VALUES OF THE BLUE NILE

An evaluation of the Nile Basin Decision Support System from a values perspective

Timo Eijkelkamp
October 29, 2021

TU Delft

Values of the Nile

An evaluation of the Nile Basin Decision Support System from a values perspective

by

T.A. Eijkelkamp

to obtain the degree of Master of Science
at the Delft University of Technology,

Student number: 4354125
Project duration: November 4, 2020 – October 29, 2021
Thesis committee: dr. ir. Edo Abraham, TU Delft
dr. Erik Mostert, TU Delft
dr. Abby Onencan, TU Delft

TU Delft

1

Abstract

The Blue Nile is characterised by growing tensions between Ethiopia, Sudan and Egypt related to increasing demands for water and upcoming unilateral developments. Growing efforts towards basin wide cooperation from the international and scientific community have led to the development of a common decision support tool, the Nile Basin Decision Support System (NBDSS), but applications are still limited. This thesis assumes that a discrepancy between values included in the design of the NBDSS and values that actually play a role in decision making might contribute to the lack of implementation. This assumption involves two important research gaps, namely the absence of a clear overview of values of decision makers in the Blue Nile countries and the capabilities of the NBDSS in considering all values in decision making. This thesis aims to fill these research gaps and finally test the assumption by evaluating the NBDSS from a value perspective. The evaluation uses four elements, namely design requirements to allow value considerations, design values of the NBDSS, actor values and associated potential conflicts and synergies. This thesis produced two main results that are valuable to the academic conmmunity, namely a list of values associated with water resources for each Blue Nile country and an evaluation of the NBDSS from a value perspective.

Literature review resulted in five design requirements: transparency, participatory development, flexibility, useful information and reasonable value judgements. Document analysis and model assessment yielded nine design values that should constitute the core functionalities of the system, namely economy, environment, equity, inclusiveness, international cooperation, society, sustainability, trust and usability. However, none of the analysed documents on the NBDSS talks about value considerations explicitly.

Discourse analysis was applied on political sources from Ethiopia, Sudan and Egypt to identify the prevailing discourse and underlying values in the countries. This resulted in the discovery of two discourses: one discourse that focuses on the transboundary nature of water resources management and accentuates values related to international relations and another discourse that focuses on domestic aspects of water resources management, highlighting the national economic and social values with a strong focus on agriculture. The analysis further resulted in the deduction of values associated with water resources, both mutually shared between countries or country specific. Shared values are agriculture, cooperation, participation, knowledge and international equity. Within the analysed discourse, Ethiopia particularly values energy, national pride and socio-economic development. For Sudan, environment, society, livestock and national government are of particular importance. Egypt mainly demonstrates value for agriculture, technology and identity.

The similarities and differences between the respective values provide potential for conflict and cooperation. An already observable value conflict can be attributed to Ethiopia's value of pride and Egypt's value of identity. Other potential value conflicts arise due to differences in definition of spatial equity and society and due to the mutual valuation of agriculture. On the other hand, mutual valuation of cooperation, knowledge, participation and economy provide possibilities for fruitful interaction and point to design features with significant support and related potential impact.

The NBDSS can play a facilitating role for the consideration of values in decision making. The use of a participatory tool such as the NBDSS can activate statement of and discussion on values, thereby creating a sense of mutual understanding between participants. It can contribute to achieve the objectives of the NBI to shift towards decision making from a regional perspective. Such processes

require a cooperative attitude and a sense of trust between the participants, which seem to lack in the transboundary context of the Blue Nile region. Both trust and mutual understanding can gradually be increased by first assigning a central role to national values and interests in the evaluation of transboundary development strategies. When relationships are improved, a gradual shift towards trade off assessment associated with exchanging sovereignty for negotiated benefits could be made, placing the regional perspective central. The NBDSS is particularly capable of assessing scenarios based on economic and environmental values, but its output might lack depth on social aspects.

Value considerations are further restricted by: 1) the failure of national governments to bring the complex and diverse range of national values into transboundary negotiations; 2) the importance of non-operationalisable values such as cultural-ideological ones; 3) a lack of transparency at the governance level of the NBDSS, including data sharing; and 4) the absence of a clear protocol and measurable attributes to monitor distributional aspects related to both harms and benefits. To reduce these limitations, it is recommended to implement the NBDSS at different scales (e.g. locally, nationally and regionally), to develop a clear protocol for monitoring of spatial and social equity and to create awareness of the limitations of the NBDSS in considering all values. Local deployment of the tool can contribute to identification of locally residing values and interests. In case such knowledge is properly communicated towards the national representatives in the transboundary decision making process, this would allow them to pursue a more inclusive version of ”the national interest” during the evaluation of transboundary development strategies. It would further lead to an increased trust in the system because of the focus on national interest, and increase local and national capacities as a result of the increase in application. Additionally, NBDSS output should be combined with qualitative assessment and interpretations of non-quantifiable values in order to consider them before taking a decision. It therefore is essential to be aware of existence and definition of the value, as well as of the limitations of the NBDSS. Nevertheless, even full understanding of such interactions between values and decisions can only be effective when the cooperative attitude of the participants is increased. The main limitations to unlock the full potential of the NBDSS are human induced, thereby acknowledging the relevance of values in such decision making processes, particularly on water resources.

2

Preface

This thesis marks the end of my time as a student at TU Delft, a journey that started back in 2014 because of a deep admiration for the mightiness of civil constructions. Apparently, my interests have shifted to a ”softer” field of study over the years. The endless possibilities to select courses during the master track Water Management has provided me with the possibility to study the social sides of water resources. In the end, it turned out that people are as fascinating as structures. My specific interest for the endless variation in human perceptions and desires became the starting point of this final master thesis, although I had little experience with such researches. Despite the difficulties that came with this inexperience, the topic has never disappointed. It even triggered me to apply for a position related to Integrated Water Resources Management in Ethiopia.

On the other side, the feeling of loneliness that came with all restrictions regarding the worldwide pandemic posed major challenges to my work ethic. I sincerely belief that writing a thesis at the faculty with various like-minded students around can be a pleasant and fruitful period in your academic journey. My perception of writing a thesis is slightly different. Nevertheless (or maybe therefore), I am beyond proud of the final product here in front of you. It would not have been possible without the guidance of my committee. Edo, you have given me the freedom to pursue my own interests within the field of water management. Your introduction to the world of values in design have opened a new chapter for me, for which I am grateful. Erik, your typical humorous approach always contributed to my confidence and pleasure. Thanks for the endless conversations on the concept of discourse, which was completely new to me at the start of this thesis. Abby, you were always ready with relevant contacts. It is a shame I could not use them to the full extent. In addition, your kind words after the green light meeting deserve a special appreciation.

I would like to use this space as well to thank my parents for their endless support, both mentally and financially, during my academic career. Lastly I would like to thank my lovely housemates and friends, who have dealt with me during not-so-happy moments but, more importantly, always were there to celebrate my highlights. I count on you for the latter after the presentation.

Contents

List of Figures

List of Tables

Nomenclature

CBA	cost benefit analysis
DHI	Danish Hydraulic Institute
DSS	Decision Support System
$GERD$	Grand Ethiopian Renaissance Dam
$IWRM$	Integrated Water Resources Management
MCA	multi-criteria analysis
$NBDSS$	Nile Basin Decision Support System
UN	United Nations
VFT	value-focused thinking

3

Introduction

Over the past decades, the Nile Basin has been characterised by inefficient water use, unilateral developments, climate change and rapid population growth (Cascão, 2009a; Nile Basin Initiative, 2012). This has increased tensions between states, brought to a new height by the construction the Grand Ethiopian Renaissance Dam (GERD) along the Blue Nile. This tributary constitutes the major part of the river Nile, both in terms of catchment and discharge, and covers parts of Ethiopia, Sudan and Egypt (see Figure 3.1). The Blue Nile is the main source of water for the latter two countries, who have therefore opposed the construction of the dam. However, multiple authors put an emphasis on the importance of transboundary cooperation in water resources development. Verhagen (2020) showed benefits from cooperative scenarios for all three Blue Nile countries using a water-energy-food model. Mason (2004) mentions that international cooperation is important to ease long-standing international tensions and support national development, mitigating poverty, unemployment and internal conflicts. Onencan and Enserink (2014) use different scenarios to demonstrate that unilateral optimisation yields short term benefits, but poor regulation and inequitable utilisation of water resources can lead to loss of benefits in the future.

Figure 3.1: Overview of the entire Nile basin. The Blue Nile origins in Ethiopia and meets the White Nile in Sudan, from where they continue as the Main Nile towards Egypt and the Mediterranean Sea.

The promotion of transboundary cooperation led to the formation of the Nile Basin Initiative (NBI), an

intergovernmental organisation founded in 1999 which formulates its main objective to be "*to achieve sustainable socio-economic development through the equitable utilisation of, and benefit from, the common Nile Basin water resources*". One of its main projects is the release of the Nile Basin Decision Support System (NBDSS). This platform offers tools for information sharing, analysis and evaluation of water resources strategies and is designed to contribute to informed decision making on water resources developments in the basin. However, application of the tool has so far been limited.

Different authors highlight the potential of using a Decision Support System (DSS) for finding sustainable cooperative water management strategies (e.g. Teodosiu et al. (2009); Georgakakos (2007); Marcomini et al. (2008)). In combination with the work of the NBI, the urgence for basin-wide interaction and usage of the NBDSS seems to be evident. Nevertheless, tensions remain and usage of the NBDSS is still limited (Jonoski and Seid, 2016). This raises the question whether the DSS in its current form is able to meet the requirements for a widely acknowledged and uniformly used tool to support decision making in the complex field of water resources management in the Nile basin.

