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Research article

The Role of Trust-building in Fostering Cooperation in the Eastern Nile Basin: A Case of Experimental Game Application

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Abstract

Escalating tension and a sense of mistrust currently prevail between downstream and upstream countries in the Nile Basin over Ethiopia's construction of the Grand Ethiopian Renaissance Dam (GERD). Striving for self-sufficiency in hydropower generation, Ethiopia has initiated a new series of upstream reservoir construction projects, with the GERD being the largest, and this may affect the water availability in downstream countries of Egypt and Sudan. This paper examines a set of compensation options to induce cooperation through trust-building, possibly minimizing uncertainties in water allocation decision-making and simplifying complex inter-relationships in the basin using laboratory game experiments. The game was developed and conducted using hydro-economic modeling of the basin with GAMS software, an expert survey with the SPSS program and Z-tree software to design and analyze the laboratory experiment. This paper presents the results of the laboratory game experiment where the Eastern Nile Basin scenario was modeled as a multi-round, adjusted trust game with non-binding deals among players. The results suggest that the "win for all" situation may be reached through a stable integrative, cooperative framework. Building the enabling environment, in particular, transparency, knowledge, trust, and confidence among riparian states is the first step in developing transboundary cooperation. Basin-wide cooperation requires a transparent environment including a variety of compensation options, institutional changes, and incentive-compatible considerations.

1. Introduction

Since natural systems do not coincide with human-made borders, more than 500 transboundary freshwater rivers, lakes, and aquifers traverse the imaginary geopolitical dotted lines of 151 countries. The 276 existing transboundary lakes and river basins cover nearly one-half of the Earth's land surface and account for an estimated 60 % of global water flow **[1]**. Promoting transboundary water cooperation is therefore vital to achieving Sustainable Development Goal (SDG) target 6.5 on transboundary water cooperation to secure peace and sustainability **[2]**. While national boundaries make water issues political and increase complexities, competition over water access in every transboundary basin is likely to escalate in the near future due to climate change and growing demand. This makes cooperation through joint management even more crucial, especially in regions where tension over water scarcity is chronic. This paper aims to explore the possibility of cooperation among the Eastern Nile Basin riparian countries, Egypt, Sudan and Ethiopia. The historical and strategic relationship between these countries has been bred on mistrust and exploitation **[3]**. However, progress has been slow but steadily gaining ground on a win-for-all opportunity in cooperative development.

This paper comes at a crucial juncture of Eastern Nile River Basin cooperation as Ethiopia's ambitious infrastructure development plans may affect the physical quantity and quality of water availability to the primary consumer of the Nile, Egypt. For many years, Egypt has enjoyed unwavering and largely unchallenged dominance over the Nile River; and this position is currently threatened as Ethiopia develops the GERD and other upcoming development projects. The interdependencies of water issues with different decision-making arenas and geographical and temporal scales in the basin also make it difficult to steer the issue towards a definitive solution. Hence, new means and methods need to be explored that develop cooperation among the Nile River Basin riparian countries by making options transparent and available to increase the chance of building trust and confidence during the decision-making phase.

This paper explores mechanisms to promote cooperation and how it can be gained in the Eastern Nile Basin by developing a practical framework to understand the impact of economic gain maximization through regional economic and political cooperation. The paper simplifies the real-world scenario of the Eastern Nile Basin into a controlled laboratory role-playing game, in which players take the roles of the decision-makers in a transboundary context. Data was collected from a variety of sources and a series of interviews with experts in the field, government officials, academics and representatives of development agencies to make estimates as informed as possible.

To examine the impact of GERD's operation in the river system on the ability of decision-makers to cooperate, a model was estimated from real-world data and a game was designed to resemble the strategic environment in the Eastern Nile Basin. Controlled laboratory experiments based on the designed game were conducted to study the likelihood of future cooperation. Building on a long tradition of experimental research, the laboratory appears to be an ideal testbed to explore scenarios of cooperation and conflict in shared river basins. An analogous, though stylized, set of conditions was re-created to simulate the strategic environment of the Eastern Nile in different scenarios.

In four separate treatments, the economic scenario was simulated as a hydro-economic model of the Eastern Nile Basin to understand current and calculate optimal water resources allocation, focusing on tradeoffs between upstream and downstream riparian states for irrigation and hydropower generation. Four different water allocation scenarios were developed for the model with varying structures of payoff for each of the three riparian states to compare the economic gains of each country in the absence of cooperation to full cooperation. The experiment was designed based on trust game algorithms, evaluating the four scenarios developed by the hydro-economic model of the basin. By conducting the experiment, the probability of cooperation in each set of the game was examined with the understanding of the influence of different factors such as data sharing, transparent choices, economic gains and the role of diplomacy during negotiation periods.

2. Study area

Hydro-politics in the Nile Basin is not a recent phenomenon. There are records of agreements and conflicts that date back as far as pre-Egyptian civilization. Mostly, water sharing agreements have been achieved under non-cooperation regimes/settings rather than mutual understanding and peaceful settings, and the previous attempts at reciprocal cooperation among the Nile riparian states have mainly been a failure **[4]**. As far as the Nile basin is concerned, there is no single binding agreement to acknowledge riparian rights to Nile water resources in any way to create an environment for trust and equitable water sharing **[5]**.

