potentially be evaluated using the percentage of a country's budget dedicated to the conservation and the monetary benefit from the utilization of a unit of water in different sectors. However, data for these could not be found, and hence they were not included in

the analysis. The statement "cost of measures" is vague. The last aspect, avoidance of unnecessary waste, which was also how this factor was phrased in the Helsinki rules, was used as a representative for this factor. As part of avoiding unnecessary waste, the irrigation savings that are possible in the basin by implementing various measures have been evaluated by the NBI, as shown in Table 10 below. These potential water savings possible for each country were considered an indicator for unnecessary waste avoidance. Data for Eritrea and Congo was not found for this factor and was hence taken to be zero. This assumption will not skew the results as these two countries have minimal irrigation demand and hence significant water savings are not expected.

Table 10. Potential water savings by countries

Countries	Potential water saving by country (MCM)	% share in basin saving
Burundi	37.76	0.10%
DRC	-	-
Egypt	4625.89	11.95%
Eritrea	-	-
Ethiopia	12128.06	31.32%
Kenya	529.20	1.37%
Rwanda	55.71	0.14%
South Sudan	7163.04	18.50%
Sudan	13,650.58	35.25%
Tanzania	404.99	1.05%
Uganda	127.74	0.33%

(Source: NBI data)

The above-described factors and their respective indicators were then used to develop a basic framework of water allocation for the basin. This framework is a simple, flexible tool that can be used by stakeholders to experiment with the shares of respective countries by playing with the

respective weights they would give to the factors, as recommended by the UN 1997 convention as well as the Helsinki rules. The methodology of developing this framework is described in the next section.

3.3 Analytical method

The methodology followed to evaluate countries' water shares based on the factors outlined in the previous subsection resembles a Multi-Criteria Analysis (MCA). An MCA analysis helps in decision making by comparing alternative courses of action based on multiple criteria and recommend the most suitable option to decision-makers (Collins, 2007). It identifies the trade-offs in the objective under multiple criteria and seeks to identify a preferable solution by giving weights to multiple criteria and evaluating based on the scores[18].

In this study, the factors outlined to be considered in the determination of equitable and reasonable use are given different weights; and the relative shares of countries are calculated based on these weights. However, unlike MCA, this study aims to present scenarios to show the implication of the factors on water share, rather than suggest a preferred alternative (which is often the aim of MCA).

In the calculation of water shares based on outlined factors, it can be seen that some factors positively affect water shares while others take away from a country's share. For instance, the more water a country contributes to the basin, the more share it is entitled to; however, the more significant alternative resources a country has, the less share it is entitled to. As such, "negative" factors multiplied by their respective weights deduced from the product of "positive" factors with their respective weights frame the countries' water-share of countries. Table 11 below summarizes how the factors affect countries' water shares and other assumptions made in the analysis.

[18] https://www.floodmanagement.info/what-is-multi-criteria-analysis-mca/#:~:text=Multi%2Dcriteria%20analysis%20is%20a,of%20achieving%20a%20given%20policy.

Table 11. Summary of factor influences

Factors	Effect		Note
Geography	Positive	*Fi*wi*	
Hydrology	Positive	*Fi*wi*	
Climate: Rainfall	Positive	*o.5*Fi*wi*	Equal weights of 0.5 assigned to rainfall and evapotranspiration under the factor of climate
Climate: Evapotranspiration	Negative	*-0.5* Fi*wi*	
Population: Directly dependent and indirectly dependent	Positive	*0.7(Fi direct*wi) +0.3(Fi indirect*wi)*	A weight of 0.7 is given to directly dependent population and 0.3 to indirectly dependent population
Existing use	Positive	*Fi*wi*	
Socio-economic demands	Positive	*Fi*wi*	
Effect of use on others	Negative	*-Fi*wi*	
Alternative resources: Desalination Groundwater	Negative	*-0.5(Fi groundwater*wi) - 0.5(Fi desalination*wi)*	Equal weights of 0.5 assigned to desalination potential and groundwater potential
Avoidance of unnecessary waste	Positive	*Fi*wi*	

The water shares of countries in the basin were then calculated, having considered all the factors mentioned above. The equation below explains how the allocations were calculated.

$$Water\ Share\ of\ a\ country\ (WSj) = \frac{Positive(Wij * Fij) - Negative(Wij * Fij)}{\sum_{j=1}^{11} positive\ wifi - \sum_{j=1}^{11} Negative\ wifi}$$

Where: *WSj*= Water-shareof countries

j = countries

i = Factor indicators

w =weights for indicators in %

Equation 7. Objective function for calculation of shares of countries

Four scenarios were then developed to show the range of possible water allocation and the resulting water shares of basin States. The first scenario gave equal weights for all the factors and calculated the resulting shares. In this scenario, each factor was given an equal weight of 1/9 and the shares of each country was then evaluated based on the equation above. The second, third, and fourth scenario optimized the factors listed to maximize allocation shares under different constraints. The optimization analysis was done in Excel using the Solver function and the Generalized Reduced Gradient (GRG) Non-linear method of solving.

Solver is an add-in program in Microsoft Excel that can perform "what-if" analysis and optimization operations. The optimization analysis can maximize or minimize the objective function, but Solver can also find optimum solutions for when the objective function approaches a certain value. The Solver program has three methods of solving problems: the Simplex Linear Program, the Generalized Reduced Gradient (GRG) Non-linear method, and the Evolutionary method of solving.

The Simplex LP method is suited to solve linear problems as the name implies, while the other two methods are best for solving non-linear problems. The GRG non-linear method of solving is a good fit for problems that are not linear and cannot be solved by Linear programming but are smooth and not too complex to demand the evolutionary method. The GRG non-linear method of solving problems essentially works by looking at the gradient of the objective function in relation to change in decision variables to determine a local optimum solution[19]. The GRG non-linear method of analysis stops when it identifies a local optimum nearest to the initial conditions and

[19]https://engineerexcel.com/excel-solver-solving-method-choose/#:~:text=GRG%20Nonlinear,the%20partial%20derivatives%20equal%20zero.

may not necessarily provide the global optimum (See Figure 10). Thus, it is faster compared to the evolutionary method of solving non-linear equations that determines global optimum in non-smooth, non-linear equations. The Evolutionary method is more robust and it is ideal for identifying the global optimum for non-smooth problems.

The analysis for optimization in this study was done using the GRG non-linear method because the objective function is a simple smooth non-linear function and hence the system will result in a globally optimized solution. This was verified when the analysis was done with the evolutionary method and resulted in the same solution points. The objective functions, changing variables, and set of constraints used in the different scenarios for the optimization exercise is outlined below.

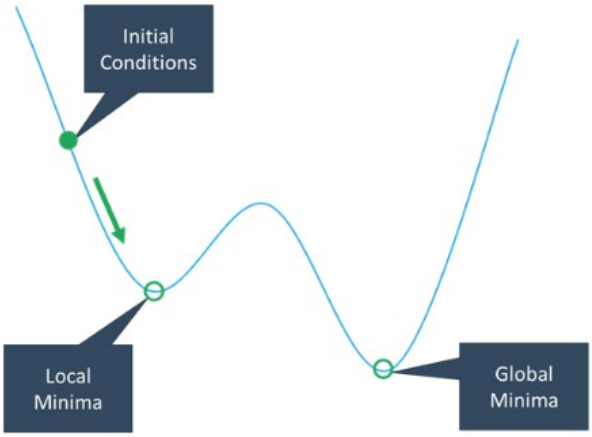


Figure 10. GRG non-linear method of analysis

(Source: https://engineerexcel.com/)

In the second scenario, the allocation was programmed to maximize the benefits for one country at a time. While the allocation equation used was the same as above, the optimization was done by programming Solver to maximize the water-share of an individual country by playing with the weights of the nine factors described above under the constraints that the weights given for the factors should be between zero and one and that the sum of the weights given to these factors should equal 100%.

$$Maximize\ Water\ Share\ of\ a\ country\ (WSj) = \frac{Positive(Wij*Fij) - Negative(Wij*Fij)}{\sum_{j=1}^{11} positive\ wifi - \sum_{j=1}^{11} negative\ wifi}$$

By changing variables *Wi for country j*

Constraints: $0 < Wij < 1$,

$\sum Wij = 1$

Where: *WSj*= Water-shareof countries

j = countries

i = Factor indicators

w =weights for factor indicators in %

$\sum Wij$ *is sum of the weights of all the factors*

Equation 8. Optimization equation in Scenario 2

The third scenario optimized the shares of countries under certain rules. This scenario is similar to scenario 2; however, the weights given for the factors is constrained between 5% and 50%. Here again, the factor constraints of 5 and 50% only indicate relative values given to ensure no one factor is dominant (more than 50%) or minimized (less than 5%). These values are open to changing upon the consensus of stakeholders.

$$Maximize\ Water\ Share\ of\ a\ country\ (WSj) = \frac{Positive(Wij*Fij) - Negative(Wij*Fij)}{\sum_{j=1}^{11} Positive\ wifi - \sum_{j=1}^{11} Negative\ wifi}$$

By changing variables *Wi for country j*

Constraints: $0.05 < Wij < 0.5$,

$\sum Wij = 1$

Where: *WSj*= Water-shareof countries

j = countries

i = Factor indicators

w =weights for indicators in %

$\sum Wij$ *is sum of the weights of all the factors*

Equation 9. Optimization equation in Scenario 3

The fourth scenario aimed to calculate the shares of individual countries by maximizing the sum of shares in the basin, i.e., maximizing the shares of all the countries in the basin to maximize the

basin total. Scenario 2 and 3 maximized the shares of individual countries at the expense of other countries. In contrast, scenario 4 maximizes the shares of all countries without trade-off with each other to maximize the basin total; see Equation 10 below.

$$\text{Maximize } \sum WSj = \sum_1^j Positive(Wij * Fij) - Negative(Wij * Fij)$$

By changing variables *Wij for all countries*

Constraints: $0 < Wij < 1$.

After the optimization, the shares of each country is evaluated as:

$$WSj = \sum_1^j Positive(Wij * Fij) - Negative(Wij * Fij) * 100\% / \sum WSj$$

Where: *WSj*= Water-shareof countries

j = countries

i = Factor indicators

w =weights for indicators in %

$\sum WSj$ *is sum of the shares of all the factors.*

Equation 10. Basin sum maximization in Scenario 4

4.Results and Discussion

In this chapter the water allocation results evaluated based on the factors and the evaluation method explained in the previous chapters is presented. Four scenarios were developed to explore a range of water sharing schemes and the results according to each scenario is presented below.

4.1. Quantification of factors

Below is the summary of the quantification of all the factors used in the formulation of an equitable water sharing scheme.

Table 12. Summary of quantification of factors

Country	F1 (%)	F2 (%)	F 3.1 (%)	F 3.2 (%)	F 4.1 (%)	F 4.2 (%)	F5 (%)	F6 (%)	F 7.1 (%)	F 7.2 (%)	F8 (%)	F9 (%)
Burundi	0.44	4.03%	13.36	6.87	2.30	2.60	0.05	0.05	0.03	0	0.02	0.1
DRC	0.69	4.29%	13.01	7.1	1.17	32.07	0.01	0.02	20.79	0.49	0	0
Egypt	9.52	0%	0.45	12.42	34.55	2.69	79.07	57.9	29.96	32.52	58.47	11.95
Eritrea	0.81	0.75%	3.41	11.09	0.89	1.42	0	0	0.18	29.65	0	0
Ethiopia	11.5	82.74%	11.49	8.65	15.14	29.21	1.83	15.57	6.89	0	16.93	31.32
Kenya	1.62	7.01%	8.1	9.98	6.93	12.19	1.67	3.35	4.8	7.11	1.15	1.37
Rwanda	0.65	4.94%	11.32	5.99	3.50	0.85	0.28	0.41	0.03	0	0.07	0.14
South Sudan	19.54	8.62%	11.21	9.09	4.79	0.05	0.11	3.27	17.15	0	3.38	18.5
Sudan	43.95	5.83%	3.01	12.64	12.65	2.22	16.35	17.92	17.15	11.32	18.96	35.25
Tanzania	3.73	4.67%	10.82	7.76	4.55	15.88	0.09	0.75	2.85	18.9	0.79	1.05
Uganda	7.56	4.56%	13.84	8.43	13.53	0.19	0.54	0.75	0.18	0	0.24	0.33

4.2 Scenario 1: Equal Weights for All Factors

The first scenario evaluated the shares of countries assuming all the factors have equal weights. In this case, since there are nine factors, each factor gets a weight of one-ninth. The resulting country shares from this scenario is presented in the Figure 11.

