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Article

Painted Water—A Concept to Shape Water Negotiation Strategies in Shared River Basins

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Abstract: In a transboundary river basin, downstream states frequently express concerns regarding the potential utilization of water resources by upstream states as a tool for exerting coercion. This fact contributes to instilling doubt in the applicability of negotiations, even in transboundary basins that possess strong international agreements. In an effort to address the issue, this paper introduces the painted water concept. It divides upstream states' available water into three triage color volumes before reaching downstream states in ascending order of negotiability: green, yellow, and red. Additionally, downstream states must consider the dynamics of transitions of painted water classes over time when developing their negotiation strategies and water policies. In order to assess the concept's contribution in practice, we analyze trilateral riparian negotiations along the Blue Nile River basin, based on a "what-if" analysis approach under four global future scenarios. These results could shed light on part of the complexity of the Blue Nile negotiation and mainstream the water policies and perspectives of riparian states. Here, this paper shows that the painted water concept can provide multidisciplinary insights into proactive water negotiations. The inclusion of such a concept can help to deepen theories, approaches principals, and any disciplines pertinent to transboundary water negotiations.

Keywords: painted water; negotiability; decision support model; Blue Nile (BN) river; international futures; geo scenarios; system dynamics

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1. Introduction

The multidisciplinary nature of water has led different disciplines to classify water from their own viewpoints. For this, scholars may refer to several terms, such as "virtual water" in political economy [1], "green, blue, and grey water" in water quality [2,3], "surface, shallow, ground, and precipitation water" in hydrology [4], and "critical, sub-critical, and supercritical water flow" in hydraulics [5]. In this paper, we develop and apply a triage of colors to assist riparian decision makers by demonstrating how an additional hydropolitical classification of international water may explain bilateral or multilateral river basin negotiations and promote effective transboundary river management.

For this purpose, we revert to the simple function of an international river, a river that flows between (in a border-creator geography) or across (in a through-border geography) at least two riparian states (states through whose territory or along whose border a water-course passes) [6]. Physically, any water extraction by the upstream states decreases the remaining flow of water to the downstream basin state(s). This is the backbone around which the primary line of water negotiation among the upstream and downstream riparian states evolves [7]. In other words, the less water withdrawal from the upstream state's natural discharge, referred to the entire outflow of a transboundary river from the territory of the upstream state if it is not contained there, the more water remains for bargaining and vice versa [6,8]. A typical water negotiation in an international basin aims to create a situation in which water capture by the upstream states is regulated so that the downstream states can meet their water demands [8,9]. Downstream states may not be able to meet their water needs but they can test it by allowing upstream interests to prevail [10].

Several mechanisms exist to build trust among riparian states. These include treaties [11], joint commissions [12], river basin organizations [13], multi-level governances [14], water diplomacy [15], and dispute resolution [16]. Among such mechanisms, the treaties represent a high level of trust among riparian states due to the formal obligations they bring upon all sides. Thus, efforts have been made to establish treaties invoking a broad spectrum of tools to reach a stable treaty which leads all signatories to want to be part of it, under various natural and political situations [17–19].

However, even when they are established, they are often not effective. To support that argument, datasets recording hydropolitical events, such as the Transboundary Freshwater Dispute Database [20] or the International Rivers Cooperation and Conflict database [21], indicate numerous disputes around international water treaties in the world in which basins continue to have disputes. They include the Indus River [22], the Helmand River [23], the Silala River [24], the Kura-Araks River [25], the Nile Basin [26], and the Mekong [27] to name a few. The above examples prove that the mechanisms governing water withdrawal by upstream states do not necessarily adhere to the treaties, even when the treaties have been based on a high level of trust between the riparian states. Warner and Zawahri (2012) mentioned, “the presence of a treaty does not automatically translate into behavioral altering cooperation.” [28] (p. 215).

Disputes in transboundary basins arise irrespective of the presence of a treaty, as upstream states exhibit an insatiable drive to fulfill their "hydraulic mission." That mission dictates that every drop of the transboundary river must be utilized at any expense and in its entirety before it is wasted by flowing into the sea [29]. Nevertheless, “put to use” does not necessarily refer to meeting water demands because political reasons often prompt upstream states to do so, rather than necessity. To provide further elucidation, we differentiate between the actions of “water capture” and “water withdrawal” in upstream states. The former, in alignment with the hydraulic mission, pertains to the act of impeding the flow of water downstream while the latter entails the collection of captured water to fulfill the upstream water demand. Water capture initiatives are dependent on infrastructural systems, such as diversion or storage dams, which serve to impede the outflow of water from the upstream territory. Whereas water withdrawal always includes water capturing, the contrary is not true. Water capture can have various functions, such as serving as a means of political leverage both domestically and internationally [30,31]. It can also be seen as a source of national pride, promoting peace and stability within a country, commonly referred to as “water nationalism” [32,33]. Additionally, upstream states utilize water capture as a strategic tool to increase their influence abroad [34], while also providing legitimacy to state building efforts at the national level [35,36]. Controlling the transboundary river is a prerequisite for realizing one of the four pillars of power, namely geographical power, needed by an upstream state to be referred to as a “hydro-hegemon”, a hegemon at the river basin level, over other transboundary water users [37]. As a result, water capturing may even exceed the water demands of upstream states, which causes downstream states to face severe uncertainty in their water policies (the cases of the Blue Nile, Ethiopia, and the Mekong River, China, are recent examples).

That leaves downstream states with fundamental questions: By giving free rein to the hydraulic mission of upstream states, how much river flow would potentially be captured out of political interest, how much out of actual needs, and how much would not be captured at all during a specific period? What are the negotiation strategies and water policies that should be taken to prevent putting the basin at stake? However, current international water negotiation decision support tools have not been promoted to deal with questions aimed to draw a clear and realistic picture of the situation for the needs of downstream states.

Currently, a number of studies have been dedicated to developing decision-support models for water negotiation. Some are applied in specific transboundary basins, such as the WRYM model that was developed for transboundary rivers in southern Africa [38], DBAM in the Danube River basin [39], and ETRAB in the Euphrates River basin [40]. Others are applicable in all transboundary basins, such as CRSS [41], SWAT [42], and WAFLEX [43].

These decision support models have attempted to provide riparian states, particularly downstream ones, with a clear understanding of the status of future water flowing to their territory, drawing on evaluating the water demands and resources of riparian states. Although the models have successfully provided riparian states with a transparent assessment of the flows of rivers under local and global environmental scenarios, such as climate change, it is most likely that they could generate unreliable conclusions because they are not sensitive to the human scenarios rooted in the intentions of upstream states to further their water capturing, which is applicable to existing and future failure in negotiation.

Closing such gaps is a crucial matter for downstream states that could play an important role in classifying water in terms of its negotiability. In light of this, we propose the concept of "painted water", which could support downstream states in designing their water negotiation strategies and policies. The painted water concept does not embody anything far from the previously mentioned negotiation approaches. Instead, it could be seen as a complementary idea increasing the accuracy of the previously mentioned decision support tools. This alerts the downstream states by drawing attention to the extreme points of a possible uncertain negotiation space that the upstream states may impose. Thus, the downstream states could regulate their national and international water strategies to prevent future risks of water shortage.