Water resources in the basin are distributed very unevenly over time and space as well as the existence of a unique interdependency among the riparian states. 99 % of the Nile's water is generated in only 20 % of its watershed, 15-20 % from the equatorial lakes of East Africa and the rest from the highlands of Ethiopia **[6]**. For countries like the Democratic Republic of Congo, Kenya, Ethiopia and Tanzania, the Nile forms only a small part of their total water resources, thus their dependency is much lower than for instance Burundi, Rwanda, and Uganda for whom the Nile is the primary source yet by no means the only one. However, for countries such as Sudan and Egypt, with a dangerously high water-dependency ratio, the Nile is the single source of water. According to the 2013 report released by the Strategic Foresight Group, water resource availability of the Nile is expected to decrease at an alarming rate to 760 m^3 per capita year in 2030 **[7]**. There is an exclusive reliance ration of the downstream countries of the basin on the waters of the Nile as their main source of freshwater.

In 1959, Egypt and Sudan signed an agreement for the "full utilization of the Nile." It effectively allocated the entire flow of the Eastern Nile the two countries, with 55.5 billion m^3 (bcm) going to Egypt and 18.5 bcm going to Sudan [8]. The agreement was the basis on which Sudan would construct the Roseires Dam on the Blue Nile and Egypt would build the Aswan High Dam (AHD) on the Main average annual flow of the Nile measured at Aswan was estimated to be 84 bcm. Netting out the Egyptian and Sudanese shares left 10 bcm for surface evaporation and seepage at the site of the AHD. No water was left over for any other riparian states, including Ethiopia which supplies around 81 % of the annual flow of the Main Nile river [9].

Nile waters have never been governed neither by law nor by common sense [6]. There has been rampant unilateral water resource development, deep-rooted mistrust and blatant exchange of water war words, specifically between Ethiopia and Egypt. There were tense political situations with minimum or no Nile dialogue until the Nile Basin Initiative (NBI) was launched as a regional intergovernmental partnership to bring the Nile riparian states together to discuss and to resolve their differences in February 1999. The primary objective of the NBI was to conclude a Cooperative Framework Agreement (CFA) to restructure allocations and control over the Nile's resources equitably and cooperatively [10]. However, the process has run into some significant difficulties retracing back to colonial treaties. As a result, the Nile cooperation failed to bring all riparian countries on board and was unable to achieve their stated objectives and only three countries of Ethiopia, Tanzania and Rwanda have ratified the CFA to date [6].

In April 2011, the construction of Grand Ethiopian Renaissance Dam (GERD) in the Benishangul-Gumuz region of Ethiopia began with public and private investment. The Ethiopian government plans to have a hydropower generation capacity of 6000 MW at peak output from GERD. This will almost double the amount of Ethiopia's electricity capacity, which currently stands at less than 1946 MW and brings additional 15000 GWh/year of hydropower production for Ethiopia [11]. The potential impacts of the dam with a storage capacity of 60 BCM have been the source of regional debate and disagreements. The GERD will control over 60–80 % of the water resources that downstream countries, Sudan and Egypt, currently receive from the Nile and challenges the existing Nile water allocation [12].

After years of hard negotiations, in March 2015, a preliminary agreement was reached by the three nations based on the UN Convention on the Law of the Non-Navigational Uses of International Watercourses. The Declaration of Principles (DOP) on the Grand Ethiopian Renaissance Dam Project (GERD) spelled out modalities and core principles on how to cooperate and work together to use the Nile water more efficiently and effectively [13]. The three states agreed to cooperate in the implementation of outcomes of joint studies on the GERD, specifically on guidelines and rules for filling the reservoir, the annual operation of the GERD, and to inform downstream states of any unforeseen or urgent circumstances. Priority is also given to downstream states to purchase power generated by GERD.

The DOP has opened the door for various interpretations and expectations and left some outstanding matters to be resolved in future negotiations as it does not address all basin-wide challenges and uncertainties. Unique upstream–downstream interdependencies in the basin necessitate the development of a shared river system in an integrated manner through the full collaboration of the riparian countries [14].

The long-term stability of cooperation in the Nile Basin is based mainly on the outcome of the diplomatic negotiations between the Nile riparian states. Up to now, there has been no comprehensive agreement acceptable to either the Eastern Nile Basin countries or for the entire Nile River Basin. The main reason for this failure is mistrust which has been caused by lack of transparency, geopolitical imbalances, lack of adequate and relevant data and shifting development ambitions. Mistrust has played a significant preventative role in reaching basin-wide cooperation and implementation of joint transboundary water management [15]. Transparent data sharing (concerning national development priorities, social and economic benefits and joint resource exploitation) increases the chance of understanding each riparian's position, hence helps to build trust. Trust is crucial for open and fair negotiations on equal terms, and such negotiations eventually lead to mutual arrangements, binding legal contracts, pivoted on the principles of benefit sharing engagements and joint management [3].

The reasons why the Eastern Nile Basin is an approrpriate case study to make a point on cooperation are a) there is an inherent and heavily lopsided power asymmetry favoring Egypt due to its large military and its strategic partnership with Arab countries, and b) the upstream countries have strong national agendas that are both indiscreet and indelicate. Therefore, more than ever in the history of these countries, it is absolutely necessary and prudent to develop a cooperative framework based on mutually agreed benefit-sharing approaches, where Ethiopia and Sudan can successfully engage in their economic development plans while Egypt can provide technical expertise and investment in return for guaranteed supply of its minimal demand.