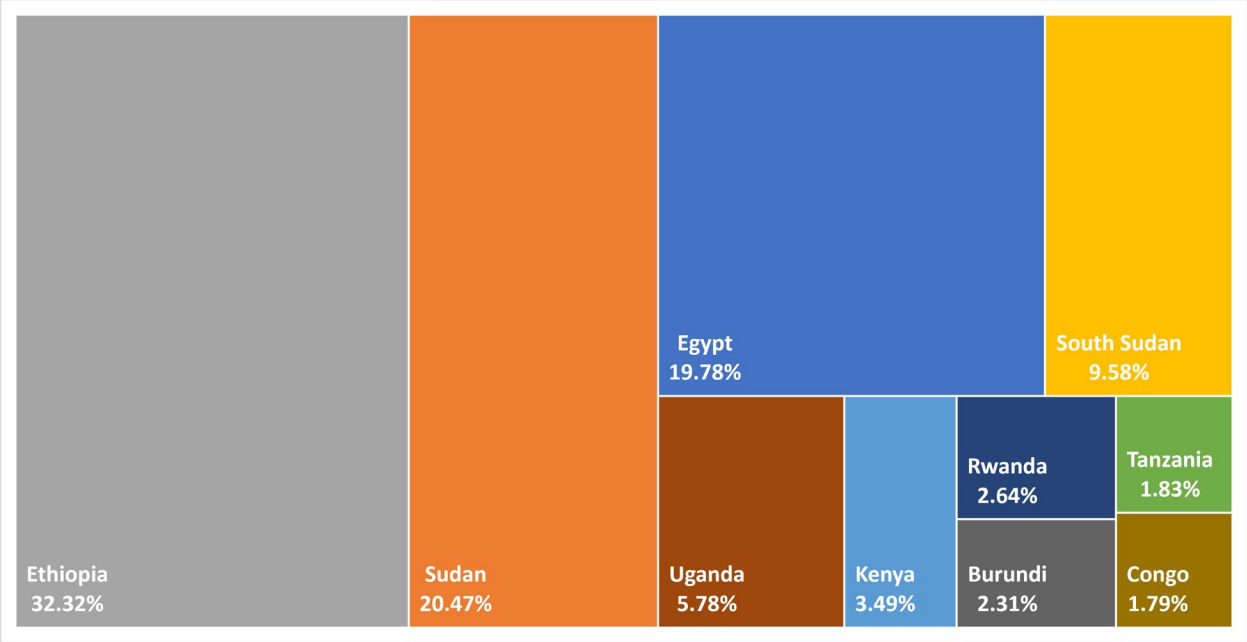


Figure 11. Country water shares according to scenario 1

As one can see from the summary above, if all the factors had equal weights, the current dominant user of the waters, Egypt, would both get approximately 20%, which is nowhere near its current claimed share. Ethiopia, as the most significant contributor of the water, would be entitled to 32 % of the Nile waters in this allocation with South Sudan taking the fourth largest share at 9.6%. The upper riparian countries roughly have similar shares between 2% and 6%, while Eritrea gets a negative share, which translates to zero share.

4.2 Scenario 2: Country Optimization

In this scenario the factors contributing to the shares of countries were optimized to result in the largest benefit or share to individual countries. The optimization equation for this scenario is given in Equation 8 in the methodology section. The resulting shares along with the dominant factors for each country according to this scenario is summarized in Table 13.

To optimize the shares for individual countries, the system gives a weight of 100% of the largest positive reinforcing factor for each country while essentially giving a weight of zero for the rest of the factors to maximize the benefit of each country. It can be hypothesized and verified that "existing share (F5)" would be the dominant factor for Egypt and "water contribution(F2)" the dominant factor for Ethiopia and "geography (F1)" i.e., the percentage of basin in the country for Sudan. Population dependent on the basin is the dominant factor for most upper riparian countries except Rwanda.

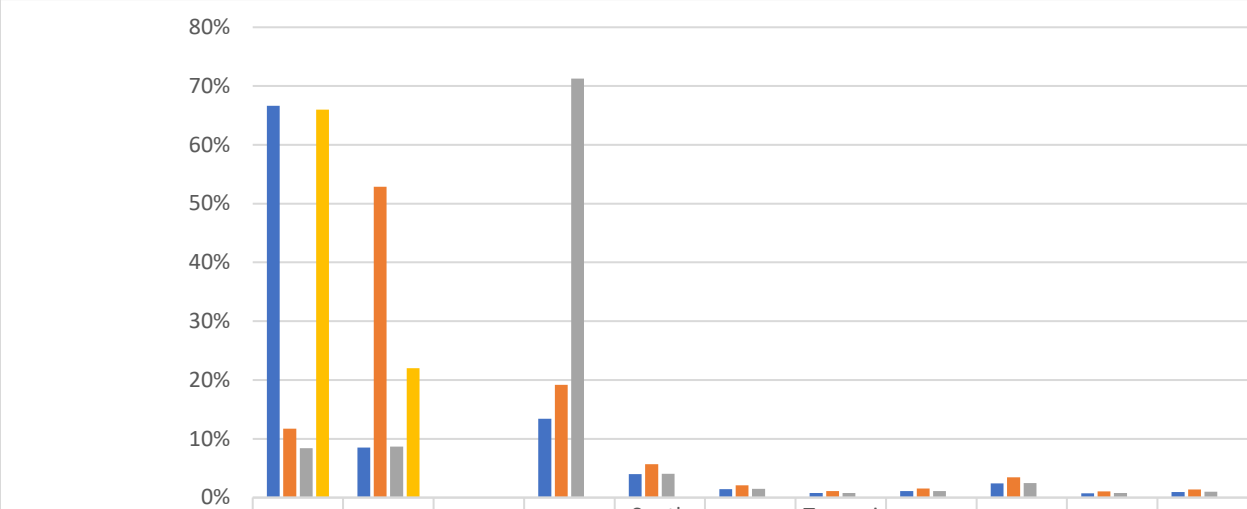
Table 13. Country water shares and corresponding dominant factors according to scenario 2

Country	Country Optimized	Dominant Factor
Burundi	8%	Hydrology
Congo	18%	Population
Egypt	67%	Existing use
Eritrea	2%	Population
Ethiopia	71%	Hydrology
Kenya	15%	Population
Rwanda	9%	Hydrology
South Sudan	30%	Geography
Sudan	53%	Geography
Tanzania	14%	Population
Uganda	17%	Population

Egypt, which is the current dominant users of the water, currently use more than 66% of the Nile water. The system, when it is optimized for Egypt, allocates 67% of the Nile water to Egypt, which is almost the same as it its current use. This means the current allocation scheme, which gave 66% to Egypt and 22% to Sudan is basically a system which is optimized for Egypt alone.

Obviously, such kind of allocation, while maximizing individual benefits, comes at the cost of the shares of other countries. This can be seen in Figure 12 below which shows the shares of other

basin States when the allocation is optimized for a certain country. The Figure shows the respective share of other countries when the share of water is maximized for Egypt, Sudan and Ethiopia as examples. It also compares the shares from these scenarios with the current allocation scheme in the basin.



	Egypt	Sudan	Eritrea	Ethiopia	South Sudan	kenya	Tanzania	Rwanda	Uganda	Congo	Burundi
Egypt Optimized	67%	9%	0%	13%	4%	1%	1%	1%	2%	1%	1%
Sudan Optimized	12%	53%	0%	19%	6%	2%	1%	2%	3%	1%	1%
Ethiopia Optimized	8%	9%	0%	71%	4%	1%	1%	1%	2%	1%	1%
Current allocation	66%	22%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 12. Comparison of country optimized shares with current allocation shares

It can be easily seen that optimizing the shares for one country clearly comes at the expense of the shares of other riparians. However, compared to the current existing allocation, which gives 66% to Egypt, 22% to Sudan and 0% to the rest of the countries, even the country optimized allocation scheme is favourable since it allocates at least some share to basin countries.

4.3 Scenario 3: Country Optimization Under Constraints

As can be seen in the previous scenario, maximizing allocation for countries results in a very skewed allocation arrangement. By default, the factors which favour the country are given a factor of 1 (100%) and the rest given a weight of 0, resulting in maximal benefits for countries. To ensure that all factors are considered in relative importance, certain "rules of the game" can be established. This will allow the allocation to be relatively more balanced while still maximizing the benefits of individual countries.

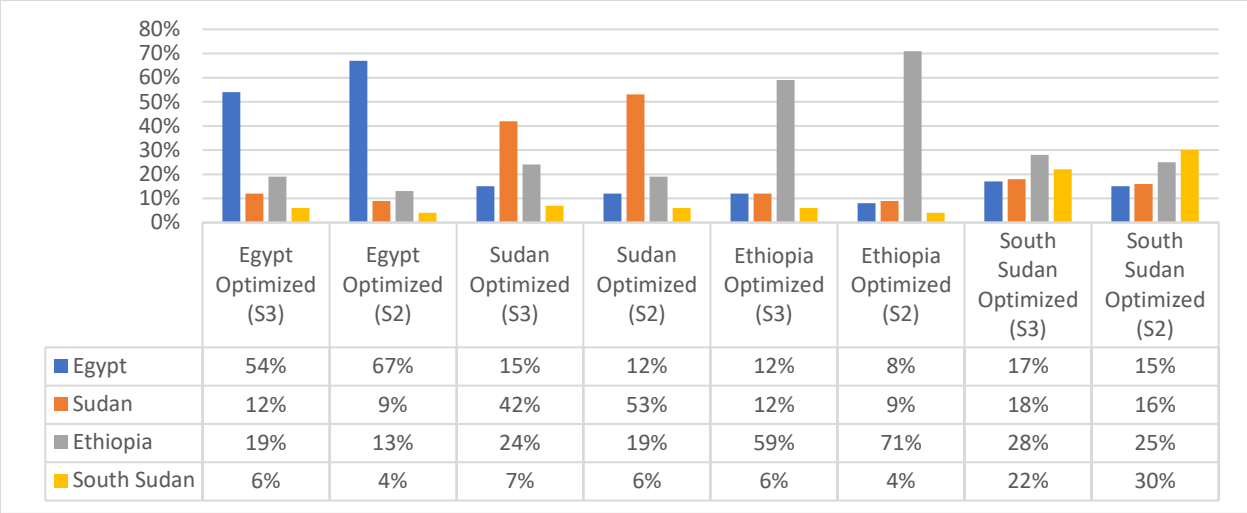
In this scenario, the allocation is optimized for countries under the restriction that no one factor can be given a weight of more than 50% or less than 5%. This way it is ensured that all factors at least get some minimal weight and no on factor dominates the allocation scheme. These numbers are not set-in stone and can be changed upon the agreement of relevant stakeholders. But for this study, no one factor can have a weight more than 50 % and less than 5%. The equation of optimization for this scenario is given in Equation 9.