This paper aims to advance the painted water idea by explaining the general concept of shared river basins. In doing so, we demonstrate the concept in a simplified case study, the Blue Nile basin, to explore the usefulness of the methodology in practice. The dynamics of painted water classes are investigated through a scenario analysis approach. Finally, we discuss the general implications for the riparian states' negotiation strategies and their water policies as reflected in the results.

2. Explanation of the Painted Water Concept

We assumed that an upstream state's water capture from transboundary rivers does not necessarily reflect only its water demand. In this way, water flowing in the upstream state, in every single time step, can be categorized into three components in ascending order of the uncertainty degree of obtaining certain water components by downstream states.

The first component, coined "Green Water", is the amount of transboundary river water in the upstream states that it cannot capture on its own due to limited water capture capacity, either due to improper landscape or shortage of funding for storage. As the name suggests, this component allows downstream states with a green light to use this amount flowing into their territory without negotiation. It is worth noting that green water in this paper is entirely different from the colloquial one being used for the water held in soil and available to plants [2].

The second component, termed "Yellow Water", is the amount of available water that the upstream states can control while not requiring that water for consumption. Upstream states do not tend to announce formally or informally that they capture water from the transboundary river beyond their demand. In order to achieve it, they attribute the need for hydro energy or flood control as the driving force behind the construction of extensive hydraulic structures, facilitating the water capture in upstream regions. However, yellow water is the most mysterious part of available water to downstream states because it can serve many other purposes than what upstream states declare, from promoting negotiation power abroad to reinforcing military power [30]. This particular component conforms to the notion put forth by Homer-Dixon (1994) regarding water that instills apprehension in downstream states owing to the possibility of its utilization by upstream states as a tool of coercion [44] (p. 19). A large amount of the yellow water does not guarantee more water for the downstream states but represents a possible basis for negotiation. In a nutshell, this component of available water for the upstream states allows the downstream states to utilize it under successful negotiations. Thus, a wise downstream state does not take yellow water for granted, even if it is already identified as water rights in a treaty. This water component can be considered as "negotiable water" in a transboundary basin.

Finally, "Red Water" refers to the portion of the captured available water by upstream states that is fully demanded or consumed by different sectors and regions within the upstream states. Downstream states are less likely to be successful in obtaining any drop of this amount of water. Negotiating over red water requires complex strategies (e.g., Issue linkage, see [27] for the case of the Mekong). Red water is, therefore, a "non-negotiable" water in the basin among upstream and downstream states. Contrary to yellow water, upstream states tend to overestimate their declared red water in order to reduce their obligations to provide water to downstream states. Furthermore, this excuse allows upstream states to take advantage and continue their hydraulic development unstoppably.

The messages that each color brings for downstream states is similar to triage in medicine and traffic lights, which are the reasons we chose these colors in our paper. Like triage colors, the green water maintains that downstream states need less urgent negotiation with their upstream states. Correspondingly, the yellow water implies that downstream states need urgent negotiation with their upstream states. And finally, the red water implies a need for urgent negotiation procedures to move away from a non-negotiable setting among upstream and downstream states.

The dynamic nature of painted water resembles a traffic light in which colors may change over time. In this way, the green volume allows downstream states a free water withdrawal. At the same time, downstream states should be prepared to adjust the amount of yellow water volume as soon as upstream states can control all or part of the green water, either technically or financially. As yellow water may become red if it is consumed out of necessity rather than interest by upstream states, downstream states should exercise caution when using it.

The color combination of painted water in upstream states is important to downstream states in terms of which combination is included in the water demand of downstream states. That helps downstream states regulate internal and international water management strategies (Figure 1).

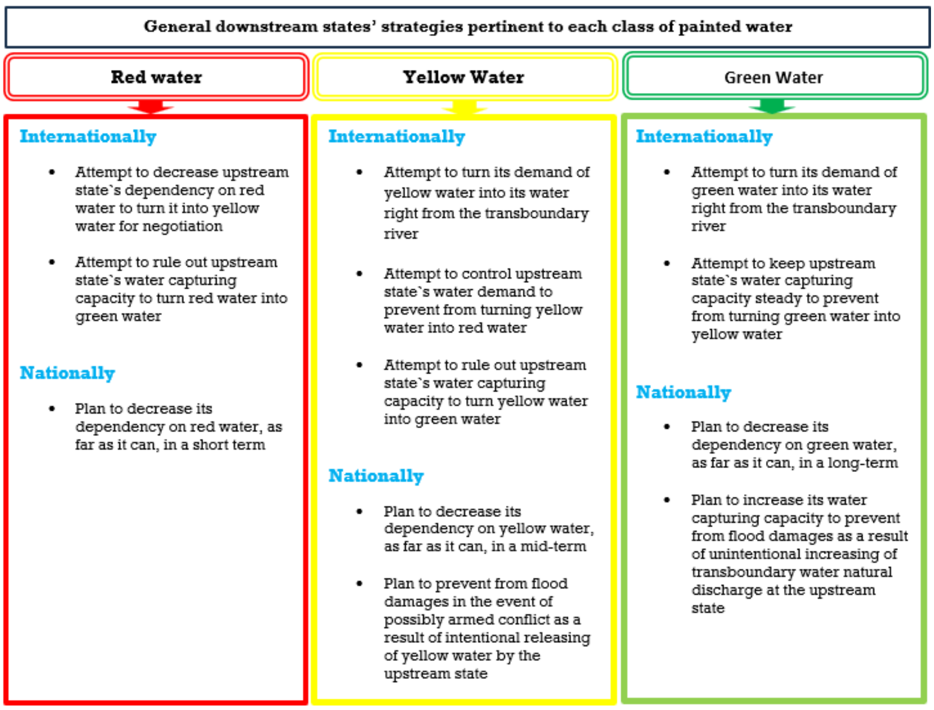

Figure 1. Downstream states' water strategies are pertinent to each painted water class.

A combination of painted water classes in downstream water demand from the upstream state determines the complexity of negotiation before the downstream state. For this, seven situations are possible which reflect seven negotiation classes. They are mapped schematically in Figure 2.

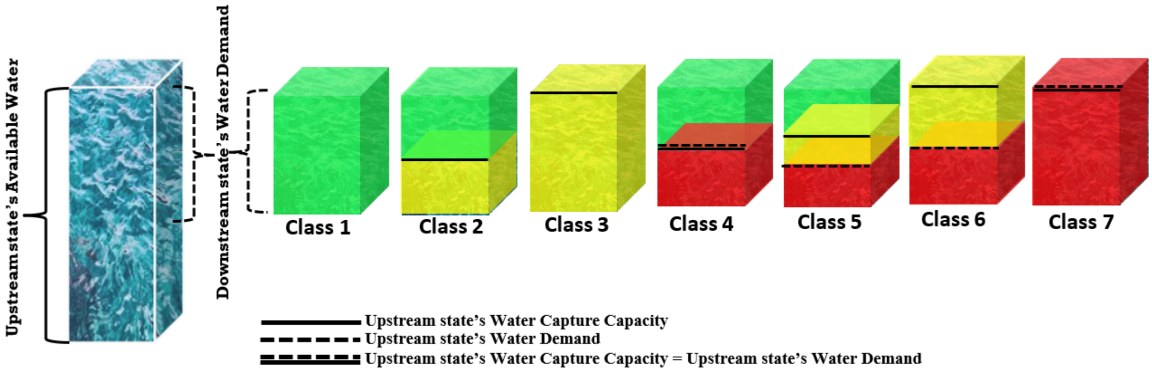

Figure 2. Schematic of a downstream state's water demand through painted water lens. Notes: (1) The definitions and descriptions of the various classes (C1–C7) are explained in the following text. (2) The levels of painted water in the different classes are for demonstration purposes and do not refer to a specific empirical situation. (3) The order of the classes does not reflect the order of the transition between classes.