Multiple studies have addressed shortcomings of DSSs in the field of water resources management. Giupponi and Sgobbi (2013) studied DSS implementation in water resources management in developing countries. They found the limited impact on end-users due to lack of usage after project completion as the major source of frustration amongst experts. This is unlikely to be the case with the NBDSS, because it was not created for a single project purpose. Nevertheless, it is more challenging to meet the requirements for development of a suitable and useful DSS in developing countries, because of lack of data, low data quality, insufficient modeling capacity, lack of stakeholder participation and challenging political decision making contexts. Transboundary river basins covering multiple countries even add to the challenge (Giupponi and Sgobbi, 2013; Jonoski and Seid, 2016).

In addition, multiple authors refer to a lack of inclusiveness in DSS design, e.g. by lacking integration and inclusion of different disciplines and decision levels (Georgakakos, 2007), by neglecting linkages and trade offs across different dimensions (Gregory and Keeney, 2002) or by lacking to bring all the right stakeholders to the table (Giupponi and Sgobbi, 2013). These disciplines and dimensions refer to physical sciences (e.g. biology, physics and chemistry) as opposed to social sciences (e.g. psychology, economy and policy analysis). A lack of integration and trade offs can potentially result in an incomplete range of objectives (Gregory and Keeney, 2002). Similarly, the exclusion of certain disciplines, decision levels or stakeholders might result in missing perspectives and objectives. In that case, decisions based on DSS results do not reflect the full range of values and interests, which might result in less effective management strategies. Inclusion of the full range of actor values in the design of DSSs is therefore essential for the success of the particular system.

The importance of value based decision making in resources management is addressed by multiple authors. Gregory and Keeney (2002) mention specifying and organising values and usage of values during development of alternatives as an unmissable step in evaluating natural resource options. Bradley et al. (2016) state that inclusion of values supports the creation of alternatives with a better chance of acceptance and successful outcome. Yet in the case of the Blue Nile a clear overview with values of the actors relevant to water resources management still lacks. This master thesis suggests a link between the underuse of the NBDSS and the lack of a clear and explicit overview of relevant values that should be part of every decision making process on water resources management. The main question it seeks to answer is:

"What role can the Nile Basin Decision Support System play in the consideration of all values in decision making at the Blue Nile level?"

This main question is first divided into five subquestions, which allows to separate this large question into manageable parts:

1. *What are the main advantages, requirements, challenges and limitations for a decision support system to consider values in decision making on water resources management?*
2. *Which values are considered for design and usage of the Nile Basin Decision Support System (NBDSS)?*

3. *Which values and associated value conflicts and synergies play a role in the position of decision makers at the Blue Nile level?*
4. *To what extent does the NBDSS incorporate the identified design requirements and design values and what are the consequences of exclusion?*
5. *To what extent is the NBDSS able to address the applicable values, value conflicts and synergies?*

This thesis uses a qualitative approach based on literature study, model assessment and discourse analysis. These methods are chosen over travelling to the study area and conduct interviews with decision makers, which has been impossible due to COVID-19 restrictions. It is acknowledged that engagement of stakeholders, experts and decision makers in a participatory decision making process is essential to generate useful, accepted outcomes (Gregory and Keeney, 2002; Bradley et al., 2016; Hill et al., 2019). Discourse analysis does not provide such a participatory platform. However, this method can identify values and moral judgements that underlay claims and arguments of actors (Hermans, 2005; Hermans and Thissen, 2009). In addition, the method has been applied in other studies to identify values related to water (e.g. Mostert (2015)) and values in the political discourse (e.g. Sowińska (2013)). Therefore, this work uses the hypothesis that an analysis of the political discourse on water resources in Ethiopia, Sudan and Egypt allows to identify actor values associated with these water resources. This hypothesis is validated by explicitly relating the obtained values to their context and to other researches. In addition, this thesis presumes that values should matter in decision making and therefore should be considered in DSS designs. This research aims to test this hypothesis. To this end, theoretical requirements for value-inclusive DSS design are derived from literature. In addition, the design values considered during development of the NBDSS are determined based on documents mapping the development stages of the system. The derived design requirements, design values, actor values, and the associated value conflicts and synergies are projected onto the NBDSS in order to test its capabilities and limitations.

The objective of the research is therefore twofold:

- To present an overview of the main values and interests of actors in current decision making practices at the Blue Nile level;
- To evaluate the NBDSSS from a values perspective, thereby identifying its capabilities and limitations.

Reading guide

Chapters follow the sequence of the research questions. Chapter 2 provides a theoretical framework on values associated to water resources, their impact on decision support systems and the potential role of such systems in considering these values, thereby answering the first research question. Chapter 3 introduces the structure, components and functionalities of the NBDSS. Chapter 4 presents the applied methods for identification of values, including an explanation of the applied form of discourse analysis. In Chapter 5, the design values considered for the NBDSS are derived, thereby anwering the second research question. Chapter 6 shows the results of discourse analysis, consisting of two discourses and mutual and specific values for Ethiopia, Sudan and Egypt and their respective conflicts and synergies. Chapter 7 evaluates the NBDSS based on the derived design criteria, design values, actor values and value conflicts and synergies. Finally, Chapter 8 discusses the value and validity of the research, while Chapter 9 presents the main conclusions and recommendations.

4

Theoretical framework

This chapter provides the theoretical support for the used methods described in Chapter 6. This theoretical framework includes classifications of values relevant for water resources management, the inclusion of values in decision making and the potential role of DSSs with respect to value considerations.

A clear definition of the term *value* is essential to understand its relevance to both water resources management and general decision making. Different understandings of the term *value* exist, but in this research, it describes ”the importance people attribute to an entity, to a relation or a state of the world, or to the contribution of an action towards user specified goals, objectives or conditions” (Diaz et al., 2014). In this definition, values are always linked to a human actor and are therefore essentially human attributes, based on principles and judgements. This definition is understood to distinguish potential objects of values to be either things (or entities), relations or (changes in) a state of the world. Here, contributions towards user specified goals, objectives or conditions are interpreted to equal certain desired changes in state of the world, based on objectives or goals. These objectives and goals can also be seen as more specific expressions of values (Hermans and Thissen, 2009).

4.1. Values in water resources management

Values play a key role in natural resources management in general and water resources management in specific (e.g. Groenfeldt (2019); Liu et al. (2011)). The range of values that can be associated with nature has grown over the years, resulting in the emergence of different categorisations (Jacobs et al., 2018). The Total Economic Value framework used to be the governing approach for valuation of nature. This framework is based on a purely economic definition of value and divides values into use and non-use values. However, this thesis uses a more elaborate categorisation of values, distinguishing between:

1. Instrumental vs. Relational vs. Intrinsic values (Diaz et al., 2014)
2. Individual vs. Cultural values (Schwartz, 2011)
3. Actual vs. Ideal values (Schwartz, 1992)
4. Economic vs. Environmental vs. Social vs. Cultural values (Cardwell et al., 2006); (Giupponi and Sgobbi, 2013); (Hill et al., 2019)

The first categorisation that is used in this thesis was proposed by Diaz et al. (2014) and uses so-called dimensions: they define values of natural entities for themselves, independently of the impact on humans, as ”intrinsic” or ”non-anthropocentric” values; the benefits of nature to people as ”instrumental” values; and values relating to good quality of life and relationships among human beings and between human beings and nature as ”relational” values. These relational values cover the non-use values from the Total Economic Value framework, which include existence and bequest value[1]. However, the definition of intrinsic value contradicts the statement that values are essentially human. Furthermore, Mellor (2007) states that separation automatically leads to different forms of domination, exploitation

[1] Existence value reflects the benefits people receive from knowing that a particular natural environment or resource exists, without seeing or using it. Bequest value is defined as the value of allowing further generations to enjoy a resource or ecosystem.

and finally environmental degradation, and therefore criticises intrinsic values for separating humans from their environment.

Examples of relational values associated with water resources are principles of (inter)generational equity or a sense of identity emerging from ancient rivers such as the Nile. Intrinsic values can for example relate to the river as an ecosystem, or biodiversity. Instrumental values can be divided into three categories (Postel et al., 1997):

- Extractive benefits related to water supply, such as household water use, irrigation or industrial consumption;
- Extractive benefits other than water, such as fish, sediments and mussels;
- Non-extractive benefits such as flood control, transportation, hydropower generation and wildlife habitat.

Schwartz (2011) further distinguishes between individual and cultural values. The former are an aspect of personality and used by individuals, while the latter are at the core of societal institutions and are used by groups or society at large. In this thesis, ”societal values” is used to describe cultural values in the sense of Schwartz. Cultural values is namely used to describe values that for example relate to a sense of tradition, religion or identity. Schwartz argues that values function in different ways at these two levels. Nevertheless, individual and cultural values might influence each other. When people have little individual freedom (e.g. through totalitarian regimes), this might lead to limited expression or even change of personal values. In addition, highly ranked individuals can have significant influence on important societal institutions, e.g. through policy documents or rules and regulations that might be based on individual values of decision makers or directors rather than on cultural values of the relevant group. This holds for organisations as well as for countries or societies as a whole.

Following Schwartz (1992), values can further be categorised in ideal values, used to judge and justify behaviour (e.g. in public discourse) and actual values that are enacted in practice and embodied in institutions and artefacts. Ideal values are often expressed in policy documents (Mostert, 2018).