The summary results of the optimization for all the basin countries is given in Table 14 while the optimization result for Ethiopia, Sudan and Egypt and their relative influence on the other countries are given in Figure 13.

Table 14. Country water shares according to scenario 3

Countries	Shares
Egypt	54%
Sudan	42%
Ethiopia	59%
South Sudan	22%
Kenya	10%
Tanzania	8%
Rwanda	6%
Uganda	12%
Burundi	5%
Congo	10%
Eritrea	0%

Although minimal, the reduced shares of the country optimums can be seen in increased shares of the other basin countries, when compared to the shares in Scenario 2. Figure 13 illustrates this trade-off for the top four shares in the basin. There is a slightly more balanced share between the countries even though the scheme is still maximizing shares for individual countries. The shares of the upper riparian countries, which are small to begin with, are not affected much by this constraint on the weight of the factors and hence are not shown in the figure below.



	Egypt Optimized (S3)	Egypt Optimized (S2)	Sudan Optimized (S3)	Sudan Optimized (S2)	Ethiopia Optimized (S3)	Ethiopia Optimized (S2)	South Sudan Optimized (S3)	South Sudan Optimized (S2)
Egypt	54%	67%	15%	12%	12%	8%	17%	15%
Sudan	12%	9%	42%	53%	12%	9%	18%	16%
Ethiopia	19%	13%	24%	19%	59%	71%	28%	25%
South Sudan	6%	4%	7%	6%	6%	4%	22%	30%

Figure 13. Comparison of shares in Scenario 2 and 3

4.4 Scenario 4: Basin Sum Maximization

This scenario maximizes the sum of shares of countries in the basin as a whole to reduce the trade-off among countries. Instead of maximizing for individual countries, at the cost of one another, the process in this scenario maximizes the sum of shares in the basin implicitly maximizing the shares of all countries without harsh trade-offs as seen in country optimizations in Scenario 2 and 3. The optimization equation for this scenario is found in Equation 10 and the summary of country shares according to this scenario is given in Figure 14 below.

A closer look at the weights given to the factors in scenario 4 shows that all negative factors were given a weight of 0 and all positive factors given a weight of 100 to maximize the sum of country shares in the basin, which was later proportioned to 100%. Essentially this means countries with multiple factors that put them at a disadvantage will benefit as the effect of these factors will be nullified to maximize the share in the basin.

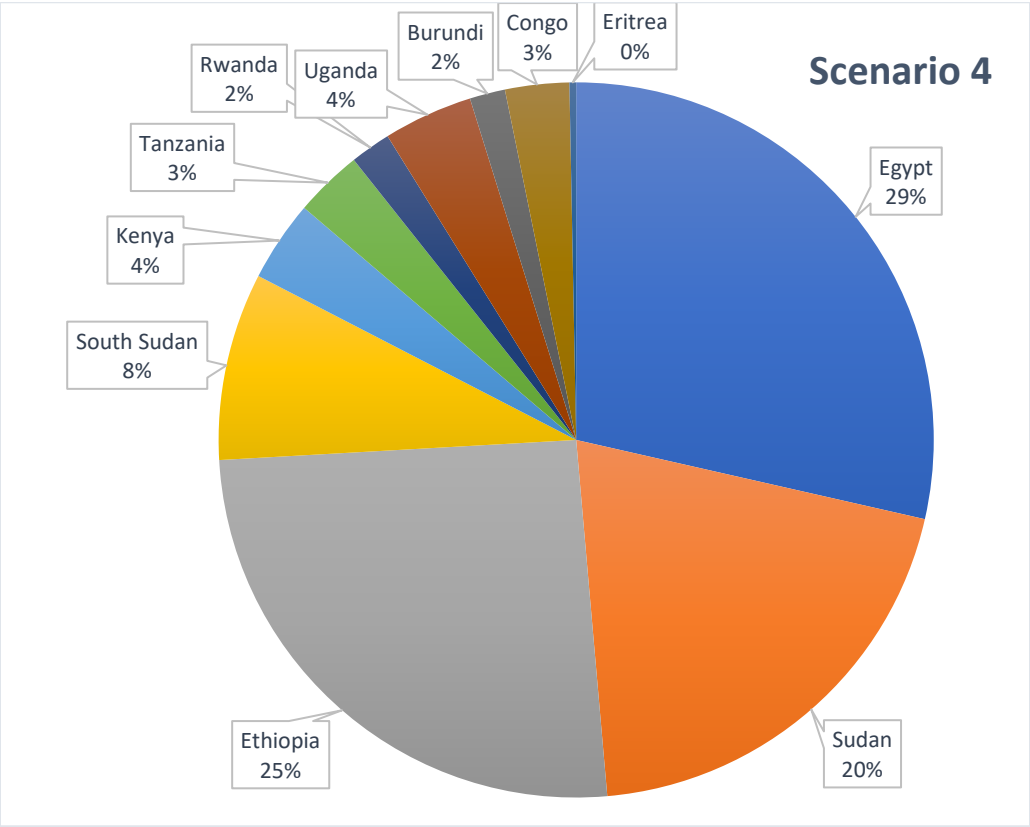


Figure 14. Country water shares according to scenario 4

In contrast to this approach of maximizing the positive values and minimizing the negative values, another scenario was evaluated by maximizing both the positive factors and negative factors, to balance out the effects of all factors. This scenario led to results like Scenario 1 (see Scenario Envelope in Figure 15). This is a natural outcome as what Scenario 1 does by allocating equal weights for all factors is balance out the influence of all factors. Therefore, the result validates its premise.

As an exercise, a modification of Scenario 4 was run by limiting the summation of the weights of the factors to 100% (1). The original scenario does not have this constraint as the aim was maximizing the sum of shares in the basin, by extension the shares of all countries, by allowing the positive factors to dominate without restricting the sum of the weights. The resulting shares of countries were identical in both exercises, however, the basin sum in the original run of the scenario was significantly higher than the basin sum in the re-run of the modified scenario. The re-run of the modified scenario essentially mimics the weight allocation in scenario 2, when the

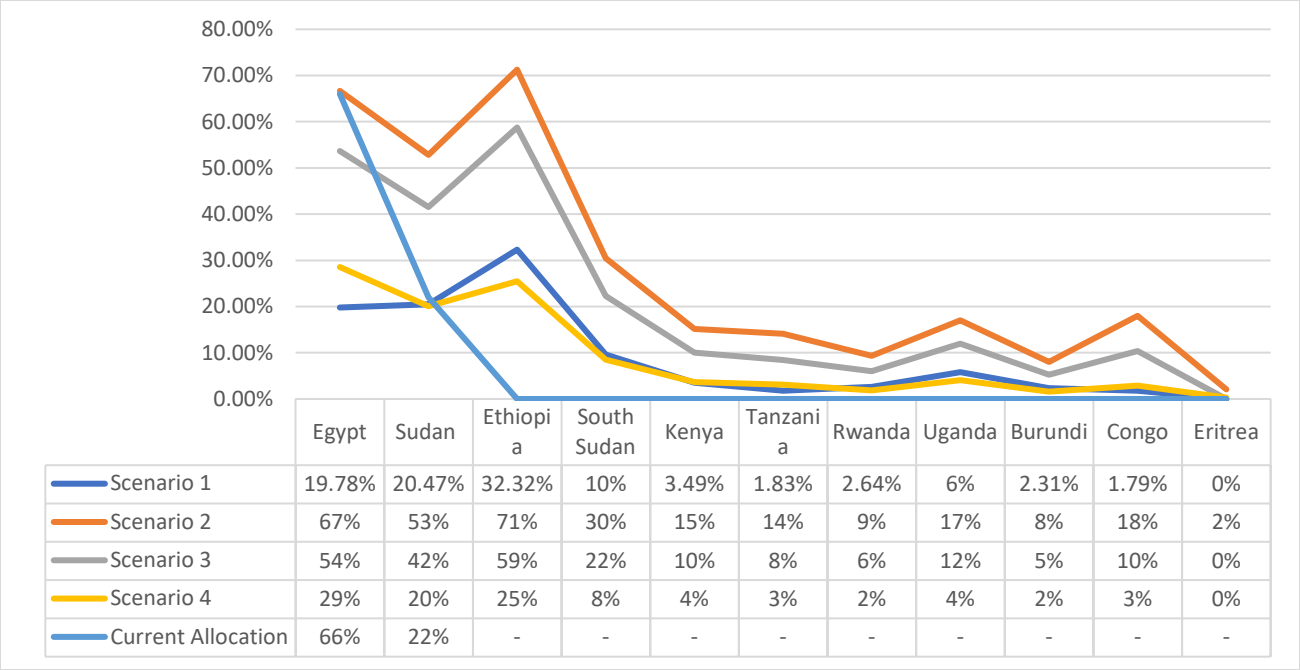
aim was just maximizing shares of one country. Since the sum of the weights was limited to 1, the system gave a weight of 1 to the most dominant factor and nullified all the other factors, while the original run of Scenario 4 gave a factor of 1 for all the positive values and nullifies the negative scenarios to result in maximum shares.

4.5 Comparison of the Different Scenarios with Existing Water Allocation

The existing water allocation framework in the basin, as described in detail in previous chapters, allocates 66% of the Nile waters to Egypt and 22% to Sudan while completely disregarding the shares of other countries. Comparing this allocation framework with the scenarios developed, one can see that all other scenarios give at least some share to all riparian countries, even though it might be minimal in some instances (see Figure 15). This fact alone puts the validity of the existing allocation scheme in the basin in question. The current allocation scheme also has no basis when evaluated against modern transboundary water sharing principles. While it disregards the equitable and reasonable use of all basin States, it in fact causes harm by precluding other basin States from using the water.

To see the collective implication of all these scenarios across the basin, a scenario envelope was developed, showing the water shares of all basin States under all the scenarios. The scenario envelope shows the pattern of allocation under different scenarios for the basin countries. The current allocation scheme forms the lower threshold for all countries except Egypt and Sudan, while Scenario 2 naturally is the universal upper threshold for all countries.

All riparian except Ethiopia, Egypt and Sudan countries have more or less have the same trend of change in all of the scenarios with Scenario1and 4 almost overlapping. While Sudan has relatively similar shares in Scenario 1, 4 and the current allocation, significant changes are observed in Ethiopia and Egypt. Scenario 1 distinctly forms the lower threshold for Egypt and Scenario 4 (disregarding the current allocation) for Ethiopia unlike the rest of the basin States where the difference between scenario 1 and 4 is minimal. Scenario 3 is the mid-way scenario for all basin States. From Figure 15 it can be easily seen that the current allocation is only favourable to Egypt. The detailed results of allocation shares and the corresponding factors for each country under each scenario can be found in the appendix.



	Egypt	Sudan	Ethiopia	South Sudan	Kenya	Tanzania	Rwanda	Uganda	Burundi	Congo	Eritrea
Scenario 1	19.78%	20.47%	32.32%	10%	3.49%	1.83%	2.64%	6%	2.31%	1.79%	0%
Scenario 2	67%	53%	71%	30%	15%	14%	9%	17%	8%	18%	2%
Scenario 3	54%	42%	59%	22%	10%	8%	6%	12%	5%	10%	0%
Scenario 4	29%	20%	25%	8%	4%	3%	2%	4%	2%	3%	0%
Current Allocation	66%	22%	-	-	-	-	-	-	-	-	-

Figure 15. Scenario Envelope

5. Conclusion and Recommendation

5.1 Conclusion

In this study, internationally accepted principles of transboundary water sharing principles were contextualized for the Nile basin, quantified, and used to develop a water allocation framework in the basin. Although the study has made numerous simplifications to quantify the factors to be used in equitable water sharing, the study results have clear trends that are of importance.