Class 1 (Dream Water): This class captures a situation in which the total water demand of downstream states can be met within the upstream states' green water. As there is no need for negotiation, this class represents an ideal situation for all downstream states. Riparian states with proactive water strategies take this class very seriously because many of the international water treaties have been signed during this class (e.g., Amu Darya—1843, Euphrates and Tigris—1930 Nile—1959, Indus—1960, and Lake Chad—1964 shared river basins treaties).

Class 2 (Trust or Dare): This class denotes a situation similar to Class 1; however, a part of the downstream states' water demand lies in the yellow water. Therefore, downstream states need to negotiate with the upstream states to obtain water. This class can be considered a sign of starting the hydraulic mission in the upstream states and instinctively tends to turn into more complex classes as water demand increases for upstream states. Downstream states can either trust the benevolent intention of the upstream states to keep generating or developing this part of yellow water or keep it at its original level.

Class 3 (Give-and-Take): This class is determined by the whole of the downstream states' demand for yellow water. In this situation, the downstream states' water supply entirely depends on negotiation with the upstream states to release the desired yellow water. The downstream states hope to meet their water demand given the fact that the upstream states do not require this type of water for consumption. Falling into this class narrows the fact that the resultant downstream states' strategies could not prevent hydraulic missions in the upstream states during Classes 1 and 2. However, the downstream states should be prepared for the process of give-and-take while keeping an eye on the drivers responsible for moving from this class to more complex ones. This is the most desired class for any upstream state because it can take maximum advantage of the privilege of being an upstream state, termed geographical power [37].

Class 4 (Purgatory): If a downstream state bears this class, it means that it should expect a decrease in part of its water demand by accepting red water to fill in for the reduction in its water supply. This situation leaves the downstream states with no other options nor possibilities for negotiation over red and green water, respectively.

Class 5 (Fear and Loathing): This class resembles Class 4 but adds more complexity to it. In this class, downstream states should negotiate with upstream states to supplement their water demand with yellow water after reducing their expectation of receiving water in the red category. Downstream states still enjoy meeting their water demand from the green water in this class though.

Class 6 (Hope Gap in Twilight): In this class, there is no hope for green water to meet the downstream states' water demands. Downstream states should brace for laying aside activities relying on the red water and gear up for a serious negotiation with upstream states over the rest of their water demand. This class tends to convert into the most complex class (i.e., Class 7).

Class 7 (Duel): The most complex, this class barely leaves hope for downstream states to meet their water demand from the transboundary river, even through negotiations are supported with major bargaining power. Upstream states tend to unreasonably raise the cost of negotiations with downstream states. However, when they do this not only the downstream states but the entire transboundary basin will also be at stake. Thus, this class can be treated as the most undesired class for all of the riparian states.

There is no robust rule for placing the classes in a particular order of importance for a downstream state. However, for the same water demand and water capture capacity by upstream states, the order of classes is compatible with the ascending order of complexity facing the downstream states. Likewise, no rule is recommended for the order of transition among the classes because many factors are responsible for shaping the dynamics. The increasing population [1,45] and global temperature [46] are the main drivers for rising water demand and reduced natural discharge in basins worldwide. Those factors strengthen the speculation that the transition instinctively tends to move from Class 1 to Class 7 globally, not necessarily in the order of class number. In that regard, environmental drivers (like climate change) as well as interventions by riparian states play significant roles in leading both the direction and the speed of transition among classes as explained below.

For instance, increasing natural discharge at upstream states will shift the downstream states towards less complex classes by reducing the possibility of including red water in their water demand. Moreover, increasing water demand in both downstream and upstream riparian states, as a result of climate change, will propel the basin towards Class 7.

Human interventions, such as invoking power, can unquestionably determine painted water classes in the basin. For instance, geopolitically, if three out of four pillars of the hydrohegemony concept [37], including bargaining, material, and ideational powers, skew towards the upstream states already enjoying geographical power, described as "Bully and bullied" situation [47], the transition highly tends to convert into complex classes. In contrast, if an equilibrium of power occurs between the upstream and downstream states, described as an "escalation" situation [48], the upstream states cannot easily maintain their hydraulic mission. As a result, the classes barely develop into complex ones and will play out within a range that imposes less pressure on downstream states. In the following section, we apply the idea of painted water to a case study of the Blue Nile River Basin.

3. Materials and Methods

3.1. Analyzing Painted Water in the Blue Nile River Basin

The dynamics of the painted water set in an upstream state depend partly on the upstream state's activities and partly on external impacts (e.g., climate change). To formulate the dynamics, we consider a shared river basin that crosses two or more riparian states within a specified period, lasting between t0 and tn. Dinar (2008) catalogued 226 bilateral rivers in the world into 13 geographies [6]. Of all 226 bilateral international rivers that Dinar (2008: Appendix B) analyzed at that time, 100 are through border, 16 are border creators, and all the rest include all other 11 geographic configurations [6]. In that year, the number of identified international basins that are a combination of configurations of the main two we discussed (Dinar 2008: Appendix B) (including multilateral) was 271 [6]. Ten years later, McCracken and Wolf updated the number of international basins using new measuring techniques [49]. Their count was 310 international river basins, of which 232 are bilateral and the rest are multilateral. As can be seen from these analyses, the majority of the cases have through-border geography, thus making our focus on through border relevant for this paper.

For this purpose, we investigate the Blue Nile (BN) river basin, which originates in the Ethiopian highland at Lake Tana and is the source of nearly 80% of the total Nile River's streamflow below Khartoum, where it meets with the White Nile. The BN travels through Ethiopia and Sudan and drains an estimated natural discharge equal to 88 billion cubic meters (BCM) per year in Ethiopia, a negligible amount in Sudan, and no contribution in Egypt [50]. It is a major source of the flooding of the BN in Egypt and contributes to 50% of the water flow (55 BCM) of the High Aswan Dam (HAD), which was constructed in 1970 in lower Egypt [51,52]. The river also serves as an important resource of water and hydropower for Sudan, where dams produce 80% of the country's hydroelectric power and help to irrigate high-quality cotton, wheat, and animal feed crop production [53,54]. Therefore, Ethiopia's hydraulic mission affects the water flows of the downstream states, particularly in Egypt.