The last classification is based on value themes. Within literature, commonly described values that play a role in decision making on water issues and the according decision support are environmental, economic and social values (e.g. Cardwell et al. (2006), Giupponi and Sgobbi (2013), Hill et al. (2019)). These values are also referred to in the concept of Integrated Water Resources Management (IWRM) as explained by the United Nations (UN, nd). Some authors replace environmental by the slightly more demarcated term ecological (e.g. Gregory and Keeney (2002)). Here, ecological focuses on the interactions between organisms with each other and their surroundings, where environmental focuses on the interaction between chemical, physical and biological processes in the environment and their impact on organisms in particular. Some authors specifically distinguish cultural values next to the common three (e.g. Giupponi and Sgobbi (2013), Hill et al. (2019)). Note that these are not cultural values as described by Schwartz (2011), as these are called societal values from here.

These values can be classified using intrinsic, instrumental and relational values as well. Economic values often relate to use values (e.g. agriculture, industry, transportation, energy) and are therefore instrumental. Social and cultural values can either be instrumental (e.g. drinking water or water for religious purposes) or relational (e.g. equity or identity). Environmental values can either be intrinsic (e.g. ecosystem stability), instrumental (e.g. trees providing shadow and coolness) or relational (e.g. living in harmony with nature). The earlier mentioned non-use values, existence and bequest, can also be linked to relational values, as it describes a relation between either human and nature (existence) or humans across different generations (bequest).

This thesis analyses the actors in the Blue Nile on an international level. Countries and organisations are interpreted as being one actor. Following Schwartz’s reasoning, the focus will therefore be on societal values rather than individual ones. The distinction between instrumental, relational and intrinsic values allows for classification of the identified values.

4.2. Values in decision making and decision support

This section discusses the different existing approaches to incorporate values in decision making and the possibilities of decision support tools to contribute to this incorporation.

4.2.1. Values in decision making

Within literature, two fundamentally different approaches to group decision making[2] are described: the more traditional alternative-based approaches (e.g. cost-benefit analysis (see Boardman et al. (2017)) and multiple criteria decision making (see Opricovic and Tzeng (2004)) and the more recently emerged value-focused approaches (see Keeney (1994) for a theoretic description and Bradley et al. (2016) for an application).

In alternative-based approaches, decision making is supported by first reducing the number of options, and second by selecting the best fit for purpose option from this predefined group. Selection can be based on a diverse range of criteria, depending on the selected strategy. These approaches have been criticised for limiting the options to already available alternatives that may not even contain the best possible one (Keeney, 1996); for being reactive rather than proactive (Aramo-Immonen and Vanharanta, 2009) (Keeney, 1996); and for overlooking the importance of organisational values and participants in the decision making process (Williams and Fang, 2019). According to Bradley et al. (2016), alternative-based decision-making does consider values, but often in an implicit way rather than explicitly stating the full range. As a result, values are often not fully taken into consideration in the process.

These critics have led to the emergence of value-based approaches to decision making, shifting the aim from solving decision problems towards identifying desirable decision opportunities and create alternatives (Keeney, 1996). This means that alternatives are assessed more explicitly before the decision is made, in order to improve the quality of the alternatives under consideration. In addition, value-focused thinking can create ”decision opportunities” rather than the traditional decision problems by uncovering hidden objectives and improving communication among stakeholders (Keeney, 1994). Two key principles in Keeney’s value-focused thinking (VFT) framework are that values should be made explicit and structured at the start of the decision process, before other activities, and should be explicitly used to create alternatives and identify decision opportunities (Keeney, 1996). Explicit statement of values, and related objectives and criteria to define and measure their attainment, promotes a more transparent, inclusive and defensible process (Bradley et al., 2016).

The significance of values in decision making on natural resources has received increasing attention, and different methods to facilitate value-based decision making have been formulated. Langsdale et al. (2013) offer a set of principles and best practices for collaborative modelling to cope with value laden decisions in resources management. Lynam et al. (2007) provide a list of different participatory methods to include local knowledge, preferences and values in decision making related to natural resource management. Gregory and Keeney (2002) present a more general approach: a step-by-step method to include values into environmental management decisions following the first five[3] steps of decision making for both personal and management problems as proposed by (Hammond et al., 1999):

1. Clarify the Problem
2. Identify Key Objectives
3. Create Alternatives
4. Assess Consequences
5. Address Trade offs Explicitly

[2] Decision making can also take place at the individual level, e.g. buying new clothes or finding a job. See e.g. Russo and Carlson (2002). However, the focus in this thesis is on group decision making.

[3] Hammond et al. (1999) actually define eight key elements. The first five elements constitute the core of a structured approach to decision making. The remaining three elements - Uncertainty, Risk Tolerance and Linked Decisions - are more specialised concepts for professional managers Gregory and Keeney (2002).

These five steps are generic for all decision making processes. Following the VFT-framework, values should be made explicit already before other the start of other activities. However, it is difficult to identify and structure relevant values when the problem at hand is yet to be defined. The often implicit character of values adds to this challenge. Therefore, it is useful to include values only after the problem is fully and explicitly described. Keeney acknowledges this by stating that values can be made explicit through formulation of objectives with a significant depth, clear structure and sound conceptual base (Keeney, 1994) (Keeney, 1996), corresponding to step 2 in the list above rather than step 1. In addition, it demonstrates the aforementioned link between objectives and values and shows that objectives can even be expressions of values as suggested by Hermans and Thissen (2009). It often requires active discussion to make values explicit, for example in terms of choices for objectives or alternatives (e.g. Steen and Van de Poel (2012)).

4.2.2. Values in Decision Support Systems

Decision support is a part of decision making processes, is meant to help people with making decisions and is a discipline within decision sciences. Different authors use varying formulations, but the general idea is that decision science can be divided into three broad areas of study, namely a normative, descriptive and prescriptive approach[4] (see French et al. (2009), Kangas et al. (2015), Bohanec (2003)). The normative approach analyses ideal theoretical decision making, based on e.g. decision theory or game theory. Descriptive approaches study real-life decision making, which involves psychology and behavioural sciences and is particularly useful for analysing politics. Finally, prescriptive approaches focus on how to help people make better decisions by combining elements from normative and descriptive approaches. Raiffa (1994) describes the latter as *"giving real people, as opposed to super rational people, some thoughtful guidance about how they might wish to act in a wiser fashion in real situations."* Obviously, this area is the domain of decision support, which exists in many different forms. In essence, pen and paper or a drawing board can already provide support to making a decision, being a structural decision support tool. Other examples relate to qualitative decision support strategies, such as brainstorming or mind mapping. Bohanec (2003) further highlights some specialised disciplines within decision support, including decision analysis and decision support systems.

The collective term Decision Support System (DSS) is used for computerised tools that support and follow the guidelines of structured decision making, in order to aid decision makers selecting an action out of a set of alternatives (Bradley et al., 2016). These systems generally make use of databases and information systems, containing large amounts of available data and information. Water resources management is one of the application areas for DSSs. According to Teodosiu et al. (2009), these are generally computerised systems that integrate watershed processes at different spatial and temporal scale, simulation models and decision making approaches. DSSs can vary in area of application, decision-making approach, levels of decision-making (e.g. individual, group or organisational) and depth (e.g. single objective, multi-objective, constraints) and can either be case specific or generically applicable. As a result, the design of a decision support system depends heavily on the choices during the development process. The inclusion of values into the system therefore already depends on the development process and its participants. Scope in terms of relevant problems, alternatives, users and information, as well as selection of evaluation methods and modelling tools all involve preferences and choices.

Different visions on inclusion of values within DSSs exist, that reflect the distinction between alternative-based and value-based approaches. Georgakakos (2007) mentions the importance of participatory DSS development in order to include all relevant disciplines. As a result, values are already taken into consideration during the different design stages of the system. This vision relates to the previous statement that choices on DSS development might contain information on value inclusion. On the contrary, Black and Stockton (2009) only consider values as "value judgements" during evaluation of alternatives, referring to decision analysis as a facilitating tool within the DSS to finally make a decision.

[4] French et al. (2009) indeed uses a distinction between these three areas. Kangas et al. (2015) distinguish only descriptive and prescriptive approaches, where the prescriptive approach is called "normative"; in other words, the normative approach is included in the prescriptive approach rather than stated separately. Bohanec (2003) uses indeed three approaches, but uses the term Decision Support directly for the prescriptive approach, instead of only linking it. However, the description of this area is the same.

This means that value considerations are relevant for assessing trade offs and finally making a decision in the DSS as well. These value judgements do not have to be predefined already in the development stage, but might be flexible for each application of the system. Therefore, there are two areas of interest to analyse value inclusion in decision support systems:

1. Choices on scope in the development stage
2. Value judgements during assessment of trade offs and evaluation.

Other perspectives on participatory approaches exist as well. Hill et al. (2019) show that the use of DSSs might have an impact on the participants within environmental planning processes such as water resources management, because of differences in positions and in the ability to work with such tools. In addition, Gregory and Keeney (2002) state that group participation might stimulate conformation and choices that fail to include individual priorities, especially those of minorities. This thesis therefore suggests that an objective evaluation of values included in the final version of decision support systems, even if it is developed using a participatory approach, can yield relevant results.

4.3. Role of DSS in decision making

This section starts with an explanation of possible facilitating roles of a DSS regarding value considerations in decision making in WRM. These are related to two main challenges that exist regarding WRM and decision making:

1. the increasing number and diversity of stakeholders, interests and values (in Section 4.3.1);
2. the often ineffective link between knowledge and action, or between information and decisions (in Section 4.3.2).

However, this role can be limited. Section 4.3.3 discusses four potential limiting factors for DSSs in order to consider all values. Section 4.3.4 reflects on three key challenges in integration of values into design and decisions, namely value conflicts, value operationalisation and value dynamics, Combination of these analyses reveals that implementation of DSSs can have adverse effects on a decision process from a values perspective.