3. Literature review and conceptual framework

In sharing transboundary waters, trust is an essential element to induce cooperation among countries. The enforcement of trust can help in solving many water conflicts, which contribute to environmental inequality. Trust thus provides an amicable framework for a solution.

There is no lack of research on the Nile basin and its sub-basins' transboundary river management and modeling. There are studies that explore the impact of cooperation on the relationship among Nile riparian countries and conflict prevention [16], while others model cooperative and non-cooperative game theory applications [17], [18]. Some research, for instance, [19]-[22], examines water resource allocation patterns under climatic uncertainty. Jeuland [23] presents a basin-wide hydro-economic framework that integrates a hydrological simulation model and an economic model for the Nile Basin. Many hydrological models have been developed to evaluate the impacts of the GERD and other planned dams, which reveal that Ethiopia's development of the waters for hydropower production would not affect water supply significantly to downstream countries, even after Nile. In 1959 the consideration of the filling stages of the dams.

Knowing that the Nile is a data-scarce region, there are considerable gaps in attempts to identify economically or politically suitable measures for benefit-sharing and joint management among riparian states. The perception of water being a limited resource is likely to contribute to conflicts and disagreements between the involved parties, nations or stakeholders. Robert & Finnegen **[24]** found that when water management and its distribution is subjected to a scientific experiment with verifiable data, it is possible actually to transform the concept of water being limited in quantity into a flexible resource and think of ways to conserve or reuse water so the same supply can address greater demand.

Baird **[25]** also specified that rather than assumptions, to enhance decision-making and end conflict or misunderstanding between involved parties, transparent, relevant and tangible tacit and explicit data with a synthesized framework forces the process of forming cooperative institutions. When such data is presented to the panel of decision-makers, it tends to instill trust and alleviate fear and misconceptions surrounding the lack of transparency in unverified data, thus leading to more sincere cooperation **[26]**.

Hagen *et al*. **[27]** discussed how useful different types of games can be in developing trust and empathy amongst stakeholders to understand the problems other groups of stakeholders face. Hagen *et al*. **[27]** indicate that not only does the strengthening of relationships between diverse stakeholders by increasing mutual trust and empathy play a significant role in cooperation, but it also improves understanding of the system and complex issues at play. "Behavioural game theory" is a recent approach linking game theory to cognitive science by adding cogent details of social utility functions, principles of limits on iterated thinking which refers to what players guess about other players moves and decisions, and statistical theories of how players learn to influence others **[28]**. New directions include the effects of game descriptions on "choice framing," strategic heuristics, and mental representation.

Different types of behavioral games as a form of game theory create knowledge that helps decision-makers in transboundary cooperation to gain meaningful insights about various scenarios **[29]**. Interactive multi-player game formats that facilitate step-wise, round-based interactions allow participants to develop a greater understanding of different perspectives of upstream and downstream contexts of a river basin **[30]**. Trust game exploration supports negotiations for decision-makers by generating a range of options for weighing information, trade-offs, and payoffs for different choices. When various factors, such as transparency and data sharing, are incorporated into the study, the negotiation and decision-making process is made faster and more accurate.

Once influencing factors are determined, the binding rules governing cooperation are in line with the agreement terms and conditions of the stakeholders **[31]**. For the success of this laboratory experiment, research is conducted to determine the factors and conditions of the stakeholders in the multi-collaboration of a transboundary water basin. Data found are then subjected to thorough analysis and presented in an understandable manner that fuels and eases the process of transboundary governance decision-making.

The game design in this study considered institutional constraints that include negotiation over transboundary water management and decision making. In negotiations, the terms of institutional arrangements bind the riparian countries and provide a range of joint opportunities, which sum up to a higher value compared to non-cooperation. Therefore, making those benefits attractive and understandable compared to non-cooperative choices in the game can influence players' decisions. One way to deal with the transboundary water governance problem is continued negotiations to give decision-makers time and opportunity to work together towards confidence-building, value creation and joint thinking for solutions by forming different compensation options for cooperation and preventing unilateral decision-making **[32]**.

To address the complex water problems on a transboundary scale, approaches that go beyond applications of technology or the implementation of management policies are required. Combination of such methods may provide a foundation for greater cooperation and avoid conflict by improving the understanding of how the physical unit of the basin intersects with the economic, social and political aspects **[33]**. The following elements are incorporated in the game design as strategic tools to promote cooperation:

- Benefit Sharing: Players have a variety of options from non-cooperation to full cooperation in each round of the game. They have the opportunity to choose the most efficient option and to gain other players trust by paying incentives **[34]**, **[35]**, **[15]**.

- Side payments: A side-payment is either direct monetary payments or units of available resources. In the game, each player is assigned a sum of virtual money that is an equivalent value to his/her geopolitical power within the negotiation platform **[36]**, **[37]**.

- Linkage issues: Issue linkages create benefits for players with a little gain ipso facto increasing probability of cooperation through peer pressure. In this instance, adding another point or being innovative during the negotiations can redistribute the benefits. This, in turn, allows all participants to experience some gains **[38]**. **[39]**.

- Diplomacy: By applying strategic tools such as creating an opportunity for joint fact-finding in the game session, players are given a chance to work together to find the best option that satisfies all members **[40]**, **[41]**.

- Legality: If trust is too risky of a decision, then policies to promote trust might best focus on creating rules that, for example, improve transparency and encourage peer-to-peer penalty of trust violations as in participatory guarantee systems. In the game payoff structure, each country has certain rights to the shared water **[42]**-**[44]**.