The history of water relations among the three riparian states indicates cooperation and conflict since the 1950s [55]. In November 2012, Ethiopia began unilaterally constructing the Grand Ethiopian Renaissance Dam (GERD), a 6000-megawatt hydroelectric dam on the river with a capacity equal to 79 BCM, of which 59 BCM have been utilized [56]. Sudan and Egypt, however, voiced their concerns over their potential reduction in water availability (ibid).

Ethiopia, Sudan, and Egypt have no trilateral treaty, except the 1959 treaty that Ethiopia challenges. In that regard, Ethiopia focuses on its geographical hegemony so that Amer (2015) casts serious doubt on increasing the dam's size and storage capacity compared to earlier plans in Ethiopia by opening a debate on whether the objective of the dam is actually more about controlling water flow than about the production of hydropower [55]. On the other hand, Egypt highlights past dependency and uses its regional and international power to destabilize Ethiopia's hydraulic mission [48,57]. This escalation is entirely compatible with what Zeitoun and Warner posit that "upstream-ers use water to get more power, downstream-ers use power to get more water" [37] (p. 46).

Most of the attempts at looking to present policies to stabilize the BN suggest trilateral cooperation to put an end to the game of "dam and power" [53,54]. However, it is not that easy to implement in practice. The riparian states exhibit very complex behaviors, replete with contradiction and inconsistencies in the basin since negotiations started in 2011, which instills ambiguity into the shared water analysis. For instance, in the year 2022, decisions regarding the BN have included a variety of contradictory behaviors. These have included Egypt's unwavering stance, as demonstrated by its declaration that "all options are open" to get water from Ethiopia [58], and Ethiopia's resolute commitment to its hydraulic mission, which it has stated "no power on the earth" can prevent the hydraulic mission [59]. On the contrary, both riparian states have also shown a willingness to engage in negotiations [59–62]. Similarly, while joint military drills have been conducted by Egypt and Sudan over Ethiopia's massive dam project [63], Sudan's alignment with Ethiopia on all issues regarding the Grand Ethiopian Renaissance Dam comes out [64].

This paper utilizes the painted water concept to scrutinize some of the possible future directions in water flows of BN riparian states. In the following section, the methodology is designed to map the painted water combination in Ethiopia and Sudan as upstream states as well as painted water classes that are imaginable for Sudan and Egypt as downstream states in the long term. Moreover, we explore the contribution of the painted water concept to add value to the course of studies dealing with the BN negotiation.

3.2. Methodology

To assess whether the painted water concept could support the BN water negotiations, we had two options: going backward or forward. The former deals with mapping painted water based on the historical records of water demand and water capturing in the basin. The latter does so based on prospective scenarios, which help decision-makers identify ranges of potential outcomes and impacts, evaluate responses, and manage both positive and negative possibilities in the future. Given that negotiation support systems are designed to facilitate international water negotiations [38–43] and typically address an uncertain future through scenario planning, we have opted for a forward or proactive approach that relies on projections and hypothetical scenarios that may or may not come to fruition [65,66]. This helps us evaluate the applicability of the idea in resonating with decision support models (Figure 3). However, this method comes with derived equations (Box 1), simplifying assumptions, and parameter estimation (Box 2) as well as related caveats discussed in the next section in more detail. In looking for a model to generate long-term data under global scenarios, we adopted the IFs (International Futures) model (Figure 3). The IF model was developed in the Pardee Centre for International Futures, University of Denver, Colorado [67], to analyze a set of data from the past and present as well as possible trends in the future under global scenarios. The forecasting model incorporates the United Nations Environment Program's (UNEP) Global Environment Outlook (GEO) series, renowned for its comprehensive evaluation of the global environment, policy responses, and future projections by countries. This integration enables the analysis of extensive data from diverse fields including economics, geopolitics, environment, and international relations [68]. Based on priorities to which state governments adhere, scenarios introduced in our model are "Market first", "Policy first", "Security First", and "Sustainability first", which are explained in detail in Box 3.

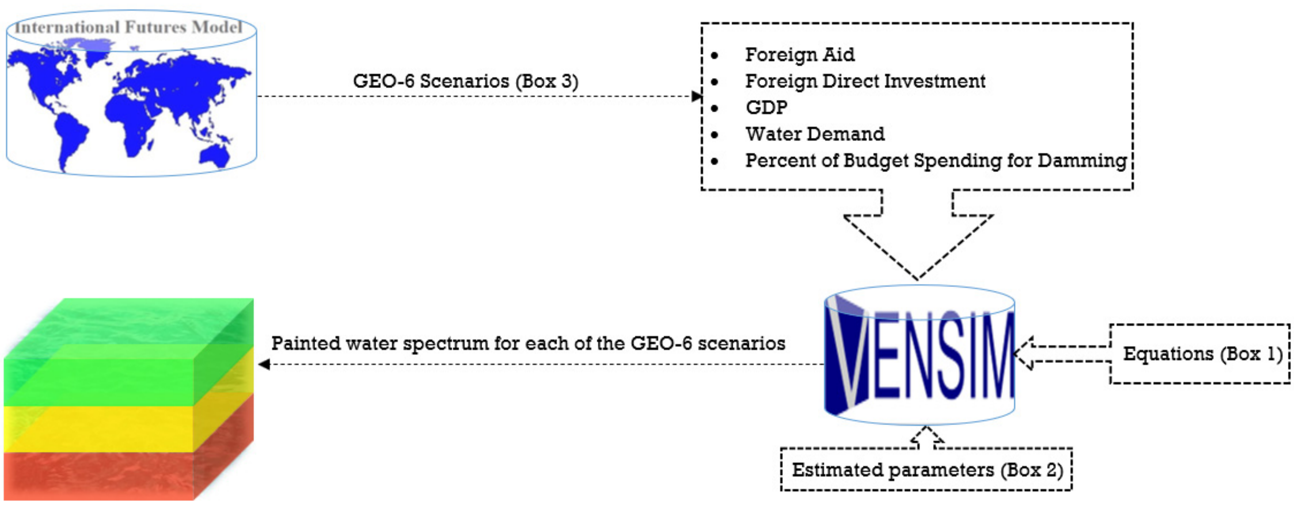

Figure 3. The adapted what-if scenario analysis method in the paper.

Box 1. Equations to calculate painted water attributes in a transboundary river.