4.3.1. DSSs and value induced complexity

WRM has become more complex over time due to the growing number and diversity of stakeholders, values and interests (e.g. (Giupponi and Sgobbi, 2013); (Ravesteijn and Kroesen, 2015)). These add to the already complex interactions between hydrologic, social and biophysical systems and the consequent competing requirements, non-linear behaviour and contradictory identifications and multiple definitions, interpretations and solutions (Pierce, 2006); (Giupponi and Sgobbi, 2013). Computerised models such as DSSs can contribute to address this increasing complexity to facilitate decision and policy making (Van Daalen et al., 2002). For example, Gastélum et al. (2009) developed a DSS for the Mexican Concho basin and specifically mention the provision of a better and more detailed understanding of the complexity of the water resources management process to water resources decision makers at different political levels as main objective of development. Giupponi and Sgobbi (2013) state that *"DSS tools providing operational MCAM [Multi Criteria Analysis Methods] can significantly contribute [to the decision making process] by making explicit conflicting values and individual preferences, thus facilitating decision makers to interactively examine the trade offs between objectives and to aggregate individual preferences"*. In addition, a DSS can actively support decision making by developing a shared understanding of the nature of problems and of values and interests of others (Jonoski and Seid, 2016).

The stages of facilitation cover problem definition and objective selection on one side and evaluation and selection of alternatives on the other. These stages can be linked to the first five steps of decision making for both personal and management problems as proposed by Hammond et al. (1999) (see Section 4.2.1). The former links to step 1 and 2, while the latter links to step 5. In addition, participatory planning approaches can contribute to make values and interests explicit, which can be valuable both

during development and usage of a DSS (Geertman, 2006). This implies both a new requirement and a new potential role. The requirement is the application of participatory planning approaches which is reflected upon later on. This however enables the consideration of values already during development of a DSS. In this way, DSS development already stimulates active consideration of values. The potential role of a DSS in addressing this growing complexity, resulting from changing and newly emerging values, to decision makers is therefore multifaceted.

Both problem definition and objective setting imply a participatory process, involving active discussion on what is considered to be relevant or important. A ready-to-use DSS does not seem to provide a clear facilitating role in doing so. This is acknowledged by the creators of the NBDSS, who state that contribution of the framework starts from development of scenarios (step 3 in the World Bank scenario evaluation approach), while both problem definition (step 1) and objective clarification (step 2) occur earlier in the process (Nile Basin Initiative, 2015). Therefore, it is rather assumed that the availability of a DSS stimulates discussion without providing a concrete functional tool to guide this discussion. This is supported by Zack (2007), who state that face-to-face interaction is more effective than a DSS in solving equivocality[5].

Secondly, a DSS can help in identification, ranking and selection of new or improved management strategies, which can be considered the main function of these systems for decision makers. In order to do so, DSSs are equipped with multiple tools in order to analyse simulation results, compare them and score them using a range of criteria. These criteria can be based on stakeholder objectives. Weights can be applied in order to account for specific stakeholder preferences, resulting in multiple rankings based on each stakeholder perspective. A comparison between these rankings enables the identification of inferior alternatives (i.e. an alternative that is outscored by another alternative according to each point of view) and alternatives that have more desirable results from one or more points of view. In addition, these rankings provide a more detailed and explicit valuation of alternatives, highlighting potential for value conflicts and synergies between different stakeholders. Multiple authors mention these type of insights and emerging discussions as valuable for WRM decision processes (e.g. (Zack, 2007), (Giupponi and Sgobbi, 2013)). Apparently, these type of explicit value statements and discussions are valuable during development of the DSS (Geertman, 2006), problem definition and objective setting (Keeney, 1996); (Keeney, 1994); (Zack, 2007);(Jonoski and Seid, 2016) and evaluation and selection (Zack, 2007);(Giupponi and Sgobbi, 2013).

The use of DSS with regard to value considerations and complexity is therefore twofold: 1) a DSS facilitates ranking, evaluation and selection of alternatives; and 2) a DSS stimulates discussion on values, preferences and interests in different stages of the decision process, which already starts during development. The former is a more concrete approach towards operationalisation of values in decision making, while the latter stimulates value thinking within decision making.

4.3.2. DSSs as the link between information and decisions

A DSS can play a role in linking knowledge and action, or science and policy, a key challenge in decision making (Cash et al., 2002). Junier (2017) calls a DSS *"a possible means of supplying expertise to the policy domain"*, providing decision makers with insights in the effects of possible decisions. Zack (2007) distinguishes two roles for a DSS, namely a concrete and relevant translation of complexity, such as discussed above, and the production of new information. The authors describe the former as limiting an overload of information, while the latter is about filling information gaps with newly produced data. In both cases, the information is used by decision makers in order to base their decisions on. Therefore, information should be trustworthy, relevant and complete (Junier, 2017) (McNie, 2007).

McNie (2007) mentions credibility, legitimacy and salience as criteria for information to be useful to decision makers. Cash et al. (2002) provides descriptions of these terms in the context of information for decision makers, describing salience as *"the relevance of information for an actor's decision choices, or for the choices that affect a given stakeholder"*, legitimacy as *"whether an actor perceives the process in a system [including decision support systems] as unbiased and meeting standards of political and procedural fairness"*, and credibility as *"whether an actor perceives information as meeting standards of*

[5] "multiple interpreations of the same thing" (Zack, 2007). This is understood to be applicable to complex WRM issues involving multiple stakeholders with a different understanding of problems and objectives.

scientific plausibility and technical adequacy". Salience than refers to context-specific, relevant information that considers among others regulatory constraints, political constraints and values and beliefs of stakeholders, while legitimacy also refers to issues of transparency (McNie, 2007). Enhancement of these three criteria increases the potential for acceptance of future decisions (e.g. Deelstra et al. (2003); McNie (2007); Cash et al. (2002)).

A DSS can contribute to enhancement of credibility and legitimacy of information. The use of scientifically proven methods and relations in the underlaying models increases credibility of the produced information. This scientific basis should be clearly demonstrated, by means of sound communication of limitations and assumptions and provision of sensitivity and statistical analyses (Junier, 2017). Uniformity and structure in the decision making process offered by a DSS, in combination with proper data management and sharing, increase transparency and consequently legitimacy of the information generation process. Openness on data, assumptions and restrictions is essential for a DSS to ensure trust in the produced information and consequently enhance support for final decisions (Geertman, 2006). Unfortunately, a lack of transparency is mentioned to be one of the main limitations of current available DSSs (van Delden et al., 2011). Finally, salience is facilitated by a DSS through its clear scope and demarcations, which is related to the issue of complexity as well. This again is part of the participatory process in which both information users and producers are involved, in order to determine which info is relevant to the final decision makers.

Trade offs between the three requirements occur, for example between legitimacy (whose perspectives are included) and credibility (information should be scientifically proven). Junier (2017) mentions another example of a trade off through the link of evidence production and policy development. On one side, information should be scientifically sound for it to be credible. On the other side, information should be relevant and useful for policy and decision making, resulting in considerable influence of decision makers on the produced evidence. This suggests a trade off between two values, namely credibility, which can be linked to the governing value of trust, and salience, which links to usability.

The descriptions of credibility, legitimacy and salience used above include the perception of users as an important factor. The idea of useful information might differ from one user to the other, for example in terms of which topics are seen as relevant or whose perspectives are to be taken into account. Many authors propose stakeholder involvement in the development process as a means to cope with these differences and increase acceptance and trust beforehand and, consequently, use after completion (e.g. Hewitt and Macleod (2017)). Therefore it is important to bring all the right stakeholders and disciplines to the table. Missing perspectives and interpretations might decrease support for final decisions and pose problems during implementation of solutions (e.g. Giupponi and Sgobbi (2013); Georgakakos (2007)).

4.3.3. Limitations to and requirements for value considerations in DSS

The two sections above contain two key requirements to allow usage of a DSS for value considerations in decision making, namely 1) openness and transparency, and 2) a participatory development process. This chapter shortly explains the two, followed by two often described limitations to the role of DSS in value considerations, which are 1) inflexibility and inadaptability of DSSs; and 2) bias in access and outcome, whether or not caused by abuse of power.

Openness and transparency

The value of transparency is discussed in terms of increased trust and legitimacy of a DSS. Without transparent reasoning and usage of assumptions, data, models and inclusions, such systems tend to become a so-called ”black box” (Junier, 2017). Transparency seems especially important in a transboundary context where decision makers of different countries interact with a DSS and might try to use it in their advantage. Limited insights into the underlaying assumptions might reduce trust in the outcomes of such a system and therefore might limit implementation.

Participatory processes

Participatory approaches, both in DSS development and WRM planning, are required in order to cope with value complexity and keep information useful. Such collaborative approaches generate mutual

understanding and trust that create a sense of legitimacy (Bingham, 1986). Giupponi and Sgobbi (2013) state that DSS tools can provide capabilities for the management of participatory processes, by providing procedures for analysis of social networks, individuals' preferences, priorities and value judgements. This potential to empower participation in a structured and scientifically sound way can therefore be seen as an additional benefit of DSS development and application to value considerations in decision making. The success of participatory processes depends on the attitude of those participating, as it requires a certain degree of willingness to cooperate. This poses a requirement to the participants, both for the design process of a DSS as during usage of the system for WRM planning processes.