4. Modeling the integrated water allocation

The hydro-economic model (HEM) developed for this study simulated the transboundary river system through a simple framework to identify hydrologic and economic impacts of different patterns of water allocation for irrigated agriculture and hydropower generation in the main sites along the Eastern part of the Nile River under the selected scenarios. Four different water allocation scenarios were developed for the model with different allocation and payoff structures for each of the three riparian states to be played in the designed laboratory experiment game. The description of the designed HEM is based on non-linear programming that is used in the determination patterns of water consumption that maximize the sum of economic benefits of irrigated agricultural production and hydropower generation at the selected sites in the Eastern Nile Basin. The GERD and its hydrologic inputs were included in the model only under scenarios after its completion.

The baseline setup of the model was similar to the approach applied in **[45]**. However, the model in the present study described only the eastern part of the Nile basin, including all existing irrigation schemes and hydropower reservoirs, and most of the confirmed future hydropower plants. Water is transmitted through a network of rivers and channels in the routing system which contains all the major sites: Lake Tana/Tana-Beles and Tekeze dam project in upstream Ethiopia; the Sennar, Jebel Aulia, Khashm El Girba, Merowe and Rosaries dams and reservoirs in Sudan; and High Aswan Dam (HAD) with Lake Nasser in Egypt. The GERD and its hydrologic inputs were included in the model only under scenarios after its completion (**Figure 1**).

Current reservoir operations and hydropower data such as capacity, dam characteristics, technical efficiency and reservoir volume were sourced from the Nile Basin Initiative (NBI), ENTRO and The Global Energy Observatory (GEO). Some analytical data on various existing models were obtained from **[12]**, **[18]** and **[23]**. These studies gave a better understanding of the data processing and measure comparisons for our methodology. Block *et al.***[7]** reported on proposed future and current projects in Ethiopia, Sudan and Egypt. Their work was used for reference on data accuracy, i.e. for cross-checking and verifying the data collected during this research. The length of the simulation period was selected to be 25 years for baseline scenarios (obtained from ENTRO database[1]) and additional ten years of projection for hypothetical scenarios after the construction of the GERD. This allowed the model to reach equilibrium so that calculations could be made on the long-term economic benefits of the river system after filling the GERD. Variability in storage is dependent on dynamics of large water bodies, where use in one location could limit options elsewhere.

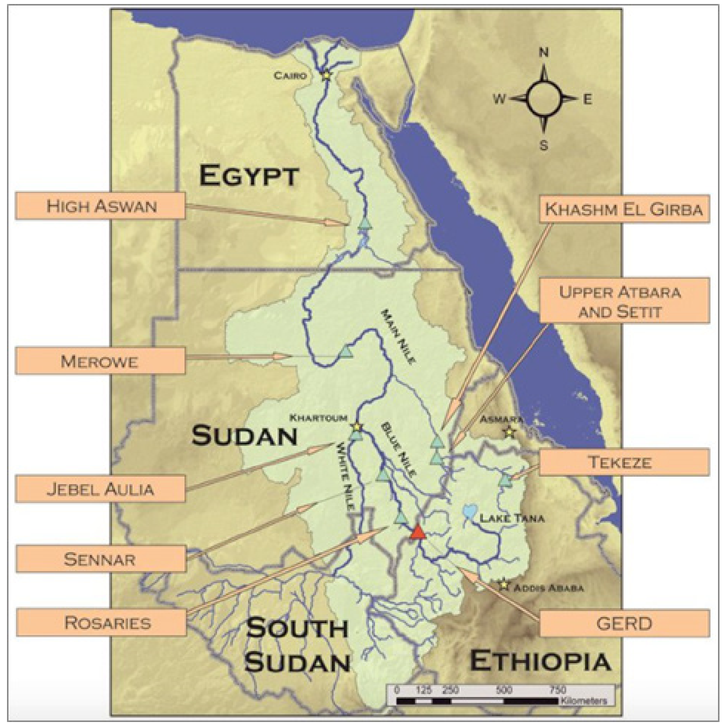

Figure 1: Eastern Nile River Basin dams

The model objective function consists of two components. The first represents the net irrigation water profitability considering the efficiency of irrigation in each country of the Eastern Nile Basin, in addition to estimating total water consumption per year by that country. The second component of the objective function represents hydropower generation in the dams and the sum up of the entire present and potential production for each country and the inferred income thereof. The basic mathematical formulation of the objective function of the model is as follows:

Objective Function:

$$\max \sum_A \{ P^A_{irr} \sum IRR^{i,A} + P^A_{hy} \sum HY^{i,A} \}$$

Irrigation water withdrawal is estimated as: $IRR^{i,A} = \mu^A.AI^A.CWR^A$

Hydropower generation at site i in country A is calculated as:

$$HY^{i,A} = \alpha^A.OF^i.f(S^i_t, S^i_{t-1})$$

A=Ethiopia, Sudan, Egypt

i= Each water storage or allocation site in each country

Non-negativity constraint: $HY^{i,A}$, S^i, $IRR^{i,A}$, $OF^i \geq 0$

Where:

- $Pirr^A$: The price of water for irrigation in country A (USD per m^3)

[1] This study obtained and compiled historical hydrologic data from a variety of sources including ENTRO (Eastern Nile Technical and Regional Office), NBI (Nile Basin Initiative), relevant ministries of the Eastern Nile riparian states, Food and Agricultural Organization (FAO), the World Bank Development Indicator Database (World Bank) and Global Runoff Data Center (GRDC), as primary sources of agriculture, hydrologic and economic data. Other data sources were also considered such as the Water Accounting database.