(1) $AW_n(t) = Green\ Water_n(t) + Yellow\ Water_n\ (t) + Red\ Water_n(t)$
(2) $AW_n + 1(t) = Green\ Water_n(t)\ Yellow\ Water_n(t) + ND_{n+1}(t)$
(3) $AW1(t) = ND_1(t)$
(4) $TSD(t) = FDI(t) + (GDP(t) + FA(t)) \times PBSD(t)$
(5) $WCC(t) = \frac{TSD(t)}{CUDC(t)}$

AW through the painted water lens:

(6) $Green\ Water_n(t) = MAX[AW_n(t) - WCC_n(t),\ 0]$
(7) $Yellow\ Water_n(t) = MAX[MIN[AW_n(t), WCC_n(t)] - UWD_n(t),\ 0]$
(8) $Red\ Water_n(t) = Min[AW_n(t), WCC_n(t), UWD_n(t)]$

DWD through the painted water lens:

(9) $D.Green\ Water_n(t) = Min[Green\ Water_n(t), DWD_n(t)]$
(10) $D.Yellow\ Water_n(t) = Min[(DWD_n(t) - D.Green\ Water_n(t)),\ Yellow\ Water_n(t)]$
(11) $D.Red\ Water_n(t) = DWD_n(t) - D.Green\ Water_n(t) - D.Yellow\ Water_n(t)$

Where:
t = time step (year).
n = The order of the states in the basin along the river flow (n = 1 implies the upstream state from which the transboundary river's tributaries originate).
ND= The Natural Discharge feeding the transboundary river flow in the upstream state's territory (Usually, the largest amount of ND occurs in the river's tributary at the first upstream state) (MCM/year).
WCC = The upstream state's Water Capture Capacity in the basin (MCM/year).
AW = Total Available Water of transboundary river flow in the upstream state's territory (MCM/year)
UWD = Upstream state's Water Demand from the AW (MCM/year)
DWD = Downstream state's Water Demand from the AW (MCM/year)
D = Downstream state's demand from the painted water
PBSD = Percent of Budget Spending for Damming (%)
TSD = Total Spending for Damming ($/year)
CUDC = Cost per Unit of Dam Capacity ($/year)
FA = Foreign Aids ($/year)
FDI = Foreign Direct Investment ($/year)
Moreover, the extracted equations in the model, assumptions, and sources of exogenous variables are represented in Tables S1 and S2 in the Supplementary in more detail.

Box 2. Simplifying assumptions and sensitivity analysis for estimated parameters.

Simplifying assumptions are:
(1) Entire upstream state's AW can flow to the downstream states;
(2) The model is run under a stable hydrological condition during the analyzed timeline. As a result, Ethiopia's natural discharge (ND) in the BN river basin was considered the constant amount at around 88 BCM, based on its average value, and for Sudan, it was considered zero [50];
(3) The model generates the maximum possible water capturing capacity, assuming that the financial ability is considered as the sufficient condition for that;
(4) The average cost per capturing is estimated at 1 $/m^3$, averaging the costs for constructing and maintaining large dams;

The model has been used in a sensitivity analysis for previously assumed exogenous parameters. This was performed by simulating painted water flow, ranging the main uncertain variable values within a domain with a 20% deviation from the estimated value. The targeted variables for the analysis are listed in the following parameters:

- Parameter 1: Ethiopia's percent of FDI being dedicated to the country's water capture capacity (primary estimation is explained in the Supplementary, Figure S4)
- Parameter 2: Ethiopia's DP (primary estimation is explained in the Supplementary, Figure S5)
- Parameter 3: Ethiopia's ND (primary estimation is explained in the Supplementary, Figure S6)
- Parameter 4: CUDC (primary estimation is explained in the Supplementary, Figure S7)
- Parameter 5: Sudan's DP (primary estimation is explained in the Supplementary, Figure S8)
- Parameter 6: Sudan's percent of FDI being dedicated to the country's WCC (primary estimation is explained in the Supplementary, Figure S8)

The results are presented in Figures S4 to S8 in the Supplementary concentrating on the security based scenario as the pessimistic one.

Figure S4 indicates that changing parameter 1 values has no significant effect in causing uncertainty in the painted water flows in Ethiopia. In contrast, doing so for parameter 6 affects red and yellow water flow in Sudan, according to Figure S8.

Ranging parameter 2 values have affected the results in Sudan while it causes a moderate change in yellow and red water flow in Ethiopia (Figure S5). Parameter 5 indicates no significant uncertainty in Sudan's red water flow, but it has caused a spectrum of uncertainties in its green and red water flows until the middle of the analyzed period (Figure S8).

The uncertainty of parameter 3 as an environmental factor, which was considered zero for Sudan, has led to a substantial band of uncertainties in the painted water flow of both countries (Figure S6). As a result, climate scenarios will play a considerable role in determining painted water flow in the basin.

Scrutiny of the results for parameter 4 indicates no significant uncertainties for Ethiopia's painted water flow during the entire analyzed period, but considerable uncertainty for yellow and green water flows in Sudan during the early years of the analyzed period.

Box 3. Geo-6 Global scenarios in the IFs model.

Market first Scenario: From the GEO-6 description depicted in the IFs model online manual [67] appearing during the model run, "The private sector, with active government support, pursues maximum economic growth as the best path to improve the environment and human well-being. Lip service is paid to the Brundtland Commission's ideals, agenda 21, and other major policy decisions on sustainable development. There is a narrow focus on the sustainability of markets rather than on the broader human-environment system. Technological fixes to environmental challenges are emphasized at the expense of other policy interventions and some tried-and-true solutions."

Policy first Scenario: From the GEO-6 description depicted in the IFs model online manual [67] appearing while running the model, "Government with active private and civil sector support, initiates and implements strong policies to improve the environment and human well-being, while still emphasizing economic development. Policy first introduces some measures to promote sustainable development, but the tensions between environmental and economic policies are biased towards social and economic considerations. The emphasis is on more top-down approaches, partly due to desires to make rapid progress on key target."

Security first Scenario: From the GEO-6 description depicted in the IFs model online manual [67] appearing while running the model, "Government and private sector compete for control in efforts to improve, or at least maintain, human well-being for mainly the rich and powerful in society. Security first, which could also be described as me first, has as its focus a minority: rich, national and regional. It emphasizes sustainable development only in the context of maximizing access to and use of the environment by the powerful."

Sustainability first Scenario: From the GEO-6 description depicted in the IFs model online manual [67] appearing while running the model, "Government, civil society and private sector work collaboratively to improve the environment and human well-being, with a strong emphasis on equity. Equal weight is given to environmental and socio-economic policies, and accountability, transparency and legitimacy are stressed across all actors. As in Policy first, it brings the Brundtland commission's idealism to overhaul the environmental policy process at different levels."

The generated data by the IFs for each scenario are mapped (in a graphic mode) in Supplementary Figures S1 and S2 for the period 2020–2100.

To translate the generated data by IFs into painted water language, we adopted Vensim professional software (for windows version 5.5a), relying on system dynamics modeling [69] from which derived equations (Box 1) and estimated parameters addressed in Box 2 are extracted (Figure 3). The software considers the IF's data as exogenous variables and works with the stock flow diagram, as depicted in Figure S3 in the Supplementary Materials.

The verification of the generated data by IFs was performed by [67]. However, the Vensim model only works as a prism to turn generated data into a painted water spectrum under each scenario. As a result, based on the derived equations (Box 1) and estimated parameters (Box 2) in the paper, a set of sensitivity analyses were performed, the results of which are presented in Supplementary Materials, Figures S4–S8.

4. Results and Discussion

4.1. Dynamics of Painted Water and Classes in the BN

Given the methodology to assess the dynamics of painted water combinations in upstream states and to recognize related painted water classes for downstream states (Figure 3), the model was run under quadruple Geo-6 global scenarios to the year 2100. Correspondingly, results have been mapped in Figures 4 and 5. They are discussed from each riparian state's point of view and the entire basin's sustainability viewpoints as follows.