Other perspectives on participatory approaches exist as well. Hill et al. (2019) show that the use of DSSs might have an impact on the participants within environmental planning processes such as water resources management, because of differences in positions and in the ability to work with such tools. In addition, Gregory and Keeney (2002) state that group participation might stimulate conformation and choices that fail to include individual priorities, especially those of minorities. The latter might be applicable on both DSS development and WRM decision making using DSS. These notions however contradict with earlier mentioned reasons to implement participatory processes in the first place, implying a need for proper management and execution in order to reduce potential bias. Giupponi and Sgobbi's vision suggests a potential role for DSS in doing so. This thesis further suggests that a retrospective evaluation of the value considerations during development of a DSS can yield relevant results for improvement of inclusiveness and prevention of group think.

Inflexibility and inadaptability

Inflexibility is said to be a major reason for non-use of DSSs (van Delden et al., 2011). Inability to adapt to evolving needs might limit the inclusion of values belonging to newly emerged stakeholders (Walker, 2002). A lack of both adaptability and flexibility might pose requirements to scenarios, alternatives and the associated input data, limiting the range of understandings of a decision problem to those that fit the format of the DSS. This kind of "tunnel vision" might prevent the invention of new, better alternatives or the integration of new desires, which contradicts Keeney (1994) and his strive for value opportunities. In case a system does not provide the opportunity to accommodate these changes but is nevertheless in use, new stakeholders might not be able to implement their values into management alternatives, even if they are part of the decision process. In this way, inability to deal with value change might lead to persistence of value exclusions and consequently, decisions might favour certain parties over others. These considerations are often taken into account during development to limit their consequences, given that most DSS development processes are participatory. Nevertheless, newly emerging stakeholders, in combination with failure to bring all the right parties to the table in the first place (Georgakakos, 2007), both pose requirements to a certain level of adaptability in order to facilitate implementation of decisions and future usage of the system.

Bias in accessibility and outcome

Wong (1997) (in Walker (2002)) uses the collective term 'bias' to describe a set of factors that might have a negative effect on the quality of decision making, distinguishing bias in access and bias in output. She states that bias in output might arise due to flawed information or choices related to the applied method, relating to for example problem definition, boundaries, assumptions, data and models. Such choices influence the outcome, which might result in bias in decisions towards certain preferences Junier (2017). This again highlights the importance of a participatory development process to prevent such forms of bias.

Bias in accessibility might as well result in exclusion of certain values. In general, accessibility can be divided into conceptual (referring to complexity of the DSS, which is discussed above), technical (referring to the necessary technical resources and skills) and physical accessibility (referring to the location of the DSS) (Walker, 2002); (Van Meensel et al., 2012). Political accessibility (referring to power relations and participatory processes) can be added to this list (Wong, 1997). The set of technical and analytical competences that is required to effectively use the system limits the range of potential users. Giupponi and Sgobbi (2013) conclude that lack of adequate capacity and trained technical personnel is a major constraint for the effective application of DSSs in integrated water resources management in many developing countries. Walker (2002) points out a correlation between cultural, language and

conceptual gaps between developers and target managers, and the economic status of these target managers, complicating decision support in developing economies.

Walker (2002) considers some forms of bias as examples of abuse of power, possibly intentionally. This can be attributed to for example existing imbalances of power or a lack of awareness or unwillingness to accept mutual interdependencies and hence the need to include other actors' values. This means that powerful parties can make decisions on software, access or information as they desire, thereby affecting the outcome of a decision process and highlighting their values over those of others. The same holds for inaccessibility of a technology to certain groups, thereby providing groups that have the required access with the power to make exclusive decisions. As a result, decision outcomes will mostly favour parties that have access to the system. Abuse of the acquired power can lead to ascendancy of certain values and preferences in the final decisions while excluding others. In this way, bias is not only a result of imbalances of power, but might also maintain or even exaggerate these imbalances.

4.3.4. Role DSS in addressing value challenges in WRM

This subsection reflects on three key challenges in integration of values into design and decisions, namely value conflicts, value operationalisation and value dynamics. It turns out that DSSs can play a role in addressing value conflicts and potentially reveal value synergies. On the other hand, both operationalisation and value dynamics pose additional challenges for the design of a DSS.

Value conflicts

Out of the three challenges, the implementation of a DSS mainly targets the aspect of value conflicts. Such a conflict arises when a different option is selected as the most suitable for two or more values, in case multiple values are considered in a design or decision making process. Consider for example value A and B, which are said to be in conflict. This means that a preference for value A over value B automatically results in an outcome with a lower satisfaction rate for value B compared to value A. In that case, a trade off emerges between the two, where relative importance of both values is to be determined in order to draw a conclusion on the final design or decision criteria and levels of acceptability. As described above, such choices are susceptible to bias and power abuse.

According to Beck et al. (2012), two different types of conflicts can be distinguished. First, there are inter-value conflicts, referring to a clash of two or more separate values in a situation of choice. The other type, intra-value conflicts, basically is a different understanding of the same value or different interpretations of the same term which effectively reflect different values. Here, it comes down to a difference in definition of the respective term or value. According to Van de Poel (2015), value conflicts in design are generally conflicts between specifications of values, because abstract values are often too general and abstract to decide between different alternatives. These can either be specifications of the same value (intra-value conflicts) or of different values (inter-value conflicts).

Two clear strategies to deal with value conflicts in design exist, namely design innovations and balancing of values Taebi (2017). The former refers to technical and institutional innovations that embed multiple conflicting values, The latter strategy entails a search for a certain ratio between value A and B. This might result in a balance which favours value A over B or vice versa, but might as well result in a balance that favours both values A and B, compared to the current situation. Such a win-win solution is obviously desirable. On the contrary, zero-sum solutions as well exist, where the preference for value A results in no consideration of value B in the final outcome, or vice versa. As value A and B might be advocated by different actors, these balances can result in clashes or cooperation between different parties.

Van de Poel (2015) discusses six methods, which can all be attributed to either of these two categories. Four of these methods aim for ranking alternatives in order to select the best one out of a range, all with their own definition of ”best”. These are cost-benefit analysis [6], direct trade off analysis [7], application

[6] Comparison based on expression of all considerations, including values, in monetary terms, where ”best” depends on a aggregation of all costs and benefits, with a aggregation method of choice

[7] Direct comparison between values based on a commensurable unit and scale, where ”best” depends on the scores on individual values

of the maximin rule [8] and satisficing [9]. Such methods match the description of evaluation, ranking and selection that are often included in DSSs. These systems can therefore provide possibilities to analyse and address value conflicts during development of water resources solutions, adding to the identified role of purely facilitating ranking, evaluation and selection of alternatives.

However, the potential to address value conflicts in water resources might differ for each method, depending on the requirements. Cost-benefit analysis for example requires expression of values into monetary terms, which might not always be intuitively possible. Think of the monetary expression for the loss of wildlife: how could such a value be expressed in dollars? A similar argument holds for direct trade offs, that rely on a commensurable unit and scale. It might be problematic to decide how many units of increased flood protection (e.g. in number of fatalities, or in damage cost in dollars) compensate for a unit of lost animal species (e.g. in number of fish species). These requirements can limit the applicability of these methods, dependent on the values at stake. The maximin rule and satisficing both reduce the required number of translations and expressions, but do not completely ban the necessity. In this way, choices on evaluation tools integrated into the design of a DSS can have an impact on the potential to include value considerations into the evaluation process.

In addition, Van de Poel describes a method based on judgement, conceptualisation and specification of values. This method starts with creating an understanding of implications and importance of values at stake, after which they are made specific in design requirements. This relates to the issue of value operationalisation. A DSS can contribute to analysis and assessment of alternatives based on design requirements. As the established understandings and corresponding specifications might vary amongst actors, these steps should involve active discussion. Again, a DSS does not necessarily provide a framework for these discussions, but rather creates the urgency of conceptualisation and specification of values to allow for assessment, thereby stimulating discussion.

Finally, there is innovation, which coincides with Taebi's first strategy, and is all about finding new alternatives that might solve or reduce value conflicts. The role of a DSS in the establishment of new alternatives is limited, as its main function is to evaluate existing alternatives rather than creating new ones. When an alternative based decision process is limited to the considered alternatives, then the function of a DSS is limited to a simple evaluation of their respective performances. Evaluation tools can however provide insights into the acceptability of design features, some of which receive strong opposition ("value dams") while others provide opportunities ("value flows") (Miller et al., 2007). These insights point decision makers and designers towards so-called value flows, referring to features that for value reasons are favoured by a large number of stakeholders. Incorporating such a feature in the final design may increase adoption and support. This seems relevant for selection between water resources alternatives, especially in case none of the existing alternatives performs according to the standards. Therefore, a DSS can contribute to Keeney's value-based decision making which aims for new alternatives based on value opportunities.

There is an additional important consideration, namely that a DSS itself is the result of a design process and its associated value conflicts. The development of DSSs can be seen as an innovation, contributing to decision making in various fields, including water resources management. Such methods as described above might therefore be used to determine the functionalities and capabilities of the system. The role a DSS can play in resolving value conflicts between water resources alternatives is therefore influenced by choices in the development stage of such a system. An example of such a value conflict is the earlier mentioned trade off between credibility and salience of information, that affects the final design of a DSS.

Value operationalisation

One major challenge in integrating values in decision making is the translation of abstract values into concrete, measurable criteria. This is based on Kroes and van de Poel (2015) and their vision on design for values. They argue that the operationalisaton of moral values shows similarities with that of physical concepts, and consists of roughly two steps. First, a moral value is translated into more specific

[8] Comparison of alternatives where "best" is the best-scoring alternative on its lowest-scoring value

[9] This method does not necessarily select a "best" solution, but reduces the set of potential solutions to those that satisfy a threshold for each value. This can be zero, one or more

evaluation criteria for a design, after which these morally relevant evaluation criteria may be operationalised through linkage with measurable attributes. This theory is applicable on decision making as well, showing similarities in the use of evaluation criteria to come to a decision. In addition, Keeney and Gregory (2005) discuss the importance of thoughtful selection of attributes in decision making.