- $IRR^{i,A}$: Mean quantity of water withdrawal for irrigation in country A (million m^3)
- P^A_{hy} : The price of electricity for country A (in USD/kWh)
- $HY^{i,A}$: Mean annual hydropower generated at site i for country A (GWh)
- S^i : Mean reservoir storage for reservoir j (million m^3)
- IF^i: Average inflow to site i (million m^3)
- OF^i: Average outflow from site i (million m^3)
- EV^A: Average percentile evaporation loss in country A (%)
- e^A: Evaporation rate at country A (million m^3)
- R^A: Addition to flow in country A from annual precipitation (million m^3)
- S^i_{Min} and S^i_{Max}: Minimum and maximum storage for reservoir i (million m^3)
- μ^A : Efficiency of irrigation in country A
- CWR^A: Crop water requirement in country A (m^3/ha/year)
- AI^A: Current area under irrigation in country A(ha)
- AI^A_{Max}: Maximum irrigable area in country A (ha)
- f (S^i_t , S^i_{t+1}): Function determining average productive head at site i
- α^A: Hydropower efficiency in country A
- $HyMx^{i,A}$: Maximum hydropower that can be generated at site i (GWh)

$IRR^{i,A}$ and $HY^{i,A}$ were calculated for one year to determine the combination of monthly releases from each hydropower generation site and yearly allocation for irrigation schemes. The total water loss to evaporation and seepages was deducted from the full benefit at each node with a fixed rate for each of the three countries. Optimization of the objective function thus maximized the net benefit of both components of the model, minimizing losses using GAMS software (General Algebraic Modeling System). When the model was optimized for scenarios with cooperation and joint basin management, along with the simplification of the situation, the calculation respected the constraints on water availability but supposed that the available water can be stored and delivered efficiently to existing users to enable agricultural production.

The HEM was applied to a set of hydrological, development and governance scenarios, to determine the value of basin-wide cooperation on the economics of the river and the position of the GERD towards downstream riparian countries. As a result, four scenarios were formed. These scenarios represented different levels of development of the river basin, regarding water usage or alternative transboundary strategies as full or no cooperation among the riparian countries. In other words, under status quo, no beneficiary agreement exists, and irrigation water is allocated to individual riparian countries approximately as in the current allocation pattern. The study included volunteer side-payment options into the game design to motivate willingness to cooperate with other representatives in the design of the experiment. The scenarios are as follows:

Scenario 1: Unilateral management without GERD

This scenario approximates current water withdrawal and infrastructure conditions in the basin. Status quo allocation can be used as a first reference point for calibrating the economic benefit of the current water consumption scheme. The baseline scenario is where countries manage the river unilaterally without compensation of any sort towards their riparian neighbors.

Scenario 2: Unilateral management with GERD

The construction of GERD would undoubtedly affect the entire system regarding physical water availability and economic benefits derivable, especially for downstream countries. Therefore, for the second scenario, GERD is included as a fully functional system, keeping all other parameters unchanged. Scenario 2 aims to evaluate the impact of the GERD on the water distribution and economic structure of riparian countries while they are still non-cooperative. In other words, the model estimates water allocation and the resulting economic benefits for each country and the region once GERD becomes fully operational with unilateral arrangements for development in the basin. Comparing scenario 1 and 2 reveals the impacts of the GERD on the rest of the river system, in particular on agricultural and energy sectors in all NRB riparian states. The situation is a common strategy pursued by riparian countries because of the lack of basin-wide cooperation.

Scenario 3: Cooperation without GERD

Scenario 3 is an efficient allocation model of Nile River water through restructuring the current allocation system assuming basin-wide cooperation. In this scenario, Nile water is allocated to the activity within the riparian basin that generates the maximum economic benefit, i.e. either for agriculture and hydropower generation regardless of where it is located within the territories of the three riparian countries. The basin is considered a single system and the benefits generated are considered as one system output that is shared optimally.

Scenario 4: Cooperation with GERD

The fourth scenario is a situation in which the GERD would be operated to add to current energy production in Ethiopia, only with cooperative arrangements. Comparing scenario 4 with scenario 2 discloses the extent of the risks and associated costs faced by downstream countries in the case of the unilateral operation of the GERD. Scenario 4 examines whether the GERD has the potential to foster cooperation by offering a sharp increase in economic benefits to the whole region. It tests if the GERD could form a basis for a new era of cooperation in the Eastern Nile Basin as a catalyst for future change and side-payment arrangements as compensation options for joint management of the basin. The grand coalition in the model is described as the full cooperative development situation, in which all proposed infrastructure projects would be completed and operated to optimize the total economic benefits for the entire basin. In the case of scenarios 3 and 4, full cooperation is assumed, meaning that there is coordinated operation of the basin's infrastructure to optimize the total basin-wide economic benefits of efficient allocation of water for irrigation and hydropower generation.

According to **Figure 2**, the results of the model demonstrated a significant rise in economic benefit for the Eastern Nile Basin from the operation of the GERD under the full cooperation of all riparian countries (Scenario 4). The economic benefits for the whole basin are greater in both scenarios with cooperation (Scenario 3 and 4) and the highest in cooperation with the GERD (Scenario 4). The degree of economic power, which affects trade and political relationships between states, is an essential factor to understand whether a cooperative outcome will be successful or is bound to failure.