The study clearly showed that the existing water allocation framework in the basin can not stand in the face of equitable and reasonable water sharing rules. Secondly, the study showed water allocation scenarios, which gave broad thresholds for rough shares of countries to be expected under the framework of equitable and reasonable use. Thirdly, the study highlights the need to go beyond numerical water allocation and find innovative and sustainable ways of utilizing the water. To this end, eight mechanisms of sustainable water sharing and utilization for the basin, which had their basis in the equitable and reasonable allocation of water between countries.

Evaluation of multiple allocation scenarios showed a range of country shares. Giving equal weights to all factors considered in equitable share resulted in relatively balanced shares between the four country with the largest shares (Ethiopia, Egypt, Sudan, and South Sudan), with Ethiopia getting the maximum share of 32%, Sudan and Egypt 20% and South Sudan 10%. The upper riparian countries have relatively lower and similar shares between 2 and 6 %, with Uganda getting the largest share in the pool.

In scenario 2, it was seen that optimizing the allocation for individual countries comes at the cost of other country's shares. This scenario also showed that the current allocation scheme was, in essence, optimized for Egypt as its current share (66%) and its optimized shares (67%) were roughly similar. However, unlike the existing allocation scheme in the Nile basin where the other riparian countries except Sudan have zero shares, the optimization allocation still entitles all basin States to a certain proportion of water, regardless of how small it is. It was noticeable that Egypt's existing use and the geography of Sudan were dominant factors in the optimization analysis. Hydrology was the dominant factor for Ethiopia, while the population dependent on the basin was the dominant factor for most upstream countries. Scenario 3, where some constraints on the

weights capped the optimization exercise, the factors showed a similar pattern with scenario 2 with a slightly more balanced allocation.

Scenario 4 aimed to maximize the allocation for all countries without impacting serious trade-off between countries. In this scenario, upstream countries get roughly similar shares between 2 and 4%, while Ethiopia, Egypt, and Sudan get 25%, 29%, and 20%, respectively. While this scenario was roughly similar to Scenario 1 for most countries, it gave a heavy advantage for Egypt while putting Ethiopia at a disadvantage. This last scenario favors countries with larger negative factors as it only gives weight to the positive reinforcing factors of countries to maximize the shares in the basin.

What is very clear from this allocation exercise is that Egypt, the current dominant water user, would not get its claimed shares under any conceivable equitable water sharing principle framework. It was interesting to note that it was only when the allocation exercise was optimized for Egypt that Egypt remotely had a share that resembles its current use. This means that the current allocation scheme in the basin is optimized for Egypt, without the other countries' benefits.

According to the current allocation scheme in the basin Sudan, the next dominant water user is entitled to 22% of the total Nile water flow. Sudan's current share mimics what Sudan would be equitably entitled to under scenario one (20.5%). The same kind of analysis cannot be done for the other basin riparian countries as their current use of the Nile water is zero.

It is evident that if countries of the basin come together to renegotiate the redistribution of the Nile water, the allocation will resemble a pattern somewhere in between Scenario 1, 4, and Scenario 3. The shares would be nowhere close to the share Egypt currently enjoys, while the new allocation would apportion significantly more water to the other riparian countries. The countries' exact shares would be dependent on the weight countries would give to the factors and the "rules of the game", as shown in Scenario 3. Still, it can be safely deduced that the current allocation scheme would not stand in the face of equitable and reasonable reallocation of water in the Nile basin.

However, it should also be noted that regardless of the new shares that would be reallocated in the Nile basin, assuming that countries can agree on an equitable and reasonable water redistribution scheme, it will not mean that Egypt and Sudan will suddenly start using less water or cope with the new lesser allocation shares immediately. The Nile waters are already accounted for by

numerous uses in these two countries. Millions of people, homes, numerous sectors, cities, and industries depend on the water. A new allocation plan coming into force does not mean that the current use pattern in the existing users of the water will change immediately. Developing new and innovative ways to accommodate existing uses of these two countries without encroaching on the other riparian countries' rights and water shares is, therefore of the utmost importance.

This is where the practice of water allocation becomes indispensable. Knowing, at least on a foundational, epistemic level, how much water each riparian country is entitled to under international rules allows for further stretching of the imagination on how to use the basin water sustainability and economically. Measures such as benefit-sharing, co-owned infrastructures, and joint projects can only be done with the explicit knowledge of who contributes what in the first place. If there is a fair, equitable, and reasonable water allocation scheme in the basin, then there are numerous ways to satisfy all basin countries' water needs without jeopardizing the rights and benefits of other riparians. Outlined below are some of the measures proposed for the Nile basin to ensure the water security of all basin States.

5.2 Recommendation

1. Physical water trade

Assuming that all riparian countries' fair water shares are known, it is evident that not every country will utilize its allocated water share, at least not immediately. Some countries would need more than their share, while other countries would not use their share's totality. This can already be seen in Sudan and Egypt's current situation: while Egypt uses more than its "allocated share" of 55.5 BCM, Sudan does not use its complete "share" of 18.5 BCM, and the unused water goes to supplement Egypt's demand. Sudan claims that Egypt is using Sudan's quota while Egypt refutes this argument stating that Egypt is only "relieving" Sudan of the excess water above its absorptive capacity[20]. Here is where the concept of physical water trade comes in. By pricing water on a regional basis, countries with water surplus can sell their excess to countries in need, fostering economic integration.

[20] https://www.sudantribune.com/spip.php?article64078

This is especially doable in the short term with upper riparian countries possibly immediately exporting water to downstream riparian countries from their surplus share to supplement the deficits downstream countries are expected to incur. This is an expected scenario as upstream countries would require some time to develop the infrastructures necessary to utilize their fair share. In the meantime, instead of letting the water go to waste, they can benefit by exporting the physical water to countries with deficits, resulting in a win-win solution, at least in the short term. This will create regional economic ties and integration, which will be the foundation for the later recommendations outlined below.

In addition, physical water trade will stimulate basin-wide water-saving practices. Upstream countries would have the incentive to save more water to export more, while downstream countries would also want to keep their water import down and save on money by implementing water-saving infrastructures and practices. This is expected to result in a net reduction in water waste and use, especially from sectors which used to be water inefficient, freeing water to be used in other much needed sectors.

A good international experience that can be used as an example here is the European Emission Trading System (ETS), commonly called the EU carbon trading system[21]. Following the global goal of reducing emissions by 2030, the European Commission implemented a "cap and trade" carbon trading system. The European Commission has set a cap on the amount of greenhouse gases emitted by multiple sectors to reduce emissions. Under this system, the EU allows for trading of "carbon credits" where companies and sectors with lower carbon emissions can sell their saved carbon allowances/credits to companies above their emission limit. However, this trade is not unlimited as only a limited number of credits can be bought to ensure that the incentive to reduce emissions is not abused.

With this system in place, the EU aims to reduce European emissions by 21% from 2005 levels by 2020 and by 43% in 2030. This system has already allowed the EU to surpass its target for 2020, and the EU ETS is an integral part of the European policy to reach its emission target as per the Paris 2015 accord. The EU ETS has been successful enough to inspire other national and sub-

[21] https://ec.europa.eu/clima/policies/ets_en#:~:text=The%20aim%20of%20the%20EU,be%20achieved%20at%20least%20cost.

national trading systems in Canada, China, Japan, New Zealand, South Korea, Switzerland, and the United States[22].

Similar benefits in terms of reduced water use and increased efficiency as well as regional integration in the Nile basin can be expected from implementing a physical water trading system in the Nile basin as part of a sustainable water use practice in the basin.

2. Virtual Water Trade

The concept of virtual water trade—trading the water embedded in commodities—is one way of overcoming global water scarcity worldwide, and this applies to the Nile basin as well. The concept, developed by Tony Allan, argues that countries rich in water can export their water virtually to water-scarce areas by trading commodities and, by extension, the water embedded in these commodities (Alan, 2011). For example, instead of growing cotton, a water-intensive crop in a water-scarce area, the idea would be to grow the cotton in a water-rich and climatically favorable area and export the product to where it is needed. In this way, precious water can be saved and available for other uses by utilizing water judiciously, making water-smart decisions, and capitalizing on location efficiency i.e., exploiting favourable conditions for production and making the most of out of the opportunities of trade.

Virtual water trade already helps the world save a significant amount of water. A study by the German development institute cites that 8% less water was needed globally between 1997 and 2001 because of virtual water trading in agricultural products (Horlemann & Neubert, 2007). This concept is not only limited to food production but can also be extended to hydropower. Instead of building a hydropower dam in stifling lowlands where evaporation loss is high, hydropower would be produced in cooler areas, and the energy exported to where it is needed. Initiatives such as the Eastern Nile Power Export (between Ethiopia, Sudan, South Sudan, Kenya, and Djibouti) as well as the Nile equatorial lakes power export (between Kenya, Uganda, Rwanda, DRC, Burundi, Tanzania, and Zambia) are good examples (NBI, 2016). By trading commodities, primarily energy and food, water embedded in these products are essentially traded.

[22] https://ec.europa.eu/clima/policies/ets/markets_en

This proposal requires considering the whole Nile basin as an economic unit and capitalizing on its resources. It requires significant political will and regional integration on the part of the basin countries to benefit from the concept. This means countries should pursue their interests through more cooperation and less competition. The basin is endowed with significant hydropower, irrigation, fishing, and navigation potential. By investing in these resources at a basin-wide scale and virtually trading water through other resources, more water is freed for other non-tradable services, such as domestic use, in addition to saving water that would otherwise have been lost to inefficiencies.

This concept is not without its critics. The most relevant criticism in the context of this thesis against the concept of virtual water is that it neglects the dependence importing food and other basic commodities such as hydropower creates for a sovereign nation. This is especially relevant in the Nile basin, as many basin States are still not food, water, and energy secure. The development agenda is set on being fully independent and securing food, water, and energy availability to citizens. While this is a formidable political challenge against the concept of virtual water trading, two major arguments can be made against it.

The first line of argument is that since virtual water trade is already happening in the background, it might be used proactively to benefit the basin. The export of commodities, food, energy and industrial products is already happening among countries worldwide. Water is being virtually traded within but mostly outside the basin. Engaging proactively in virtual water trade within the basin guarantees that the basin States' needs are met, the water of the basin is kept in the basin, and whatever dependency that results from reliance on trade will be kept regional and minimal.

The second line of argument relates to the fact that the world is increasingly becoming more globalized, and hence interdependence of countries is inevitable. For most countries globally, it has become almost impossible to exist without having to depend on others for a country's basic needs. This is especially true for developing and water-scarce countries. This trend will only be strengthened as the world becomes more global and by extension, more local. The smart thing to do is proactively ride the wave of globalization and utilize the movement to benefit the basin instead of burying one's head in the sand and chasing narrow conceptions of ensuring self-interest alone.

3. Increased efficiency

Current water uses in the Nile basin, especially by the dominant water users Egypt and Sudan, is extremely inefficient. Overall, irrigation efficiency in Egypt stands at 40-60% (Mahmoud & El-Bably, 2017). Sudan is no better; a study by the International Water Management Institute (IWMI) and NBI puts the overall irrigation of the Gezira scheme, which accounts for 50% of the irrigation in Sudan, at 22% while overall irrigation efficiency is expected to be slightly higher (Mohamed et al, 2011). The seepage from watercourses and dams is significant, especially in Egypt and Sudan where open irrigation canals are common. Just the evaporation loss from the High Aswan dam is between 12 and 15 BCM per annum (Hamdan & Zaki, 2016). Seepage and evaporation from unlined open canals added to this loss results in a significant amount of the precious resource lost. This should raise the alarm to increase efficiency and conserve and judiciously use precious resources.

The focus on Egypt here is because Egypt is currently the major water user in the basin and possibly the place where the largest savings can be expected. In Egypt alone, there is a deficit of 13.5 BCM of water annually and this number is set to rise to 26 BCM if things continue business as usual (Din & Moussa, 2016). Increasing water use efficiency and reducing losses is integral to ensure sustainable water use in the basin.