Kroes and van de Poel (2015) describe two main challenges related to these operationalising practices. Firstly, second-order value judgements play a role both in linking evaluation criteria with moral values and in linking these evaluation criteria to measurable attributes. These value judgements are called second-order because they are involved in the operationalisation of moral values; first-order value judgements are judgements about the moral value itself. These value judgements complicate objectivity in measurements. Secondly, it is difficult to ascertain inclusiveness of associated attributes and to determine relative importance between those, which relate to what Kroes and van de Poel call ”content validity”. The operationalisation of values therefore requires consensus on attributes and measurements.

Kroes and van de Poel (2015) propose technical codes and standards for design. However, such codes and standards do not necessarily provide outcome because of the context dependency. In addition, a lack of such codes and standards might enforce other ways of achieving consensus. In a multi-actor decision process, discussion and negotiation are potential means towards such a consensus. However, final choices should be justified in order to prevent them from being arbitrary. In addition, Keeney and Gregory (2005) highlight the potential absence of what they call ”natural attributes”, which are in general use and have a common interpretation. Due to the abstractness of moral values, these natural attributes might not yet exist or be available. In that case, Keeney and Gregory first propose to construct a relevant attribute. Only in case that is not possible, they recommend to select a proxy, which differs from a natural attribute in that they do not directly measure the objective of concern. Directness is one of five properties they suggest in order to select good attributes, which should be:

- unambiguous
- comprehensive
- direct
- operational
- understandable

These operationalisation issues pose challenges to the design and functionality of a DSS. Firstly, a DSS is in essence a tool to facilitate evidence-based decision making. The described value judgements and required consensus imply a sense of subjectivity that contradicts the demanded objectivity in order to keep the information scientifically credible. In addition, the complications regarding selection of measurable attributes, which relate to content validity, to base a decision on are especially relevant to a system that is designed to support decision making; these should be represented in evaluation tools and guide the selection of the best suitable alternative. This again implies a value conflict: on one side there is credibility, while on the other, the inclusiveness of a DSS is at stake. In case this trade off is not properly taken care off, a tendency towards either credibility or inclusiveness both might result in a lack of trust, support and usage. By ”loosing” credibility to gain the incorporation of values, users might become sceptical about the impartiality of provided information, while the exclusion of certain values due to the subjective nature of conceptualisation and specification might lead to mistrust amongst those whose values are not heard.

Keeney and Gregory (2005) acknowledge that subjectivity, but offer certain options to limit it in selecting attributes. One requirement is that these value judgements should be reasonable; such a requirement can only be validated in case the reasoning and implications of a value judgement has been made explicit. Furthermore, the set of desired attribute properties provides a means to evaluate potential attributes. The similarity with a decision process is obvious: Selection of attributes requires a similar approach. This implies that trust and understanding can be created by ensuring transparency and openness on these value judgements. Nevertheless, as far as these issues can be coped with, a DSS does not provide an outcome for such issues in value operationalisation. Rather, these complications pose challenges to the final functionality of the system. Additionally, conceptualisation and specification

of values and selection of attributes should be approached carefully, transparent and participatory to ensure an acceptable, useful DSS.

Value dynamics

Values might be susceptible to changes (van de Poel, 2018);(Jørgensen and Vrangbæk, 2011). These value dynamics do not happen overnight but are typically long-term. The possibility of changing values poses challenges to a value based design of technologies such as a DSS, and might even lead to limitations in their functionality. van de Poel (2018) distinguishes five types of value changes. These are:

1. The emergence of new values;
2. Changes in what values are relevant for the design of a certain technology;
3. Changes in the priority or relative importance of values;
4. Changes in how values are conceptualised;
5. Changes in how values are specified, and translated into norms and design requirements.

These value changes are observable in water resources management as well. The newly emerging stakeholders in recent water resources practices have for example brought the value sustainability, an example of a newly emerged value, while the growing attention for social values in water developments shows that the importance of a value can change as well. Type 4 and 5 relate to operationalisation of values, where values might remain the same, but their conceptualisation or specification might change. van de Poel (2018) suggest three features that improve capabilities of designed products in coping with these value changes: adaptability (”the possibility to change the composition or configuration of the design”), flexibility (”different possibilities for using the design”) and value robustness (”the ability of a design to perform its function while respecting a range of values despite variety in, among others, circumstances in which the design has to function and variety in how the relevant values are exactly specified, conceptualised or prioritised”). These features do not seem to provide an opportunity for a DSS to contribute, but rather imply certain requirements for the system design in order to improve the sustainability of the system from a values perspective. As described above, both inflexibility and inadaptability are described as common reasons for non-use of DSSs, although they can be seen as requirements for success of such a system. Changing values therefore remain a challenge to current DSS development.

4.4. Conclusion

A DSS can ...
1) ...facilitate value-based evaluation
2) ...stimulate explicit value statements
3) ...contribute to useful information
4) ...empower participation

A DSS might ...
1) ...result in non-inclusive decisions
2) ...be susceptible to value dynamics
3) ...affect power relations
4) ...lack trust and support

A DSS should ...
1) ...be open and transparent
2) ...be developed participatory
3) ...use reasonable value judgements
4) ...be flexible and adaptable
5) ...produce credible, legitimate and salient information

Table 4.1: Overview of the potential benefits (*can*), negative consequences or limitations (*might*) and requirements *should*) for consideration of values in decision making.

Values have different effects on decision making. They add to complexity of water resources problems, pose constraints on what information is considered to be useful, and influence ranking and selection

processes. Values do not only influence the decision process itself, but partly determine the design and features of a DSS as well, because of its function within the decision process. This poses additional challenges to the incorporation of values in design, such as value dynamics, value conflicts and value operationalisation. DSS can contribute to value considerations in decision making, but this requires certain design features. The consequences might be adverse in the case these requirements are not fulfilled. Benefits, requirements and potential consequences are summarised in Section 4.4.

5

The Nile Basin Decision Support System

The NBDSS is a common computer-based platform for communication, information management and analysis of the Nile water resources, developed in name of the NBI. It provides a framework for sharing knowledge, understanding river system behaviour, evaluation alternative development and management strategies and supporting informed decision making in the Nile Basin. This model-based DSS framework includes diverse toolsets for data processing, modelling, scenario management, optimisation and multi-criteria decision making and offers tools for integrating environmental, social and economic objectives. Target users are water resources planners, managers and experts in the Nile basin countries. It is a generic system that can be applied at national as well as transboundary levels. The DSS makes use of the open-source programming language Iron Python. Development involved multiple consultancies and was completed in 2012. The system was mostly funded by the Nile Basin Trust Fund, administrated by the World Bank. The DSS has been updated several times, the 2020 version being the most recent edition.

The NBDSS integrates modelling, evaluation and storage of information related to water resources management in the Nile River Basin in one environment that consists of three major components:

- An information management system
- A water resource modelling system, including hydrological, hydraulic and water budget allocation modelling possibilities.
- Tools for participatory evaluation of alternatives

Figure 5.1 displays a schematic overview of the three system components and the system aspects that are developed based on stakeholder engagement. These aspects link to the conceptual approach for evaluation of and decision making on water management interventions used by the NBI. This approach is based on a six step approach based on reports of the World Bank:

1. Definition of Problem / Key Water Management Issues
2. Clarification of Objectives
3. Development of Scenarios
4. Definition of Indicators and Evaluation Criteria
5. Simulation and Quantification of Indicators
6. Evaluation/Interpretation of Results and Trade offs.

The first two steps are not part of the NBDSS internal process, but can be considered as preparation in order to effectively use the functionalities of the system. These steps are similar to the first two elements for general decision making as presented by Hammond et al. (1999) (see Section 4.2.1), and include intensive stakeholder engagement to completely understand the problem at hand and the objectives to be achieved with the desired solution. These objectives form the basis for the last four steps, for which the NBDSS provides support.

These steps link to Hammond et al.'s key elements. Scenario development encompasses creation of different alternatives for policies, strategies and developments to improve on the current undesirable situation, combined with variation in external conditions such as climate change, population growth and

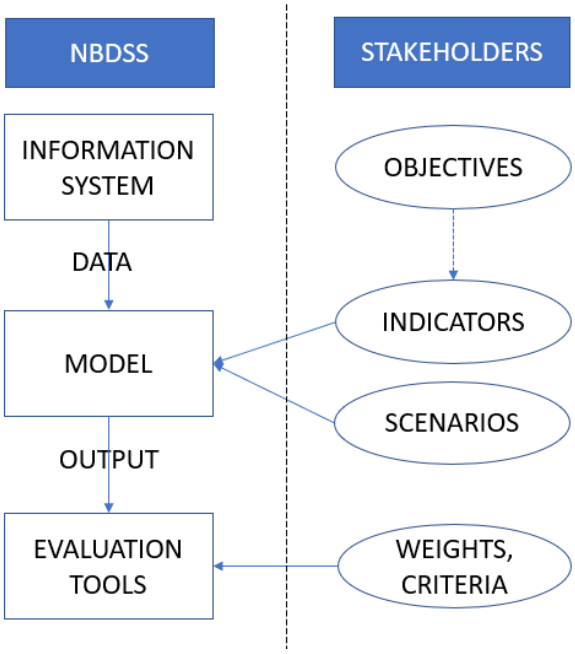

Figure 5.1: Schematic overview of the three NBDSS system components, the system interactors influenced by stakeholders and the relation between components and interactors.

other socio-economic developments. These scenarios are evaluated based on criteria, agreed upon by the relevant stakeholders. These criteria are assessed using indicator variables that are computed based on computer simulations of the various scenarios. After quantification, the criteria are used in the selected evaluation tool. The NBDSS enables both different evaluation methods, which are discussed under in In this last step, trade offs between different criteria are made using weight factors for stakeholder preference and potential factors for cost and benefits.