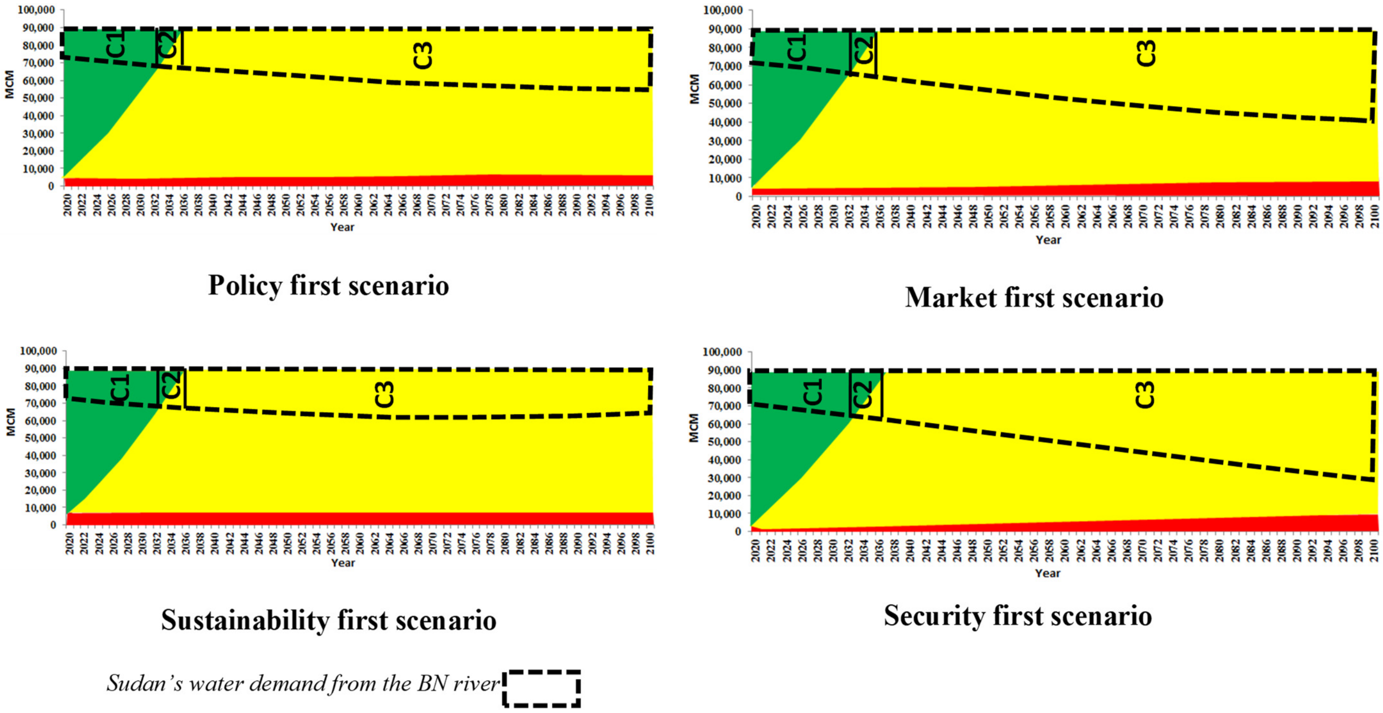

Figure 4. Simulated results for Ethiopia's available water from the BN through a painted water lens and negotiation classes before Sudan.

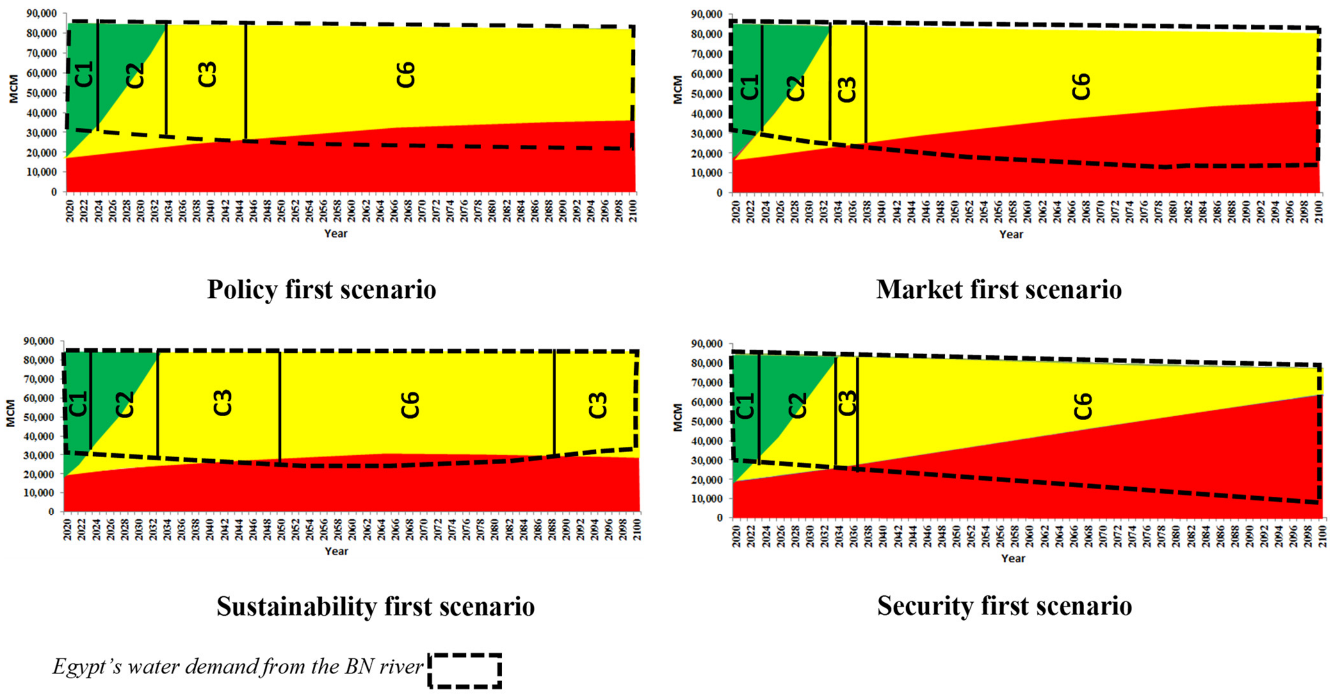

Figure 5. Simulated results for Sudan's available water from the BN through a painted water lens and negotiation classes before Egypt.

Results in Figure 4 indicate that Ethiopia will continue to generate a large amount of yellow water in the long term after running all scenarios. The acquisition is important and could result in Ethiopia taking the hydro-hegemony position in the basin. The maximum potential for Ethiopia in this regard is if downstream states keep relying on yellow water, at best resting in Class 3 (Figures 4 and 5).