A study done by NBI (2018), which was used as a source in this thesis, evaluated irrigation savings in all basin States by implementing four measures i.e., increasing rain-fed agriculture, increasing efficiency, implementing deficit irrigation, in-country, and regional cropping. According to this study, 137 BCM of water would be required for irrigation demand if all countries would develop their irrigation potentials to the fullest. A potential saving of 38.7 BCM can be attained from implementing these four measures. While increasing efficiency alone will not move the needle, in conjunction with other mechanisms, investing in increasing inefficiency and reducing waste can free water, which can be used for other purposes.

4. Water-smart investments

The judicious use of water resources is necessary if limited resources are expected to be used sustainably. This cannot happen unless water-smart investments increasingly replace wasteful ones. Because there is no basin-wide, integrated-use approach in the Nile basin, countries try and

maximize individual benefits, and hence many water-related investments in the Nile basin are not 'smart.' Owing to these myopic national investments, the basin loses a staggering amount of water. Growing water-intensive crops in arid areas, building large, open reservoirs in deserts come about because nations feel justified to ensure their national benefits at any cost.

However, integrated water-resource management, such as storing water in places of low evaporation, capitalizing on suitable irrigable land where appropriate, investments in conservation and water-storage enhancement practices upstream on the Nile's head waters are critical for ensuring the Nile is a sustainable resource. This requires looking at the basin as an economic unit and creating trust, alliance, strong economic ties, and political relationships among the basin States. Without the prerequisite of an alternative to ensure national demands without implementing narrow national agendas, countries cannot be expected to engage in water-smart basin-wide projects, but rather feel emboldened to pursue non-smart projects at all costs.

This recommendation relates to the virtual water trade concept and the recommendation to develop synchronized regional planning and operation. If there is a framework that ensures the demands of riparian states can be met through water-smart investments across the basin, then the stress on countries to pursue detrimentally short-sighted investments under the guise of ensuring national benefits can be firmly checked.

5. Regional integration for synchronized planning and operation

Unless integrated planning and use of the Nile water is in place, there is no way the Nile river's current water supply can sustain the existing demand and the demand that will substantially increase in the near future. A scenario study by the NBI found out that if countries were to fully utilize their irrigation potentials, the projected water demand would be around 137 BCM by 2050. This is not including other needs such as domestic, industrial, and municipal demands in the region. The fact of the matter is that the Nile cannot sustain the ever-increasing needs of the basin. Therefore, it becomes imperative to utilize the water most efficiently and supplement it with other water resources.

As part of this objective, the NBI and the Eastern Nile division (Eastern Nile Technical Regional Office, ENTRO) researched possible mechanisms for integrated planning and use in the Eastern Nile basin in a study it did in 2017. This study's findings stressed that against the backdrop of

climate change, increased population and demand, the Nile cannot sustain its population and stressed the need for integrated planning. As conclusions, this study recommends a regional, whole-basin perspective in investments in the basin, regional planning and operation of irrigation and hydropower plants in the basin, multi-sector coordination, and a regional approach to agriculture and food security in the basin (ENSAP, 2017). This study was a modest attempt at quantifying a future of "business as usual" vs. an integrated regional basin, and the results clearly support the regional approach for a sustainable future. The Nile basin should make the most out of such initiatives and develop a comprehensive regional development plan to utilize the basin sustainably, instead of unilateral endeavours.

6. Benefit-sharing and co-owned projects

Experiences from other international transboundary river basins such as the Senegal river basin in West Africa and the Parana river basin in South America are shining examples of how co-owned infrastructures and benefit-sharing schemes can be efficient ways of sharing a scarce resource and satisfying contested demands.

The Manantali dam, located in Mali but co-owned by three of the four riparians of the Senegal river basin, i.e., Senegal, Mali, and Mauritania, was able to satisfy the navigation demand of Mali as well as the power and irrigation demand of the other two countries (Tignino, 2016; WWAP, 2003). The same story goes for the Itaipu Dam, the second-largest operational energy-producing dam globally, located on Brazil and Paraguay's border[23]. This dam is co-owned and co-operated by these two countries since 1984, fostering cooperation and mutual benefit between these countries and others in the region, most notably Argentina. The GERD could have been one such co-owned project, had there been the political and economic readiness for a joint investment on the project.

One of the most critical arguments against benefit-sharing schemes is that one has to know how much one has and can contribute to start talking about benefits. This is where the foundation of water allocation comes in handy. If there is a framework of allocation outlining how much water each basin State is entitled to and, by extension, how much each basin State can legally contribute

[23] https://www.internationalwaterlaw.org/documents/regionaldocs/parana2.html

to a benefit-sharing scheme, it then becomes simpler to engage in a benefit-sharing scheme equivalent to the contributions of riparian states. This approach is again in line with all of the above recommendations, doubling down on capitalizing on location efficiency and favoring a regional approach rather than unilateral endeavors for sustainable use of the Nile.

7. Exploring alternative water resources

The Nile river has a limited amount of water. Even though water is a renewable resource, the rate at which the demand in the Nile basin is growing will outstrip the river's supply by 2040. With all the practices mentioned above Nile water use can be stretched and extended —but it can only be spread so far. It is important to explore other sources to supplement Nile water use.

Rainwater harvesting, groundwater recharge, wastewater reuse, and alternative sources such as desalination are worthy avenues to pursue. The database AQUASTAT by the United Nations Food and Agriculture Organization (FAO) shows that wastewater reuse in all Nile Basin riparians except Egypt is minimal to none, and this presents a big opportunity. In addition, six of the eleven Nile basin riparians have coastlines, which potentially enables them to embark in desalinating seawater as a supplement for basic water demands. With the increasingly lower price of desalination, this option will become a plausible option for many of the Nile basin countries in the future. Rainwater harvesting, especially in upstream riparian countries that are relatively more wet than the downstream countries, is another feasible supplementing Nile water use mechanism. Judiciously utilizing renewable and non-renewable groundwater reserves, as the significant basin reserves, should also be noted. Upstream riparians have renewable groundwater resources while downstream basin States Sudan and Egypt have considerable fossil groundwater reserves. The judicious use of these non-renewable resources, as well as working on the recharge and sustainable use of renewable groundwater resources, should be part of the recommendation of exploring alternative resources.

8. Environmental Conservation and creating improved water consciousness

Concerted environmental conservation endeavors by all riparian countries—to increase the water stored in the basin and reduce pollution and enhance the ecosystem—is necessary for sustainable use. Environmental conservation activities should be synchronized and implemented with the collaboration of all basin States. Environmental conservation and protection upstream in the basin

benefit the whole basin and should not be the responsibility of upstream states alone. Similarly, pollution of the river downstream will have an implication on the water quality and use upstream as well. Hence a coordinated environmental reclamation, conservation and protection mechanism needs to be in place by all basin States.

In conjunction with this, creating a water-conscious population, one that knows the value of water and uses it judiciously, by starting with children, enforcing water-conservation measures, and promoting water-saving practices is necessary in the basin. The sustainable use of the Nile water largely hinges on the population's awareness and consciousness that uses it.

It is also necessary to stress that all countries, but especially economically better-off countries such as Egypt in the basin should gradually move away from agriculture to a more industrial economy so as to reduce their dependency on the Nile. The Nile water cannot support an indefinite increase in demand so there needs to be a shift away from irrigation and agriculture intensive economy in the basin. ENSAP (2017) reinforces this suggestion as it states that the basin cannot support any more unilateral expansion in agriculture in the basin. These recommendations are not expected to be silver bullets to solve the Nile basin issues, rather starting points to flex the imagination and as starting points to develop further options for sustainable and equitable use of the basin.

This thesis was a first try and a modest attempt to quantify the legal principles of transboundary water sharing for the Nile basin. As such, it is only a starting point for further research on the topic. Future research can further develop the current allocation framework based on more nuanced quantification of factors used in determining equitable and reasonable use. In addition to this, granted there is time and resources available, the allocation framework can be co-developed with relevant stakeholders in the process. It is also a worthy avenue to see the physical implication and efficiencies of the recommendations given in this study in terms of stretching the Nile's use and ensuring sustainable use in the basin.

6. References

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Legal Agreements (Chronologically)

1. Protocols between Great Britain and Italy on the demarcation of their respective spheres of influence in East Africa: Rome. Italy. 15th April 1891.
2. Treaty between Ethiopia and the Great Britain on the Delineation of the Frontier between Ethiopia and Sudan: Addis Ababa. Ethiopia. 15th May 1902.
3. Agreement between Great Britain and the independent State of the Congo: London, UK, 9th May 1906.
4. Agreement between the Great Britain, France and Italy respecting Abyssinia/ Ethiopia: London, UK, 13th December 1906.

5. Exchange of Notes between Great Britain and Italy respecting concessions for a barrage at Lake Tsana and a railway across Abyssinia from Eritrea to Italian Somali land: Rome Italy. 20th December 1925.
6. Exchange of Notes between her Majesty's Government in the United Kingdom and the Egyptian Government on the use of the waters of the Nile for Irrigation: Cairo. Egypt. 7th May 1929.
7. Exchange of notes constituting an agreement between the government of the United Kingdom of Great Britain and Northern Ireland and the Government of Egypt regarding the construction of the Owen Falls Dam, Uganda: Cairo, Egypt, 30 & 31st 1949.
8. Agreement between the republic of Sudan and the United Arab republic on the full utilization of the waters of the Nile: Cairo. Egypt. 8th November 1959.
9. Framework for General Cooperation between Ethiopia and the Arab Republic of Egypt: Cairo 1st July 1993
10. Agreement on the Nile River basin cooperative Framework (CFA). Entebbe. Uganda. 14th May 2010.
11. The Declaration of Principles (DOP) between the Arab Republic of Egypt, the Federal Democratic Republic of Ethiopia and the Republic of Sudan on the Grand Ethiopian Renaissance Dam Project: Khartoum. Sudan. March 23rd, 2015.
12. Communique released by the Ministry of Foreign Affairs of Ethiopia. Addis Ababa. Ethiopia. 6th February 1956.
13. Aide-Memoire by the Imperial Ethiopian Government. Addis Ababa. Ethiopia. 23rd September 1957.
14. Memorandum released by the Ministry of Foreign Affairs of Socialist Ethiopia. Addis Ababa. Ethiopia. 7th May 1980.
15. Extract from the statement by Comrade Lt. Col. Addis Tedla, to the extraordinary session of the heads of state and government of OAU. Lagos. Nigeria. 29th April 1980.
16. The Nyerere doctrine. Notes sent on 4th of July to the governments of Britain, Egypt and Sudan outlining the policy of Tanganyika on the use of the waters of the Nile.