5.1. Information management system: PostgreSQL

The system makes use of PostgreSQ, a free, open-source relational database management system. These databases can handle all types of DSS data, including spatial GIS data, time series, hydro objects such as reservoirs, canals and water users, and scenario data. The training module Database Manager Utility and the System Manager provides insight into the functions of these databases (Nile Basin Initiative (NBI), 2014b). It states that all data used and produced in the DSS is saved in a central database, ensuring integrity and consistency and allowing controlled data access according to access rights. At this moment, this central database seems to mean a local version of a central database for single use. A central database accessible to all system users is not yet identified, nor is it clearly described in the documents.

5.2. Modelling system: Linked existing model tools

The modelling system is based on existing hydraulic and hydrologic model tools that are linked with the DSS user interface, but are not a part of the front end of the system. These models therefore should be set up outside of the NBDSS environment, configured and stored to the NBDSS set up and simulated afterwards. Configuration and simulation is performed using so-called *adapters*. Several adapters already exist: next to the MIKE software packages, adapters for WEAP and SWAT are available. In addition, the system allows development of new ones for other model tools.

The initial modelling system uses MIKE software developed by Danish Hydraulic Institute (DHI), a Danish research and consulting agency which has been the main consultant during DSS development

(Jonoski and Seid, 2016). This software includes MIKE HYDRO BASIN (a river basin simulation model for analysis of water budgets and allocations), MIKE 11 (a hydrodynamic one-dimensional river hydraulic model for simulation of flows, water quality and sediment transport in rivers, irrigation systems, channels and other water bodies) and MIKE SHE (a detailed numerical hydrological model for analysis of catchment hydrology).

Next to these model tools, the DSS framework provides functional components that serve several task-specific functionalities within its front end. These components are called ”managers”. Specific managers exist for scenarios, time series, spreadsheets, GIS, scripts, indicators, analysis (providing evaluation tools) and system (to manage workspaces and users). Other tools provide more generic functionalities, such as data import/export.

The website of the NBI specifically mentions reservoir operation to be a typical application of MIKE 11, and optimisation of reservoir operation as a typical application for MIKE HYDRO BASIN. It further provides a manual on modelling tools (Nile Basin Initiative (NBI), 2014c) which elaborates on MIKE HYDRO, MIKE 11 and MIKE SHE. In addition, a special chapter is dedicated to NAM, a specific rainfall-runoff module for the MIKE HYDRO and MIKE 11 modelling systems.

5.3. Development of scenarios

The hydraulic and hydrologic models are used to simulate invented scenarios and test their performance against a certain baseline scenario or against each other. Scenario development includes invention of alternatives for issues related to water resources, in combination with projected external changes. Alternatives could for example involve different allocation strategies to water users, configurations of infrastructures, reservoir operation strategies, scale variations and combinations of measures. Different alternatives are simulated by changing parameters or model input data. Jonoski and Seid (2016) highlight the creation of scenarios as an important step in the decision making process.

The NBDSS provides a Scenario Manager. This is a tool that helps with creation of alternative scenarios, runs simulations and stores model outputs to the DSS database. The Scenario Manager is not a model on its own, but calls the previously defined model structures for simulation and quantification. Storage of the model output allows usage of the simulation results to quantify specific desired variables called indicators. The Scenario Manager further enables optimisation of indicators. The optimisation tool uses objectives, decision variables and constraints, and supports both single- and multi-objective optimisation. It allows for five traditional optimisation methods such as Shuffled Complex Evolution (SCE) and Monte Carlo.

Scenario results can be compared within the Scenario Manager without need for external tools, via direct comparison (e.g. by plot or table), comparison of specific scenario elements (e.g. duration curves) or direct indicator comparison.

5.4. Indicators for decision making

The NBDSS makes use of indicators for the evaluation of the alternatives. These indicators are used to describe the considered water resources system, often in environmental, social or economic terms, and should be useful to assess the interests of stakeholders and decision makers. Relevant indicators are therefore defined beforehand. The NBDSS computes indicators using scripts containing algorithms that are specific to that indicator. These scripts make use of scenario outputs that are stored in the DSS database as a post-processing step. After calculation, the indicators can be used to either quantified predefined evaluation criteria, or used to compare alternatives and find an optimum. The built-in Indicator Manager provides an interface to view a list of all indicator values for each scenario. This manager also allows for formulation of specific indicators that do not follow from simulation (i.e. costs), enabling to use these indicators during evaluation in the same interface.

The NBDSS allows to use both predefined and newly created indicators. Predefined indicators are connected to a ready-to-use script and were the result of a number of consultation meetings and work-

shops with stakeholders, led by a consultant. This resulted in three indicator categories, namely social, environmental and economic, all divided in several subcategories that contain one or more indicators. Indicators, subcategories and categories can be found in Appendix A. Indicators can be both quantitative and qualitative parameters. Examples of predefined indicators are the water pollution downstream major areas, the change in crop income of existing irrigation schemes or the annually produced hydropower per catchment/region/country. Indicator formats vary between percentages (e.g. change in dry flow compared to baseline), ratings (e.g. impact on environmentally sensitive areas) or absolute values (e.g. areas, distances, fish productions, energy generation).

In case a user of the DSS aims for a different indicator, the system offers the possibility to create a new one. Calculation of a newly developed indicator requires provision of an algorithm and data, either internal or external (e.g. not yet existing in the DSS). Modification of an existing indicator is also possible. The NBI points out that addition or modification of an indicator requires stakeholder consultation and scripting knowledge.

5.5. Towards a decision: the available evaluation tools

The NBDSS offers five different methods to evaluate model simulation output:

1. Direct comparison
2. Indicator comparison
3. Multicriteria analysis
4. Cost Benefit Analysis
5. Optimisation

Selection of the evaluation method depends on the purpose of the evaluation. Direct comparison does not include any post processing, but directly compares model simulation output using graphs or tables. This method is mostly interesting for users that directly interact with the modelling components (user group 1), because it gives quick insights into model performance. Indicator comparison firstly translates this output to indicators, selected prior to model simulation. This enables evaluation based on information that is not directly generated by the model components. These two methods are rather straightforward in evaluation of results, and provide basic insights in differences between scenarios.

The Analysis Manager provides functionalities that enable decision analysis, in order to evaluate scenarios or alternatives. Available methods are either based on cost-benefits via cost benefit analysis (CBA) or using weight factors and evaluation criteria in a multi-criteria analysis (MCA). These methods are suitable for ranking of alternatives and prioritisation of measures.

CBA aims to assign monetary value to the performance of a scenario. The NBI explains in its Analysis Manager Trainings Module (see (Nile Basin Initiative (NBI), 2014a)) that valuation is based on potential benefit gainers' willingness to pay and potential losers' willingness to accept compensation for their losses. These calculations can either be performed based on simulation results or other sources (e.g. expert judgement). Discount rates over time can be added to the analysis. Values that cannot be expressed in monetary terms are taken into account qualitatively, alongside the CBA results. Potential results of CBA are the benefit-cost ratio, return on investment and the net present value.

MCA is used to evaluate a set of alternatives using the agreed upon indicators and criteria, reflecting the predefined objectives. These indicators entail both predefined and newly created ones. The latter do not necessarily have to depend on simulation output. Nile Basin Initiative (NBI) (2014a) offers an example that uses the indicator Public Acceptance, ranging between one (low acceptance) and five (highly accepted). This indicator determines the acceptability of the various alternatives, and is not based on any simulation output but rather on additional social information in terms of surveys and interviews. Indicators and criteria can be weighted, to reflect relative importance based on stakeholder interests. To accommodate differences in preferences between different stakeholder groups, MCA

facilitates the execution of different sessions with differing weights and criteria for each stakeholder group.

Finally, the NBDSS offers an optimisation tool that allows to find optimal solutions and configurations, for example on reservoir operation or irrigation schemes. Optimisation searches for the best available values of an objective function, restricted by certain constraints. These best values would result in the most optimal strategy solution or configuration for the given objective. Both single-objective and multi-objective optimisation are facilitated.

6

Method: Analyses of values

The method consists of two main components. The first part consists of three separate analyses. Together, these shape the image of what the NBDSS should be or do in order to consider all values. This image is built of design requirements, design values and actor values and provides a concrete overview of requirements and values relevant for a DSS to support value-inclusive decision making on the Blue Nile. The second part compares this overview to the actual NBDSS design and functionalities. In other words, this thesis compares what a DSS should do to what the NBDSS actually does (see Figure 6.1). This evaluation allows to identify key strengths and weaknesses of the NBDSS from a values perspective and to formulate recommendations for improvement of decision making at the Blue Nile level in general and the NBDSS in particular, in order to achieve more value-inclusive decisions. This final result provides an answer to the main question:

"*What role can the NBDSS play in the consideration of all values in decision making at the Blue Nile level?*"

Figure 6.1: Schematic representation of method.

Figure 6.1 shows an overview of the chosen method. As can be seen, the first three subquestions together result in a measure for what the NBDSS should do. The first subquestion was already addressed in Chapter 4. This methodology describes the approach for the other four subquestions.