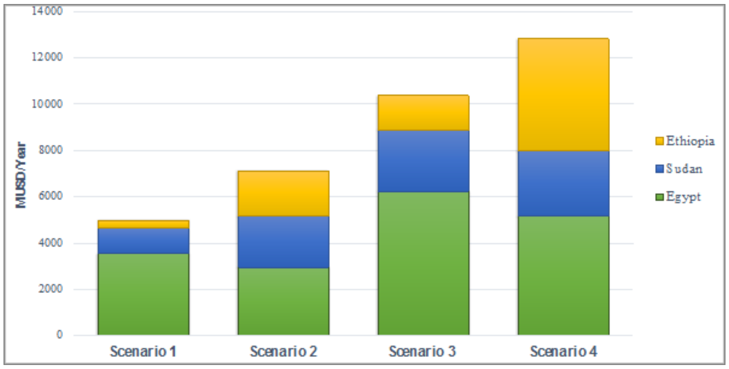

Figure 2: Economic benefits for each Eastern Nile riparian state under the four designed scenarios

5. Design of the Trust Game Experiment

The experimental laboratory game was designed based on the result of the HEM to find the best values under different water allocation patterns along the river, seeking a win-for-all range of options that could promote cooperation in the Eastern Nile Basin. Since the payoff functions developed from the available real-world data were complex, they needed to be presented in the simplest possible way for the experiment. Tables were used to list the payoffs obtained by each combination of water releases from Ethiopia to Sudan and from Sudan to Egypt based on the four scenarios developed for the HEM.

In the transboundary governance of the Eastern Nile, practical cooperation among the riparian states is not guaranteed due to inadequate cooperation incentives such as joint development projects. One way to deal with the problem is continued negotiations to give decision-makers time and opportunity to work together towards confidence-building, value creation and joint thinking for solutions by forming different compensation options for cooperation and preventing unilateral decision-making **[40]**. In this study, players were given time for negotiation in each round of the game with various sets of information and payoff tables. In the designed game experiment, decision-makers were able to learn cooperative behavior in the case of repeated conditions and differing interests by conducting joint fact-finding workshops in a transparent environment. Therefore, making cooperation more attractive compared to non-cooperative choices in the game, created the opportunity to study how additional benefits due to cooperation promote or influence a player's decision to cooperate. In the transboundary basin contexts, the capabilities of each party refer to the relative power from their economy, politics and geographic location on the river, i.e. upstream or downstream, and the related bargaining power of the riparian states, forming the basis for their degree of compensation. Each country's preferences or interests determine the costs and benefits, potential strategies and outcomes of the game.

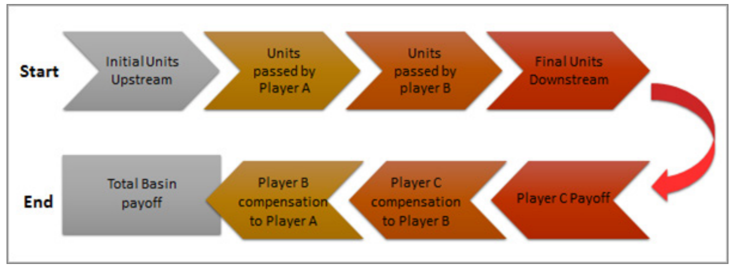

Figure 3: Schematic stages of Trust Game for three players

The basic form of trust games consists of two players, one endowed with money (the trustor) and one without (the trustee). The trustor decides either to keep the money for him/herself or to 'invest' some or all of it by sending it to the trustee. The term invest here loosely refers to a formal or informal arrangement of mutual benefits in exchange for goods or services. Any money invested generates a return value. After receiving the multiplied money, the trustee must decide to either to keep the money and not return anything to the trustor or to return the initial amount or a greater sum (**Figure 3**). According to the rules of the trust game, the amount sent is a measure of trust, and the amount or proportion returned as a measure of trustworthiness.

In this study, players played the role of decision-makers in the Eastern Nile Basin, Ethiopia, Sudan and Egypt, which were randomly allocated to positions A, B, C. The players kept the same position for the entire duration of the experiment. The experiment mimicked provision of distribution of water that is available from the upstream, and real-world current allocations.

Players were given ample time for negotiation in each round of the game except for the first round. This time had an attachment of some sets of information and payoff tables. When playing, every player became a decision-maker, thus learning the behavior of cooperation in a setup of a mutually inclusive probability where the experiment is repeated under some guidelines of modified regulations that differ interests by conducting joint fact-finding actions in an audible, accepted and transparent environment. The economic rationale of this long-conceived beneficial idea sharing rather than water sharing is an elevation for both up and downstream compensation **[17]**. The distribution of incentives and side-payments became skewed when asymmetric externalities were regarded.

Side payments were weighed based on the financial conditions determined by the estimated economic power of the country represented in the game. Economic power is considered in the design of the game, differentiating the capability for strategies for incentives in accordance with the representatives of each country. The primary linkages in the game were formulated from the trade-offs among different water allocation plans, strategic national priorities, and assigned payoffs.

The game was designed in a way to make the win-for-all situation recognizable and achievable. The states of winning and losing were critically analyzed through the assigned values, i.e. until the set of games reaches a minimum mutually acceptable option for the satisfaction of all the players to continue playing. At the end of a set of games, each player won, i.e. each particular player's interest for cooperation was fulfilled. The game design simulated possible strategic alternatives for negotiation between Egypt, Sudan, and Ethiopia. The three players had an initial set of choices to make a strategic decision that then influenced others to make their decisions similarly, and the game then moved forward one round.