7. Appendices

7.1. Summary of Factors in the Helsinki rules, the UN 1997 convention, the CFA and this Study.

	Factors	Helsinki 1966 rules	UN Convention 1997	CFA (2010)	Used in this study
1	Geography	Yes	Yes	Yes	yes
			with more natural factors added (hydrography and ecology)	with more natural factors added (hydrography and ecology)	
2	Hydrology	Yes	Yes	Yes	yes
			with more natural factors (hydrography and ecology)	with more natural factors (hydrography and ecology)	
3	Climate affecting the basin	yes	Yes	Yes	Yes
			Under natural factors	Under natural factors	
4	Social and economic needs of basin States	yes	yes	yes	yes
5	Population dependent on the water resource	yes	yes	yes	yes
		No,	yes	yes	yes

6	Effect of use on other basin States	Phrased as the degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State.			
7	Existing and potential use	Yes Includes past utilization as well	yes	yes	Yes Past use not included
8	Availability of alternatives, of comparable value, to planned or existing use	No, But can be related to the comparative costs of alternative means of satisfying the economic and social needs of each basin State;	yes	yes	Yes Together with availability of other resources

9	Conservation, protection, development and economy of use of the water resources and the costs of measures taken to that effect;		yes	yes	yes
		No			
10	The availability of other resources	Yes	No	No	Yes Together with Availability of alternatives, of comparable value, to planned or existing use
11	the practicability of compensation to one or more of the co-basin States as a means of adjusting	Yes	No	No	No

	conflicts among uses;				
12	the avoidance of unnecessary waste in the utilization of waters of the basin;	Yes	No	No	Yes, related to conservation, protection, development and economy of water use and the cost of measures taken to that effect

7.2. Detailed Data of Current and Projected Water Use in the Basin by Sectors

Municipal Water Use (MCM/year)			
	Current	High Projection (2050)	Medium Projection (2050)
Burundi	11.47	42.23	38.98
DRC	7.19	27.18	25.00
Egypt	2261.00	5691.43	5118.91
Ethiopia	73.82	213.94	193.32
Kenya	910.71	2782.91	2515.63
Rwanda	147.05	419.04	379.62

S Sudan	74.32	236.26	215.70
Sudan	260.59	808.59	741.31
Tanzania	10.60	40.01	36.54
Uganda	167.26	645.61	590.50
Total	3924	10907.21	9855.50

Industrial Water Use (MCM/yr)			
	Current	High Projection (2050)	Medium Projection (2050)
Burundi	2.981	10.981	10.135
DRC	1.869	7.066	6.499
Egypt	587.859	1479.771	1330.917
Ethiopia	19.194	55.625	50.262
Kenya	236.785	723.557	654.064
Rwanda	38.232	108.952	98.701
S Sudan	19.324	61.427	56.081
Sudan	67.752	210.235	192.742
Tanzania	2.755	10.403	9.500
Uganda	43.487	167.859	153.530
Total	1020.24	2835.87	2562.43

Irrigation Water Use (MCM/yr.)			
	Irrigation water withdrawal requirement (MCM)	Actual Irrigation water withdrawal (MCM)	Future Planned Annual Withdrawal Requirement (MCM)
Burundi	28.9	28.7	28.9
DRC	0	0	0.000
Egypt	66,551.5	66054	80,861.7
Ethiopia	2,018.2	1500.9	23,407.8
Kenya	367.4	307.5	1,589.2
Rwanda	58.6	57.4	92.5
S Sudan	3.4	3.2	4,669.4
Sudan	13,959.8	13921.6	26,226.5
Tanzania	102.2	63.4	1,093.3
Uganda	260.4	260.3	329.0
Total	83350.4	82197	138298.2

7.3. Detailed Country Data of Factors Used in Equitable Water Allocation

		Egypt	**Sudan**	**Eritrea**	**Ethiopia**
F1	Geography				
	Area in the basin (km2)	302452	1396230	25697	365318
	% of basin in country	9.52%	43.95%	0.81%	11.50%
F2	Hydrology				
	Water contribution BCM	0	5.61	0.72	79.59
	%	0.00%	5.88%	0.75%	83.37%
F3	Climate				
	Rainfall mm/year	39.9	264.8	300.1	1011.9
F3.1	%	0.45%	3.01%	3.41%	11.49%
	Evapo-transpiration (mm/day)	5.60	5.70	5.00	3.90
F3.2	%	12.42%	12.64%	11.09%	8.65%
F4	Population				

	Directly dependent	85.8	31.4	2.2	37.6
F4.1	%	34.55%	12.65%	0.89%	15.14%
	Indirectly dependent	5.7	4.7	3	61.8
F4.2	%	2.69%	2.22%	1.42%	29.21%
F5	Existing use from the basin	68902.85648	14249.93726		1593.918629
	%	79.07%	16.35%	0.00%	1.83%
F6	Socio economic needs				
	projected water use 2050	88032.87	27245.37		23677.36
	%	57.90%	17.92%	0.00%	15.57%
F7	Available Alternatives				
	Renewable Groundwater	1.5	3	0.5	20
	%	0.28%	0.57%	0.09%	3.80%
	Total Groundwater	55,200.00	31,600.00	333.00	12,700.00
		29.96%	17.15%	0.18%	6.89%
	Coastline in KM	2450	853	2234	0
	%	32.52%	11.32%	29.65%	0.00%
F8	Effect of use on others				
	water requirement for planned irrigation use (BCM)	80,861.7	26,226.5	0	23,407.8
	%	58.47%	18.96%	0.00%	16.93%
F9	Conservation, protection, development and economy of use of the water resources and the costs of measures taken to that effect; (including the avoidance of unnecessary waste in the utilization of waters of the basin)				
	Irrigation savings (BCM)	4,625.89	13,650.58	-	12,128.06
	% saving	11.95%	35.25%	0.00%	31.32%
	Legend		Incomplete or no data		

		South Sudan	Kenya	Tanzania	Rwanda
F1	Geography				
	Area in the basin (km2)	620626	51363	118507	20625
	% of basin in country	19.54%	1.62%	3.73%	0.65%
F2	Hydrology				
	Water contribution BCM	8.29	6.74	4.49	4.75
	%	8.68%	7.06%	4.70%	4.98%
F3	Climate				
	Rainfall mm/year	987.5	713.3	953	997.3
F3.1	%	11.21%	8.10%	10.82%	11.32%
	Evapo transpiration (mm/day)	4.10	4.50	3.50	2.70
F3.2	%	9.09%	9.98%	7.76%	5.99%
F4	Population				
	Directly dependent	11.9	17.2	11.3	8.7
F4.1	%	4.79%	6.93%	4.55%	3.50%
	Indirectly dependent	0.1	25.8	33.6	1.8
F4.2	%	0.05%	12.19%	15.88%	0.85%
F5	Existing use from the basin	96.846099	1454.99735	76.7516398	242.679147
	%	0.11%	1.67%	0.09%	0.28%
F6	Socio economic needs				
	projected water uses 2050	4967.04	5095.68	1143.7	620.45
	%	3.27%	3.35%	0.75%	0.41%
F7	Available Alternatives				
	Renewable Groundwater	4	3.5	30	7
	%	0.76%	0.66%	5.69%	1.33%
	Total Groundwater	31,600.00	8,840.00	5,250.00	49.00
		17.15%	4.80%	2.85%	0.03%
	Coastline in KM	0	536	1424	0
	%	0.00%	7.11%	18.90%	0.00%
F8	Effect of use on others				
	water requirement for planned irrigation use (BCM)	4,669.4	1,589.2	1,093.3	92.5
	%	3.38%	1.15%	0.79%	0.07%

F9	Conservation, protection, development and economy of use of the water resources and the costs of measures taken to that effect; (including the avoidance of unnecessary waste in the utilization of waters of the basin)				
	Irrigation savings (BCM)	7,163.04	529.20	404.99	55.71
	% saving	18.50%	1.37%	1.05%	0.14%

		Uganda	**Congo**	**Burundi**	**Total**
F1	Geography				
	Area in the basin (km2)	240067	21796	13869	3176550
	% of basin in country	7.56%	0.69%	0.44%	100.00%
F2	Hydrology				
	Water contribution BCM	4.39	4.13	3.88	95.47
	%	4.60%	4.33%	4.06%	127.65%
F3	Climate				
	Rainfall mm/year	1219.2	1146	1177	8810
F3.1	%	13.84%	13.01%	13.36%	100.00%
	Evapo transpiration (mm/day)	3.80	3.20	3.10	45.10
F3.2	%	8.43%	7.10%	6.87%	100.00%
F4	Population				
	Directly dependent	33.6	2.9	5.7	248.30
F4.1	%	13.53%	1.17%	2.30%	100.00%
	Indirectly dependent	0.4	69.2	5.5	211.6
F4.2	%	0.19%	32.70%	2.60%	100.00%
F5	Existing use from the basin	471.045459	9.05812232	43.14733011	87,141.2
	%	0.54%	0.01%	0.05%	100.00%
F6	Socio economic needs				
	projected water uses 2050	1142.46	34.24	82.1	152041.27
	%	0.75%	0.02%	0.05%	100.00%
F7	Available Alternatives				
	Renewable Groundwater	29	421	7.5	527

	%	5.50%	79.89%	1.42%	100.00%
	Total Groundwater	339.00	38,300.00	47.00	184,258.00
		0.18%	20.79%	0.03%	100.00%
	Coastline in KM	0	37	0	7534
	%	0.00%	0.49%	0.00%	100.00%
F8	Effect of use on others				
	water requirement for planned irrigation use (BCM)	329.0	0	28.9	138,298.2
	%	0.24%	0.00%	0.02%	100.00%
F9	Conservation, protection, development and economy of use of the water resources and the costs of measures taken to that effect; (including the avoidance of unnecessary waste in the utilization of waters of the basin)				
	Irrigation savings (BCM)	127.74	-	37.76	38,722.97
	% saving	0.33%	0.00%	0.10%	100.00%

7.4. Detailed Results For Scenario 1

Factors	Indicators		Egypt		Sudan		Eritrea	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	9.52%	0.1111111	43.95%	0.111111	0.81%	0.111111
Hydrology	% of water contribution to the basin	F2	0.00%	0.1111111	5.83%	0.111111	0.75%	0.111111
Climate				0.1111111		0.111111		0.111111
	Rainfall	F3.1	0.45%		3.01%		3.41%	

	Evapotranspiration	F3.2	12.4%		12.6%		11.1%	
Population				0.1111111		0.111111		0.111111
	Directly dependent	F4.1	34.55%		12.65%		0.89%	
	Indirectly dependent	F4.2	2.69%		2.22%		1.42%	
Utilization	Existing use	F5	79.07%	0.1111111	16.35%	0.111111	0.00%	0.111111
Socio economic needs	Water demand for 2050		57.90%	0.1111111	17.92%	0.111111	0.00%	0.111111
Alternative resources				0.1111111		0.111111		0.111111
	Groundwater	F7.1	29.96%		17.15%		0.18%	
	Shore line	F7.2	32.52%		11.32%		29.65%	
Effect on others	potential Irrigation water demand	F8	58.47%	0.1111111	18.96%	0.111111	0.00%	0.111111
Avoidance of unnecessary waste	Irrigation savings	F9	11.95%	0.1111111	35.25%	0.111111	0.00%	0.111111
				1		1		1
	Allocation based on +ve factors		20.41%		14.48%		0.48%	
	Allocation based on negative factors		10.66%		4.39%		2.27%	
	Allocation		20.53%		21.25%		-3.78%	

	Allocation corrected for -ve shares		19.78%		20.47%		0.00%	
	Legend		Negative Factors					

Factors	Indicators			Ethiopia		South Sudan	
			Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	0.111111	11.50%	0.111111	19.54%	0.111111
Hydrology	% of water contribution to the basin	F2	0.111111	82.74%	0.111111	8.62%	0.111111
Climate			0.111111		0.111111		0.111111
	Rainfall	F3.1		11.49%		11.21%	
	Evapotranspiration	F3.2		8.6%		9.1%	
Population			0.111111		0.111111		0.111111
	Directly dependent	F4.1		15.14%		4.79%	
	Indirectly dependent	F4.2		29.21%		0.05%	
Utilization	Existing use	F5	0.111111	1.83%	0.111111	0.11%	0.111111
Socio economic needs	Water demand for 2050		0.111111	15.57%	0.111111	3.27%	0.111111
Alternative resources			0.111111		0.111111		0.111111