Outputs represent a possible transition from painted water Class 1 to Class 3 in the case of Sudan, while experiencing a very short period of Class 2 after running all scenarios (Figure 4). Although this reflects undesired changes in Sudan's situation, the good news is that there would still be enough space to meet Sudan's water demand through a give-and-take process with Ethiopia (a long-term painted water Class 3 appears in all scenarios in Figure 4). Consequently, Sudan's main strategy is to plan for a successful negotiation with Ethiopia while being hopeful of the presence of water in the country as a key negotiation element.

Running scenarios for painted water in Sudan and highlighting Egypt's painted water classes infer that the situation would be much more complex in Egypt than in Sudan (Figure 5). Accordingly, painted water dynamics in most of the scenarios, in particular the security one, suggest it is possible that Egypt could remain in painted water Class 6 for a long time (Figure 5). And if such a class of painted water is realized, a large amount of red water that market and security first scenarios suggest must be kept in mind (Figure 5), which seriously jeopardizes Egypt's national security. Only in that situation does Egypt's "all options are open" strategy make sense and thus should be taken seriously by all riparian states.

According to the results in Figure 5, Sudan and Egypt's growing water demands are blamed as the most effective factors for causing Egypt to move from painted water Class 2 to Class 6. Even so, the results suggest that Egypt can still avoid such an undesirable class by changing its transition path towards Class 3, similar to what the sustainability scenario suggests in Figure 5. Then, Egypt would need to decrease both Sudan's and its own water dependency on the BN River in parallel with or even before dealing with Ethiopia. In the event that Egypt succeeds in doing so, it will be able to maintain negotiations with Ethiopia and remain optimistic about the availability of yellow water.

It is evident from Figures 4 and 5 that painted water Class 1 will be a myth in the BN and sooner or later it will be superseded by Class 2 and then Class 3 or 6 in both downstream states. Moreover, we witness much more speed in doing so in the real world than what the results suggest because the end of the Renaissance Dam construction that maintains passing painted water Class 1 in the downstream states has recently been revealed by Ethiopia [63].

Overall, results suggest a substantial transition in painted water combination in upstream states in the near future, which will affect the stability of all riparian states in the long term (Figures 4 and 5). To prevent unintended consequences, all riparian states should regulate their strategies to prevent the conversion of painted water classes in the downstream states into more complex ones. To do so, they should embrace the forthcoming transition in the BN as follows. During a relevant transition period, Egypt should decrease or stop its growing dependency on BN water as an ongoing transition in its painted water class. A neglected point in previous efforts, the results reveal that Sudan plays a pivotal role in changing Egypt's painted water classes. As a result, Egypt should monitor Sudan's water demand and assign high priority to supporting the country in its water demand management even before negotiating with Ethiopia. That will lead to preventing Egypt from falling into the complex painted water classes in the future. Moreover, Egypt should avoid military operations [58] that complicate negotiations with Ethiopia, at least as long as it would not have reached painted water Class 6. Otherwise, it would not be surprising if Sudan gives up following Egypt in accusing Ethiopia in the future to abstain from taking a position that hardens its negotiation with Ethiopia [64]. Similar to Ethiopia, Sudan can take advantage of its geographical power provided that Egypt does not fall into complicated painted water classes. In a situation as such, Sudan could enjoy Egypt's technological and financial power in the name of benefit-sharing [70] to decrease its water demand while it has the upper hand in negotiations with Egypt.

As the first upstream state, Ethiopia should regulate its strategies to hold downstream states in painted water Class 3 to take the hydro-hegemony position in the basin. To this end, Ethiopia should not let its painted water set change anymore in the future because it could force downstream states into complicated painted water classes that could jeopardize all the riparian states.

4.2. Limitations

We applied the idea of painted water in the BN as an example to assess a part of the potential of painted water concept in a simplified multilateral shared river basin. Consequently, the following caveats need to be addressed:

- As the adopted methodology relies heavily on data already generated by the International Futures (IFs) model, there was not enough space in our calculations to study all human and natural factors. The paper attempted to portray a big-picture view of the prospective scenarios in the future, which may or may not happen. Therefore, highlighting the role of human and environmental interventions, in particular power and climate change, would have significantly accurate results;
- The importance of environmental drivers in the painted water analysis was already explained. Additionally, the sensitivity analysis results revealed the pivotal role of natural discharge as the most sensitive factor causing uncertainties (Box 2). However, we assumed natural discharge for a normal value according to the long-term historical records which has wide space for improvement;
- As water-capturing capacity relies on dam construction, it plays an immense role in estimating painted water combinations; the more accurate methods in doing so will improve the results significantly. Here, the maximum financial ability to do so has been assumed as the representation for water capturing which comes with either over- or under-estimation of the potential hydraulic mission in upstream states;
- Over and above that, calculating water demand both in upstream and downstream states was handed over to the IFs model, which is designed for yearly time steps at a global scale. Whereas, water decision support models tend to work with monthly time steps at the basin scale. Moreover, there is a lost opportunity because the spatio-temporal dimensions of water resources such as seasonal changes in water storage and water-rich and water-poor sub-basins are not represented in the current approach. So, it is worth incorporating an accurate water resources decision support model to do so more precisely.

As a whole, the limitations outlined above do not call into question the basis of the painted water concept or the methodology for analyzing the data.

4.3. Future Avenues

As mapped in Figure 6, the traditional path of employing decision support models as negotiation support systems in transboundary basins [38–43] deals with water supply and demand under climate and barely human scenarios without considering possible hydro-hegemonic processes by upstream states, a topic that can be discussed from a hydropolitical perspective. The traditional course is not smart enough to awaken downstream states of the possibility of transition among painted water classes which may lead to a complex negotiation. As a result, a typical decision support model cannot be expected to advise downstream states to be more cautious about green water dependence, to recognize the possibility of water terrorism due to an unusual increase in yellow water, to be prepared to reduce their water dependence due to a possible increase in red water, etc. Accordingly, one could never see a decision support model suggesting that the upstream states "satisfy the downstream states as long as they depend on it" to retain their geographic power in the region or warn them of the possibility of armed conflict as a result of the increase in red water. Here, the painted water concept has been employed to deepen the purview of decision support models to prepare them for a proactive negotiation which has not been the case in the past (Figure 6).