Each player made a strategic counter move until they reached a mutually agreeable and satisfactory state or win-for-all situation. This was possible because every player was aware that safeguarding his/her starting lump sum amount was not a long-term win and they also knew that returning a received investment wins trust and mutual partnership. However, every player risked initial investment as side-payments; the game proceeded round after round based on transparent negotiation on available data, decisions were made, exchanged, compensated and eventually the players had the chance to reach a win-for-all position.

Four elements interact in the decision-making, including:

- Players: Playing the role of decision-makers from Ethiopia, Sudan, Egypt
- Actions and Interaction: The choices of one player affect the decisions of the others in the group.
- Strategy: Each player holds an approach and plan accordingly based on the understanding of the other players' interactions and given game instructions.
- Rationality: A player’s choices are characterized by rationality along with their role’s national interests.

Step by step, each round gave players more time to build confidence and have a friendly discussion about finding the best solution out of the available options by understanding the game, having more time for negotiation, information-sharing and joint efforts for decision-making.

According to the rules of the game, players exchanged water units in the game based on the designed combination of options on their game sheets, from upstream to downstream and used virtual money for side payments during the negotiation as a compensation alternative. The financial capacity of each player in the game directly corresponded to the economic strength of the country he/she represented in the Eastern Nile basin.

6. Laboratory Experiment

At the beginning of the game, the participants, who were MSc. Students at the Institute for Technology and Resources Management in the Tropics and Subtropics (ITT) at University of Applied Sciences in Cologne, were provided with instructions about the rules of engagement. The negotiation teams were provided with a basic fact sheet including primary data on their national objectives and interests in the use of the Nile River as described in the table (in Appendix). Moreover, each player had separate instructions on their role’s mission, describing additional information and national interests concerning the river. Each player's goal in the negotiation simulation is to negotiate and draft provisions that are most favorable to the country he/she is representing and its interests according to the given information.

In the introduction section, the game was framed in an upstream-downstream configuration, and players had the roles of decision-makers from the country they were randomly assigned. According to the rules of the game, players exchange water units in the game based on the designed combination of options in their game sheets, from upstream to downstream and use the virtual money as side payments during the negotiation as a compensation alternative.

The sequences adapted in the game were aimed to study the process of trust-building from entirely unknown until the time the players have had the opportunity to meet each other as a team with similar objectives. Step by step, each round gave players more time to build confidence and have a friendly discussion about finding the best solution out of the available options. Two scenarios were considered, not having the GERD and having a fully operational GERD, thus investigating the impact of an increase in the payoff of the basin brought by the GERD on the degree of cooperation in decision-making.

7. Results

The experiment comprised four rounds of the role-playing game experiment developed as a form of trust game with the primary focus on the implications of the GERD and the possibility of cooperation. An identical set-up and payoff matrix for each round of the game was provided as the result of the hydro-economic modeling of the Eastern Nile Basin, with different levels of information sharing. The participants were post-graduate students from a wide range of disciplines related to water resources management. The results of the experiment show that the chance of lowering the risk of non-cooperation by building trust is high when players have enough time to get to know each other and negotiate over their shared benefits.

Despite strong cooperation incentives, the result also further indicates that some players still make unilateral decisions to maximize their individual gain. This leads to untrustworthiness between them for rounds after that. Overall, the probability of cooperation was quite high (average of 76 %) of the choices each player made during the whole game in the laboratory. Although decisions were nonbinding and non-compulsory without any penalty for non-cooperation, players cooperated to win more significant gains and win the game. Moreover, the experimental results reveal that cooperation is indeed hard to establish in a strategic environment with a sense of uncertainty, but it is still attainable under some specific conditions for joint actions and satisfactory trade-offs.

These findings are consistent with evidence reported above that most of the players are conditional co-operators who prefer to cooperate when the other players' cooperation is guaranteed. The study proves that beliefs about the likelihood of being exploited and of the egoism of others were important when one had to make a cooperative move in a situation where there was a risk of being betrayed. Apparently, these beliefs are much more important for cooperative behaviour to shape players' trust attitudes. Thus, failure to cooperate should not solely be attributed to the unwillingness or incapability of players. This may partly be due to inadequate compensation and partly to an uneven split of total profit. Since cooperation is mostly conditional, providing a set of preconditions, such as a series of motivation options, are available, and certain ranges of incentives are ensured, cooperation continues **[46]**. In **Figure 4**, the percentage numbers of each round of the game represent the chances of cooperation for all the groups' decisions during the game.