	Groundwater	F7.1		6.89%		17.15%	
	Shore line	F7.2		0.00%		0.00%	
Effect on others	potential Irrigation water demand	F8	0.111111	16.93%	0.111111	3.38%	0.111111
Avoidance of unnecessary waste	Irrigation savings	F9	0.111111	31.32%	0.111111	18.50%	0.111111
			1		1		1
	Allocation based on +ve factors			18.67%		6.56%	
	Allocation based on negative factors			2.74%		1.83%	
	Allocation			33.54%		9.94%	
	Allocation corrected for -ve shares			32.32%		9.58%	

Factors	Indicators		Kenya		Tanzania		Rwanda	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	1.62%	0.111111	3.73%	0.111111	0.65%	0.111111
Hydrology	% of water contribution to the basin	F2	7.01%	0.111111	4.67%	0.111111	4.94%	0.111111
Climate				0.111111		0.111111		0.111111

	Rainfall	F3.1	8.10%		10.82%		11.32%	
	Evapotranspiration	F3.2	10.0%		7.8%		6.0%	
Population				0.111111		0.111111		0.111111
	Directly dependent	F4.1	6.93%		4.55%		3.50%	
	Indirectly dependent	F4.2	12.19%		15.88%		0.85%	
Utilization	Existing use	F5	1.67%	0.111111	0.09%	0.111111	0.28%	0.111111
Socio economic needs	Water demand for 2050		3.35%	0.111111	0.75%	0.111111	0.41%	0.111111
Alternative resources				0.111111		0.111111		0.111111
	Groundwater	F7.1	4.80%		2.85%		0.03%	
	Shore line	F7.2	7.11%		18.90%		0.00%	
Effect on others	potential Irrigation water demand	F8	1.15%	0.111111	0.79%	0.111111	0.07%	0.111111
Avoidance of unnecessary waste	Irrigation savings	F9	1.37%	0.111111	1.05%	0.111111	0.14%	0.111111
				1		1		1
	Allocation based on +ve factors		3.06%		2.63%		1.64%	
	Allocation based on negative factors		1.34%		1.73%		0.34%	
	Allocation		3.62%		1.89%		2.74%	

	Allocation corrected for -ve shares		3.49%		1.83%		2.64%	

Factors	Indicators		Uganda		Congo		Burundi	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	7.56%	0.111111	0.69%	0.111111	0.44%	0.111111
Hydrology	% of water contribution to the basin	F2	4.56%	0.111111	4.29%	0.111111	4.03%	0.111111
Climate				0.111111		0.111111		0.111111
	Rainfall	F3.1	13.84%		13.01%		13.36%	
	Evapotranspiration	F3.2	8.4%		7.1%		6.9%	
Population				0.111111		0.111111		0.111111
	Directly dependent	F4.1	13.53%		1.17%		2.30%	
	Indirectly dependent	F4.2	0.19%		32.70%		2.60%	
Utilization	Existing use	F5	0.54%	0.111111	0.01%	0.111111	0.05%	0.111111
Socio economic needs	Water demand for 2050		0.75%	0.111111	0.02%	0.111111	0.05%	0.111111
Alternative resources				0.111111		0.111111		0.111111
	Groundwater	F7.1	0.18%		20.79%		0.03%	
	Shore line	F7.2	0.00%		0.49%		0.00%	

Effect on others	potential Irrigation water demand	F8	0.24%	0.111111	0.00%	0.111111	0.02%	0.111111
Avoidance of unnecessary waste	Irrigation savings	F9	0.33%	0.111111	0.00%	0.111111	0.10%	0.111111
				1		1		1
	Allocation based on +ve factors		3.35%		2.46%		1.53%	
	Allocation based on negative factors		0.50%		1.58%		0.39%	
	Allocation		6.00%		1.86%		2.40%	
	Allocation corrected for -ve shares		5.78%		1.79%		2.31%	

7.5. Detailed Results for Scenario 2

Factors	Indicators		Egypt		Sudan		Eritrea	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	9.52%	0	43.95%	1	0.81%	0
Hydrology	% of water contribution to the basin	F2	0.00%	0	5.83%	1.56363E-08	0.75%	0
Climate				0		0		0

	Rainfall	F3.1	0.45%	0	3.01%	0	3.41%	0
	Evapotranspiration	F3.2	12.4%	0	12.6%	0	11.1%	0
Population				0		2.53285E-08		1
	Directly dependent	F4.1	34.55%	0	12.65%	0	0.89%	0
	Indirectly dependent	F4.2	2.69%	0	2.22%	0	1.42%	0
Utilization	Existing use	F5	79.07%	1	16.35%	1.36999E-08	0.00%	0
Socio economic needs	Water demand for 2050		57.90%	0	17.92%	7.15256E-08	0.00%	0
Alternative resources				0		3.75417E-08		0
	Groundwater	F7.1	29.96%	0	17.15%	0	0.18%	0
	Shore line	F7.2	32.52%	0	11.32%	0	29.65%	0
Effect on others	potential Irrigation water demand	F8	58.47%	0	18.96%	0	0.00%	0
Avoidance of unnecessary waste	Irrigation savings	F9	11.95%	0	35.25%	0	0.00%	0

	Allocation based on +ve factors		79.07%		43.95%	100.00%	1%	100%
	Allocation based on negative factors		0.00%		0.00%		0%	
	Allocation		67.69%		54.03%		2%	
	Corrected for -ve shares		66.66%		52.86%		2%	

Factors	Indicators		Ethiopia		South Sudan		Kenya	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	11.50%	9.93148E-08	19.54%	1	1.62%	0
Hydrology	% of water contribution to the basin	F2	82.74%	1	8.62%	-8.65047E-07	7.01%	0
Climate				0		0		0
	Rainfall	F3.1	11.49%	0	11.21%	0	8.10%	0
	Evapotranspiration	F3.2	8.6%	0	9.1%	0	10.0%	0
Population				1.69542E-07		0		1

	Directly dependent	F4.1	15.14%	0	4.79%	0	6.93%	0
	Indirectly dependent	F4.2	29.21%	0	0.05%	0	12.19%	0
Utilization	Existing use	F5	1.83%	0	0.11%	0	1.67%	0
Socio economic needs	Water demand for 2050		15.57%	0	3.27%	0	3.35%	0
Alternative resources				2.9873E-08		4.62166E-08		0
	Groundwater	F7.1	6.89%	0	17.15%	0	4.80%	0
	Shore line	F7.2	0.00%	0	0.00%	0	7.11%	0
Effect on others	potential Irrigation water demand	F8	16.93%	0	3.38%	0	1.15%	0
Avoidance of unnecessary waste	Irrigation savings	F9	31.32%	0	18.50%	8.88889E-07	1.37%	0
	Allocation based on +ve factors		82.74%	100.00%	20%	100%	8.51%	100.00%
	Allocation based on negative factors		0.00%		0%		0.00%	
	Allocation		72.39%		31%		15.67%	
	Corrected for -ve shares		71.27%		30.48%		15.17%	

Factors	Indicators		Tanzania		Rwanda		Uganda	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	3.73%	0	0.65%	0	7.56%	0
Hydrology	% of water contribution to the basin	F2	4.67%	4.06393E-08	4.94%	1.000000087	4.56%	0
Climate				0		0		0
	Rainfall	F3.1	10.82%	0	11.32%	0	13.84%	0
	Evapotranspiration	F3.2	7.8%	0	6.0%	0	8.4%	0
Population				1		0		1.000000481
	Directly dependent	F4.1	4.55%	0	3.50%	0	13.53%	0
	Indirectly dependent	F4.2	15.88%	0	0.85%	0	0.19%	0
Utilization	Existing use	F5	0.09%	0	0.28%	0	0.54%	0
Socio economic needs	Water demand for 2050		0.75%	0	0.41%	0	0.75%	0
Alternative resources				0		0		1.8838E-08
	Groundwater	F7.1	2.85%	0	0.03%	0	0.18%	0
	Shore line	F7.2	18.90%	0	0.00%	0	0.00%	0
Effect on others	potential Irrigation water demand	F8	0.79%	0	0.07%	0	0.24%	0
Avoidance of unnecessary waste	Irrigation savings	F9	1.05%	0	0.14%	0	0.33%	0
	Allocation based on +ve factors		7.95%	100.00%	4.94%	100.00%	9.53%	100.00%
	Allocation based on negative factors		0.00%		0.00%		0.00%	
	Allocation		4.57%		9.66%		17.59%	
	Corrected for -ve shares		14.11%		9.33%		17.03%	

Factors	Indicators		Burundi		Congo	
			Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	0.44%	0	0.69%	5.53366E-09
Hydrology	% of water contribution to the basin	F2	4.03%	1.000000105	4.29%	0
Climate				2.38419E-08		2.38419E-08
	Rainfall	F3.1	13.36%	0	13.01%	0
	Evapotranspiration	F3.2	6.9%	0	7.1%	0
Population				0		1
	Directly dependent	F4.1	2.30%	0	1.17%	0
	Indirectly dependent	F4.2	2.60%	0	32.70%	0
Utilization	Existing use	F5	0.05%	0	0.01%	0
Socio economic needs	Water demand for 2050		0.05%	0	0.02%	0
Alternative resources				0		0
	Groundwater	F7.1	0.03%	0	20.79%	0
	Shore line	F7.2	0.00%	0	0.49%	0
Effect on others	potential Irrigation water demand	F8	0.02%	0	0.00%	0
Avoidance of unnecessary waste	Irrigation savings	F9	0.10%	0	0.00%	0
	Allocation based on +ve factors		4.03%	100.00%	11%	100%
	Allocation based on negative factors		0.00%		0%	
	Allocation		8.01%		19%	
	Corrected for -ve shares		7.73%		18.00%	

7.6. Comparison Between Country Shares Under Scenario 2

Egypt	Sudan	Eritrea	Ethiopia	South Sudan	Kenya	Tanzania	Rwanda	Uganda	Congo	Burundi
67%	9%	0%	13%	4%	1%	1%	1%	2%	1%	1%
12%	53%	0%	19%	6%	2%	1%	2%	3%	1%	1%
19%	20%	2%	32%	9%	3%	2%	3%	6%	2%	2%
8%	9%	0%	71%	4%	1%	1%	1%	2%	1%	1%
15%	16%	0%	25%	30%	3%	1%	2%	4%	1%	2%
17%	18%	0%	28%	8%	15%	2%	2%	5%	2%	2%
17%	18%	0%	28%	8%	3%	14%	2%	5%	2%	2%
18%	19%	0%	30%	9%	3%	2%	9%	5%	2%	2%
17%	18%	0%	28%	8%	3%	2%	2%	17%	2%	2%
17%	17%	0%	27%	8%	3%	2%	2%	5%	18%	2%
19%	19%	0%	31%	9%	3%	2%	2%	5%	2%	8%

7.7. Detailed Results for Scenario 3

Factors	Indicators		Egypt		Sudan		Eritrea	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	9.52%	0.05	43.95%	0.5	0.81%	0.15
Hydrology	% of water contribution to the basin	F2	0.00%	0.05	5.83%	0.05	0.75%	0.05
Climate		F3		0.05		0.05		0.05
	Rainfall	F3.1	0.45%		3.01%		3.41%	
	Evapotranspiration	F3.2	12.4%		12.6%		11.1%	
Population		F4		0.05		0.05		0.5

	Directly dependent	F4.1	34.55%		12.65%		0.89%	
	Indirectly dependent	F4.2	2.69%		2.22%		1.42%	
Utilization	Existing use	F5	79.07%	0.5	16.35%	0.05	0.00%	0.05
Socio economic needs	Water demand for 2050	F6	57.90%	0.15	17.92%	0.05	0.00%	0.05
Alternative resources		F7		0.05		0.05		0.05
	Groundwater	F7.1	29.96%		17.15%		0.18%	
	Shore line	F7.2	32.52%		11.32%		29.65%	
Effect on others	potential Irrigation water demand	F8	58.47%	0.05	18.96%	0.05	0.00%	0.05
Avoidance of unnecessary waste	Irrigation savings	F9	11.95%	0.05	35.25%	0.15	0.00%	0.05
	Allocation based on +ve factors		50.55%		29.82%		0.77%	
	Allocation based on negative factors		4.80%		1.98%		1.02%	
	Allocation		54.80%		42.68%		-0.52%	
	Corrected for -ve shares		53.65%		41.53%		0.00%	