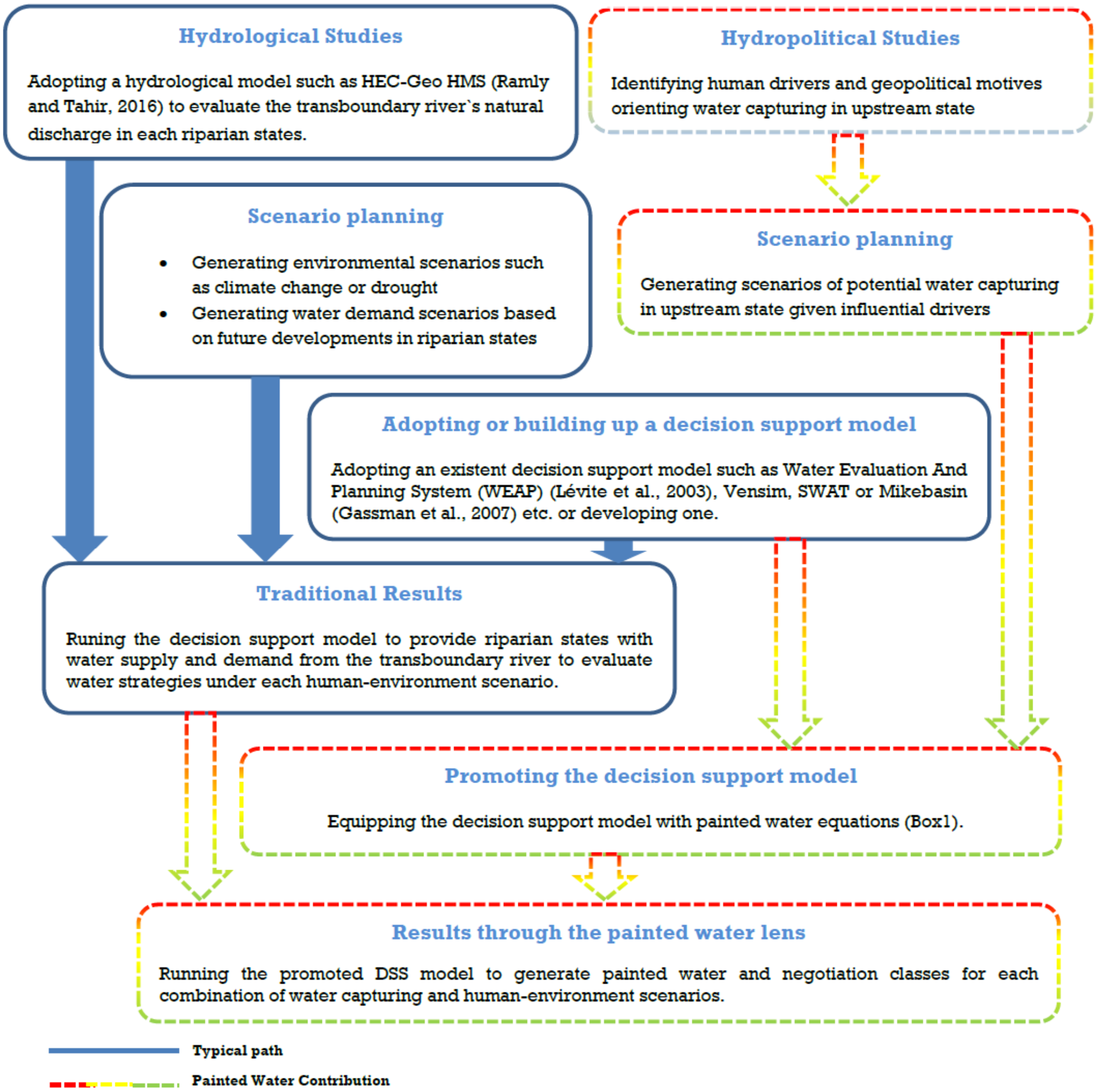

Figure 6. A schematic of the added value of the painted water concept to the typical approach in adapting decision support models for transboundary river negotiations [71–73].

Nevertheless, this concept should not be limited to decision support models and it can contribute to rethinking and promoting other concepts, theories, and principles in the field of transboundary river negotiation. The following are some fundamental research questions in the context of painted water analysis that should be carved out and rethought: How can this concept be used to promote water allocation approaches among riparian states, such as game theory [74] in a transboundary basin? In what ways can painted water classes be used to promote databases that map and forecast water conflict and cooperation in transboundary basins worldwide [75,76]? Would the painted water classes serve as a complementary measure to the reassessment of the "basin at risk" concept [77]? In order to support SDG 6.5.2, can the concept be used to assess cooperation in a transboundary basin [78] with regard to painted water combinations and classes in transboundary rivers throughout the world? Is the presence of yellow water a viable indicator for assessing the geographical power of upstream states within the framework of hydro-hegemony [79]? Can commitment to the "equitable and reasonable utilization" article [80] determine painted water classes or can painted water classes contribute to measuring commitment? In light of the essence of yellow water that can serve the upstream states as mobilization for power in war, how can painted water contribute to studies on water terrorism [81,82]? Furthermore, how can it do so with red water, which leaves no choice for downstream states but excludes the capacity of the upstream states to capture water, especially in a situation around painted water Class 7? Many other aspects and disciplines can be examined and reviewed using the painted water concept.

5. Conclusions

Due to the difference between upstream states' water capture capacity and water demand, downstream states have difficulty calculating their foreign water strategy and national water policy. While traditional negotiation supports models treating transboundary river flow as a whole without making distinctions in terms of negotiability, we suggest that the painted water idea classifies upstream states' available water flow into three triage colors and seven classes in terms of negotiability in distinctive time steps (years). The paper argues that downstream states should consider painted water dynamics and negotiation classes when forming their future water strategies. We examined the concept in the BN basin, designing a simple what-if scenario analysis approach based on projection. The results shed light on part of riparian states' general directions for future interactions with upstream states. As such, it provides proactive ideas and warnings for each of the riparian states to support their future decisions. The results suggest that, under the mapped global scenarios, respecting each other's interests, either in terms of water or power demand, is best for all riparian states. The painted water concept would have been able to capture hydropolitical scenarios better than typical decision support models, which typically focus on water supply and demand. The concept seeks to promote the philosophy of applying decision support models for negotiation rather than adding a complex accessory to them. Thus, even if assumptions were oversimplified, this article was a stepping stone for incorporating the painted water concept into shared river negotiation models.

The application of the painted water concept can extend beyond the mere promotion of decision support models. It thus encompasses a wide range of knowledge from hydrology to hydropolitics, integrating approaches and models from various fields. Providing a common language to a diverse group of scholars, this concept provides a framework for addressing some of the difficulties associated with multidisciplinary perspectives in water negotiation, which Warner and van Buuren, (2016) have dubbed a "wicked" issue in transboundary river management [83] (p. 76). The present paper leaves the door open to more studies based on the concept to promote multidisciplinary terms in shared river negotiations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w15193343/s1, Figure S1: Ethiopia's variables generated by the IFs model, 2020–2100; Figure S2: Sudan's variables generated by the IFs model, 2020–2100; Figure S3: Stock-Flow Diagrams (SFD) in the Vensim model; Figure S4: Sensitivity analysis results of painted water (MCM) in Ethiopia and Sudan's territory for estimated parameter 1 (Within four confidence bounds); Figure S5: Sensitivity analysis results of painted water (MCM) in Ethiopia and Sudan's territory for estimated parameter 2 (Within four confidence bounds); Figure S6: Sensitivity analysis results of painted water (MCM) in Ethiopia and Sudan's territory for estimated parameter 3 (Within four confidence bounds); Figure S7: Sensitivity analysis results of painted water (MCM) in Ethiopia and Sudan's territory for estimated parameter 4 (Within four confidence bounds); Figure S8: Sensitivity analysis results of painted water (MCM) in Sudan's territory for estimated parameters 5 and 6 (Within four confidence bounds); Table S1: Exogenous variables used in the model; Table S2: Equations used in the model for endogenous variables.

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