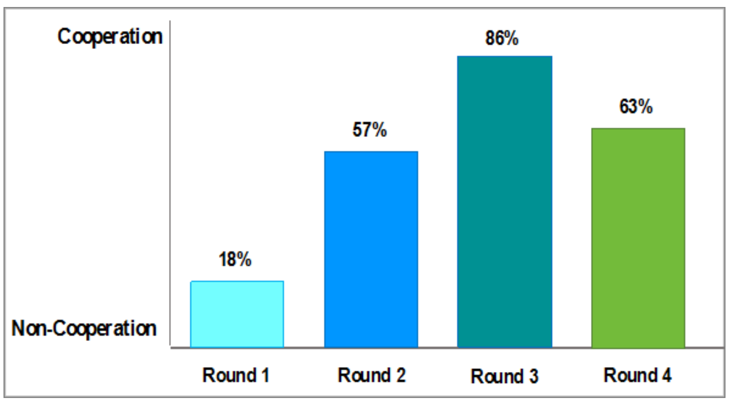

Figure 4: Result of the game experiment showing cooperation in percentage in each round of the game

Overall, our analysis suggests that changes in behaviour over time in trust games are a result of participants learning how to improve benefits while creating opportunities for better decision making. However, there is an increasing range of evidence that individuals do not play games as perfect profit-maximizing machines, that they instead exhibit bounded rationality, and can be influenced by a variety of irrelevant factors that do not affect their payoffs positively in the game. It is doubtful that decision-makers ever have perfect information and the logical starting point is one of uncertainty and how to reach a state where one can say with some confidence that the selected option is to be preferred to all others.

By analyzing the results of the HEM, considering the soon to be completed GERD in Ethiopia, it seems negotiation to establish a cooperative arrangement in the basin is Egypt's best alternative regarding economic and development concerns.

8. Discussion

Cooperation is increasingly seen as a function of economic factors rather than diplomacy and trust elements. Thus, cooperation is often founded on the principles of optimal use of resources to maximize profits, which can be shared among the stakeholders based on mutual agreements. Benefit-sharing approaches emphasize enlarging the scope of potential gains from water cooperation by looking beyond the water resources themselves, which includes the possibility of sharing economic gains from hydropower, agriculture, trade, etc.

By deconstructing negotiation processes for joint arrangements, we explored the stages of knowledge that lead to a cooperative form of decision-making. During the game, the effects of trust building factors were measured, investigating each country's priorities and preferences, and attempting to replicate the entire process of negotiation and decision making in a laboratory setup with experimental games. Since most states sharing basins have different needs, preferences, and capabilities, it is likely that linking issues opens up value-creating opportunities, compensation options and incentives for cooperation. In the experimental game conducted in this study, the simplified scenarios gave players a well-defined picture of synergies and linkages among two components of the game: hydropower and agriculture. They could make their decisions while they became aware of each other's strategic priorities in using water for specific allocations and the values assigned to each set of decisions. They also had the chance to see how their decisions affected their team member's situation for each round of the game.

Joint institutional structures with exchange platforms where technical experts and specialists will be able to analyze the data and arrive at conclusions on their positions and that of other riparian countries must precede the negotiation phase. The equilibrium states of the games, which were formed during the negotiation simulation, can provide the basis for the commencement of real negotiations between decision-makers.

It was found that transboundary cooperation is a recursive process of a dynamic and contentious information exchange between multi-level institutions and actors. Maximization of basin-wide efficiency requires continued riparian cooperation while any cooperation process implies the recognition of the different interest of the parties involved. Fundamentally cooperative framework formulation takes into consideration all interests and preferences of its parties; however, opposing is in the nature of every riparian within the system or likely to be affected by changes to the system who tries to find a mutually acceptable term for sharing the resources and its benefits in an equitable manner, through which greater long-term benefits can be realized. These challenges can be overcome through strategic and coordinated action beginning with shared data on relevant information and inclusive dialogue that build knowledge, trust, confidence and moreover, lay the foundation for cooperative transboundary institutions. To overcome the transboundary issues and competing claims, all involved riparian states must be willing to engage, commit resources and time in the negotiation processes to develop cooperative arrangements.

While the set-up of the present experiment was tailored to the Eastern Nile Basin scenario, the methodology introduced applies to many other transboundary river conflicts as well. Future work may address these regional trade-offs among Water-energy-food as an option for decision-makers to integrate issue linkages with comparative advantages to provide more insight for regional dialogue in resource management.

Appendixes

Appendix 1: Game experiment design and structure

Round	Material	Stages of the game	Procedure	Time
Introduction	ID Card, Instructor reading Rules of the game explanation General fact sheet of the basin Question time	Hand out ID cards and written instructions	Get familiar with the game rules	10 Min
1	Case study map Instruction of first round Individual fact sheet Payoff table for scenario 1 & 3	Reading the instruction Understand the role and position Individual thinking Decision making	Playing anonymous from other group members	15 Min
2	Basin fact sheet (Getting familiar with other players' interests and positions) Payoff table for scenario 1 & 3	Introduction to other team members, Data sharing, Casual negotiation Decision making	Group meeting for negotiation	30 Min
3	Payoff table for scenario 2 & 4	New Data sharing Informal negotiation Decision making	Group meeting for negotiation	30 Min
4	Payoff table for all four scenarios As in round 1 & 2	Casual negotiation Decision making	Group meeting for negotiation	30 Min
Payment	Players' gains calculation	Real money payment	in private	15 Min

Appendix 2: Game result (Result of groups' total payoff in each round of the game experiment (in Million USD)

Group	Payoff (MUSD)				Total payoff each round
	Round 1	Round 2	Round 3	Round 4	
1	10367	10367	11512	11258	43504
2	8559	9625	11295	9674	39153
3	10367	9973	11044	9538	40922
4	10121	9490	11044	11508	42163
5	10367	10267	10844	11224	42702
6	8313	9477	10567	10343	38700
7	8065	9625	11512	10460	39662
8	10367	9921	10328	11024	41640
Total gain	**76526**	**78746**	**88146**	**85029**	**328446**

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