Factors	Indicators		Ethiopia		South Sudan		Kenya	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	11.50%	0.05	19.54%	0.5	1.62%	0.05
Hydrology	% of water contribution to the basin	F2	82.74%	0.5	8.62%	0.05	7.01%	0.15
Climate		F3		0.05		0.05		0.05
	Rainfall	F3.1	11.49%		11.21%		8.10%	
	Evapotranspiration	F3.2	8.6%		9.1%		10.0%	
Population		F4		0.05		0.05		0.5
	Directly dependent	F4.1	15.14%		4.79%		6.93%	
	Indirectly dependent	F4.2	29.21%		0.05%		12.19%	
Utilization	Existing use	F5	1.83%	0.05	0.11%	0.05	1.67%	0.05
Socio economic needs	Water demand for 2050	F6	15.57%	0.05	3.27%	0.05	3.35%	0.05
Alternative resources		F7		0.05		0.05		0.05
	Groundwater	F7.1	6.89%		17.15%		4.80%	
	Shore line	F7.2	0.00%		0.00%		7.11%	
Effect on others	potential Irrigation water demand	F8	16.93%	0.05	3.38%	0.05	1.15%	0.05
Avoidance of unnecessary waste	Irrigation savings	F9	31.32%	0.15	18.50%	0.15	1.37%	0.05
	Allocation based on +ve factors		48.77%		14%		5.91%	
	Allocation based on negative factors		1.23%		1%		0.60%	
	Allocation		60.10%		23%		10.38%	
	corrected for -ve shares		58.76%		22.27%		10.03%	

Factors	Indicators		Tanzania		Rwanda		Uganda	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	3.73%	0.05	0.65%	0.05	7.56%	0.15
Hydrology	% of water contribution to the basin	F2	4.67%	0.15	4.94%	0.5	4.56%	0.05
Climate		F3		0.05		0.05		0.05
	Rainfall	F3.1	10.82%		11.32%		13.84%	
	Evapotranspiration	F3.2	7.8%		6.0%		8.4%	
Population		F4		0.5		0.15		0.5
	Directly dependent	F4.1	4.55%		3.50%		13.53%	
	Indirectly dependent	F4.2	15.88%		0.85%		0.19%	
Utilization	Existing use	F5	0.09%	0.05	0.28%	0.05	0.54%	0.05
Socio economic needs	Water demand for 2050	F6	0.75%	0.05	0.41%	0.05	0.75%	0.05
Alternative resources		F7		0.05		0.05		0.05
	Groundwater	F7.1	2.85%		0.03%		0.18%	
	Shore line	F7.2	18.90%		0.00%		0.00%	
Effect on others	potential Irrigation water demand	F8	0.79%	0.05	0.07%	0.05	0.24%	0.05
Avoidance of unnecessary waste	Irrigation savings	F9	1.05%	0.05	0.14%	0.05	0.33%	0.05
	Allocation based on +ve factors		5.23%		3.23%		6.55%	
	Allocation based on negative factors		0.78%		0.15%		0.23%	
	Allocation		8.72%		6.25%		12.41%	
	Corrected for -ve shares		8.42%		6.03%		11.99%	

Factors	Indicators		Burundi		Congo	
			Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	0.44%	0.05	0.69%	0.05
Hydrology	% of water contribution to the basin	F2	4.03%	0.5	4.29%	0.15
Climate		F3		0.15		0.05
	Rainfall	F3.1	13.36%		13.01%	
	Evapotranspiration	F3.2	6.9%		7.1%	
Population		F4		0.05		0.5
	Directly dependent	F4.1	2.30%		1.17%	
	Indirectly dependent	F4.2	2.60%		32.70%	
Utilization	Existing use	F5	0.05%	0.05	0.01%	0.05
Socio economic needs	Water demand for 2050	F6	0.05%	0.05	0.02%	0.05
Alternative resources		F7		0.05		0.05
	Groundwater	F7.1	0.03%		20.79%	
	Shore line	F7.2	0.00%		0.49%	
Effect on others	potential Irrigation water demand	F8	0.02%	0.05	0.00%	0.05
Avoidance of unnecessary waste	Irrigation savings	F9	0.10%	0.05	0.00%	0.05
	Allocation based on +ve factors		3.17%		6.32%	
	Allocation based on negative factors		0.52%		0.71%	
	Allocation		5.41%		10.74%	
	Corrected for -ve shares		5.22%		10.39%	

7.8. Comparison Between Country Shares Under Scenario 3

Egypt	Sudan	Eritrea	Ethiopia	South Sudan	Kenya	Tanzania	Rwanda	Uganda	Congo	Burundi
54%	12%	0%	19%	6%	2%	1%	2%	3%	1%	1%
15%	42%	0%	24%	7%	3%	1%	2%	4%	1%	2%
20%	20%	0%	32%	10%	3%	2%	3%	6%	2%	2%
12%	12%	0%	59%	6%	2%	1%	2%	4%	1%	1%
17%	18%	0%	28%	22%	3%	2%	2%	5%	2%	2%
18%	19%	0%	30%	9%	10%	2%	2%	5%	2%	2%
18%	19%	0%	30%	9%	3%	8%	2%	5%	2%	2%
19%	20%	0%	31%	9%	3%	2%	6%	6%	2%	2%
18%	19%	0%	30%	9%	3%	2%	2%	12%	2%	2%
18%	19%	0%	29%	9%	3%	2%	2%	5%	10%	2%
19%	20%	0%	31%	9%	3%	2%	3%	6%	2%	5%

7.9. Detailed Results for Scenario 4

Factors	Indicators		Egypt		Sudan		Eritrea	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	9.52%	1	43.95%	1	0.81%	1
Hydrology	% of water contribution to the basin	F2	0.00%	0.111111111	5.83%	1	0.75%	0.111111111
Climate				0		0		0
	Rainfall	F3.1	0.45%	0	3.01%	0	3.41%	0
	Evapotranspiration	F3.2	12.4%	0	12.6%	0	11.1%	0
Population				1		1		1
	Directly dependent	F4.1	34.55%	0	12.65%	0	0.89%	0
	Indirectly dependent	F4.2	2.69%	0	2.22%	0	1.42%	0
Utilization	Existing use	F5	79.07%	1	16.35%	1	0.00%	0.111111111

Socio economic needs	Water demand for 2050		57.90%	1	17.92%	1	0.00%	0.111111111
Alternative resources				0		0		0
	Groundwater	F7.1	29.96%	0	17.15%	0	0.18%	0
	Shore line	F7.2	32.52%	0	11.32%	0	29.65%	0
Effect on others	potential Irrigation water demand	F8	58.47%	0	18.96%	0	0.00%	0.111111111
Avoidance of unnecessary waste	Irrigation savings	F9	11.95%	1	35.25%	1	0.00%	0.111111111
				511%		600%		256%
	Allocation based on +ve factors		183.44%		128.83%		1.94%	
	Allocation based on negative factors		0.00%		0.00%		0.00%	
	Allocation		183.44%		128.83%		1.94%	
			29%		20%		0%	

Factors	Indicators		Ethiopia		South Sudan		Kenya	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	11.50%	1	19.54%	1	1.62%	1
Hydrology	% of water contribution to the basin	F2	82.74%	1	8.62%	1	7.01%	1
Climate				1		1		0
	Rainfall	F3.1	11.49%	0	11.21%	0	8.10%	0
	Evapotranspiration	F3.2	8.6%	0	9.1%	0	10.0%	0
Population				1		1		1

	Directly dependent	F4.1	15.14%	0	4.79%	0	6.93%	0
	Indirectly dependent	F4.2	29.21%	0	0.05%	0	12.19%	0
Utilization	Existing use	F5	1.83%	1	0.11%	1	1.67%	1
Socio economic needs	Water demand for 2050		15.57%	1	3.27%	1	3.35%	1
Alternative resources				0		0		0
	Groundwater	F7.1	6.89%	0	17.15%	0	4.80%	0
	Shore line	F7.2	0.00%	0	0.00%	0	7.11%	0
Effect on others	potential Irrigation water demand	F8	16.93%	0	3.38%	0	1.15%	0
Avoidance of unnecessary waste	Irrigation savings	F9	31.32%	1	18.50%	1	1.37%	1
				700%		700%		600%
	Allocation based on +ve factors		168.07%		59.01%		23.52%	
	Allocation based on negative factors		4.32%		4.55%		0.00%	
	Allocation		163.75%		54.46%		23.52%	
			25%		8%		4%	

Factors	Indicators		Tanzania		Rwanda		Uganda	
			Factors	Weight	Factors	Weight	Factors	Weight
Geography	% of country in the basin	F1	3.73%	1	0.65%	1	7.56%	1
Hydrology	% of water contribution to the basin	F2	4.67%	1	4.94%	1	4.56%	1
Climate				1		1		1
	Rainfall	F3.1	10.82%	0	11.32%	0	13.84%	0
	Evapotranspiration	F3.2	7.8%	0	6.0%	0	8.4%	0
Population				1		1		1
	Directly dependent	F4.1	4.55%	0	3.50%	0	13.53%	0
	Indirectly dependent	F4.2	15.88%	0	0.85%	0	0.19%	0
Utilization	Existing use	F5	0.09%	1	0.28%	1	0.54%	1
Socio economic needs	Water demand for 2050		0.75%	1	0.41%	1	0.75%	1
Alternative resources				0		0		0
	Groundwater	F7.1	2.85%	0	0.03%	0	0.18%	0
	Shore line	F7.2	18.90%	0	0.00%	0	0.00%	0
Effect on others	potential Irrigation water demand	F8	0.79%	0	0.07%	0	0.24%	0

Avoidance of unnecessary waste	Irrigation savings	F9	1.05%	1	0.14%	1	0.33%	1
				700%		700%		700%
	Allocation based on +ve factors		23.64%		14.79%		30.19%	
	Allocation based on negative factors		3.88%		2.99%		4.21%	
	Allocation		19.76%		11.79%		25.98%	
			3%		2%		4%	

Factors	Indicators		Congo		Burundi		Total
			Factors	Weight	Factors	Weight	Factor sum
Geography	% of country in the basin	F1	0.69%	1	0.44%	1	100%
Hydrology	% of water contribution to the basin	F2	4.29%	1	4.03%	1	127%
Climate				1		1	
	Rainfall	F3.1	13.01%	0	13.36%	0	100%
	Evapotranspiration	F3.2	7.1%	0	6.9%	0	100%
Population				1		1	
	Directly dependent	F4.1	1.17%	0	2.30%	0	100%

	Indirectly dependent	F4.2	32.70%	0	2.60%	0	100%
Utilization	Existing use	F5	0.01%	1	0.05%	1	100%
Socio economic needs	Water demand for 2050		0.02%	1	0.05%	1	100%
Alternative resources				0		0	
	Groundwater	F7.1	20.79%	0	0.03%	0	100%
	Shore line	F7.2	0.49%	0	0.00%	0	100%
Effect on others	potential Irrigation water demand	F8	0.00%	0.111111111	0.02%	0	100%
Avoidance of unnecessary waste	Irrigation savings	F9	0.00%	0.111111111	0.10%	1	100%
				622%		700%	
	Allocation based on +ve factors		22.15%		13.74%		669.30%
	Allocation based on negative factors		3.55%		3.44%		26.94%
	Allocation		18.60%		10.30%		642.36%
			3%		2%		100%