6.1. Identification of NBDSS values through document analysis

NBDSS design values are studied using available literature on the system. Studied documents are retrieved via the Nile Information System (Nile-IS), the information management system used by the NBI, by searching for "NBDSS", "NB-DSS", "DSS" and "Nile Basin Decision Support System". This resulted in three series of reports (separate ones for the inception, analysis and synthesis phase) developed by Hydrophil, an Austrian consulting firm. In addition, a descriptive study on the NBDSS

(Jonoski and Seid, 2016), co-authored by dr. Abdulkarim Seid, former Regional Decision Support Systems lead Specialist at the NBI, was used.

Texts are studied for explicit value statements and objectives (based on Keeney (1996)) and for an understanding of the system scope, focusing on thematic focus areas, decision types, output types, users, models and data (based on Jonoski and Seid (2016)). The final result is an explicit list of values that are in some way embedded in the NBDSS, shown in Section 7.1.7.

6.2. Identification of actor values through discourse analysis

This thesis uses a form of discourse analysis to identify values associated with water resources for the three Blue Nile countries Ethiopia, Sudan and Egypt. The type of analysis is inspired by Mostert (2015) and van Roon (2020), who both based their method on Fairclough (2003). The analysis roughly consists of four steps:

1. Selection of sources
2. Identification of themes
3. Analysis of how themes are covered making use of coding of sources
4. Relate obtained results to the context
5. Analysis of potential conflicts and synergies

For simplicity, this analysis starts with the assumption that all countries function as one decision making actor. Separate identified actors that operate within the same nation are therefore thought to pursue the same values, interests and objectives. Practically, this means that identified values for one of the actors are assumed to be applicable on the other actors from the same nation. This assumption allows for more texts to correspond to the same actor, reducing the amount of texts that is necessary to obtain a distinctive overview of the values that are representative for a specific nation. In case internal differences turn out to be significant, these actors are further studied in depth. In that situation, distinctions in values within the national level are made.

6.2.1. Step 1: source selection

Sources that cover the political discourse on water resources in Ethiopia, Sudan and Egypt are included. These include sources acquired from the United Nations Library, ministerial websites, official newspaper websites and search engines using key terms such as ”water resources” or ”transboundary water management” in combination with the relevant actors. This resulted in official statements at the United Nations, the most recent policy document available, relevant government publications and interviews with relevant officials found online or in newspapers, as shown in Table 6.1. A full list of sources is provided in Appendix C. Most of the sources date from 2017 or later. These sources are assumed to describe the current discourse, disregarding any changes during this time span. This is not the case for the policy documents of Sudan and Ethiopia, which are both from 1999 but are still in use and are therefore part of the current discourse as well.

Sources are selected based on relevance and public availability. Preferably, sources have a clear speaker that is directly quoted. The included texts are thought to provide a representative overview of the different discourses that exist amongst decision makers on reservoir management on the Blue Nile.

Table 6.1: Classification of sources for each country

Type of source	Ethiopia	Sudan	Egypt
Speech or letter to the UN	3	4	3
Government publications	4	0	2
Policy documents	1	2	1
Interviews / newspaper	0	1	2

A key factor in text selection is the language: only English texts are included. This leads to exclusion of local texts because the author lacks the ability to read Arabic, leaving no other choice. However, the focus of this thesis is on the international discourses rather than domestic ones. The international discourses are mainly written in English, thereby reducing the limitations for this research. English texts are selected in a wide range, to minimise the chance for exclusion. In addition, one translation performed through an online translator was used because this is deemed necessary. It is thought that this does not significantly reduce the value of the analysis, because the object of analysis is the content rather than the specific language used. Nevertheless, use of translations is reduced to an absolute minimum.

6.2.2. Step 2: coding of themes

The list of themes used for coding consists of seven themes, see Table 6.2.

Table 6.2: Themes and their corresponding codes and qualitative descriptions

Theme	Code	Description
Culture	C	Covers senses of national pride, identity, religion and heritage.
Economy	EC	Covers economic development, efficiency, funding and use for economic purposes such as agriculture, energy and navigation
Environment	EN	Covers ecology, sustainability natural and aquatic resources and existence values
International Relations	IR	Covers the international aspects of conflict, cooperation, politics, actors, laws and policies and equity on a transboundary scale
Knowledge	K	Covers technology, research and scientific knowledge, data, grounds and capacity building
National Governance	NG	Covers national organisation and institutions, laws and policies and the national government
Society	S	Covers social purposes such as health, sanitation, drinking water, poverty reduction, participation and equity on a national scale

Subcodes are used to describe the subject of the coded paragraph. These subjects are later clustered to the seven main codes, based on the reasoning as provided above. The selected method makes use of evolutionary coding, where new subthemes are invented based on the topics that are encountered within texts. The first five themes are based on the conclusions of the NBDSS value analysis. International Relations and National Governance turned out to be of specific interest after coding of five texts. The first version of themes included the themes Politics and Equity instead of International Relations and National Governance. These themes turned out to be either to abstract (politics) or to narrow (equity). The theme equity did not disappear, but was brought under Society (for references to distributional issues within the borders of a country) or International Relations (for distributional issues between countries).

Codes are applied on paragraph level. Codes are used to label subthemes, that are clustered in a theme using code groups, following the coverage above. This guarantees a certain speed and reduces the complexity of coding compared to coding at a more detailed level (e.g. sentence or word), but still provides a level of detail compared to coding a for example level of texts.

Texts are scanned from beginning to end. Texts might not always be fully committed to water resources. In that case, only the relevant parts are coded. In policy documents, only parts of the text that contain clear visions on water resources management are coded. Factual background information is therefore not part of this process. This demarcation is done during the first read. After reading, the relevant parts are read thoroughly and codes are applied.

Coding is performed with help of a computer using Atlas.ti software, a program especially useful for qualitative analysis of large bodies of text. It allows for coding on different levels of texts and facilitates multiple types of analysis, including quantitative analysis of number of applied codes.

6.2.3. Step 3 & 4: Analyses and relation to the context

Atlas.ti is used to perform a quantitative analysis of applied codes, in order to identify differences and similarities in frequency of occurrence of certain themes and subthemes. This draws attention to interesting themes and subthemes, which are analysed in detail in a qualitative manner. Qualitative analysis includes a search for both implicit and explicit value statements. Quantitative results are presented in tabular format, while qualitative results are demonstrated using quotes from the analysed sources. Combination of the analyses provides insights into the valuation of certain themes and values by each country. This allows to draw conclusions on similarities and differences in values. The final result is a list of values and their description for each country, including both mutual and country specific values. These values are related to the context to verify their validity.

6.2.4. Step 5: Potential conflicts and synergies

The identified values are analysed in terms of their potential to generate value conflicts, value synergies or conflicts of interests. This entails the identification of different values for each country that potentially conflict (inter value conflict); mutual values for each country that potentially lead to conflicts (conflict of interest); differences in understanding, conceptualisation or definition (intra value conflict); different values for each country that potentially stimulate each other (value synergy); and mutual values for each country that potentially stimulate each other (value synergy).

6.3. Value based evaluation of the NBDSS

Finally, the produced information on values is projected on the NBDSS to evaluate its capabilities from a values perspective. This evaluation consists of four aspects, namely 1) conformation with derived DSS requirements from the theoretical framework; 2) representation of identified NBDSS values; 3) inclusion of identified actor values; and 4) ability to assess value conflicts and synergies. Based on this evaluation, suggestions for improvement of both the NBDSS and the decision making process in general are made. In addition, this evaluation allows to identify the capabilities and limitations of the NBDSS in considering all values in decision making, thereby answering the main research question.

6.4. Final result

The final result consists of:

- A list of values associated with water resources for each Blue Nile country
- An evaluation of the NBDSS from a values perspective

7

Values in the NBDSS

The value analysis of the NBDSS consists of two parts. In both analyses the NBDSS is the object of analyses, but the process of interest varies between 1) the design process of the system itself and 2) the decision making process in which the system plays a role. First finding is that none of the analysed documents talks about value considerations explicitly. Both analyses yield different types of conclusions. Both analyses entail challenges related to embedding values.

7.1. Analysis of value considerations in the design process

The documentation on the NBDSS development and design phase contains three clear terms indicating value considerations, namely 1) the predefined objectives for final functionalities of the system; 2) a list of seven questions used to scope the requirements of the system in Jonoski and Seid (2016); and 3) An overview of the main design principles in Fedra et al. (2008b). The seven questions can be clustered into four topics, resulting in six topics in total: Goals and objectives, Focus areas and related decisions, Output, Models & Data, Users and Design principles. These topics show similarities with the the different steps of the workflow for NBDSS usage as shown in Figure 7.1, covering input, modelling tools, output of system components and decisions. Based on the analysed documents, the developing process starts at the end by first determining the type of decisions. This process then follows the workflow in Figure 7.1 in opposite direction, moving from abstract decisions gradually towards concrete modelling tools. The reported scoping choices provide information on value judgements. This chapter therefore starts at objectives and decisions and will gradually work towards modelling tools.

Figure 7.1: Workflow of the NBDSS from input to decision. system components are in blue, input/output in green. The figure shows the relation between output types 1 and 2 and the indicators and criteria.

7.1.1. Goals and objectives of the system

The primary objective of the design process of the NBDSS was to *"to develop a shared knowledge base, analytical capacity, and supporting stakeholder interaction, for cooperative planning and management decision making for the Nile River Basin."*, while the desired output was an *"agreed upon tool that will be accepted and used by all riparians in the management of the shared Nile water resources"*. The expected function of the final product, the NBDSS, was *"to support basin wide information exchange, enhance capacities and contribute to identifying transboundary opportunities for cooperative development and thus increase the overall efficiency of the management and use of the Nile Basin water resources."* (Fedra et al., 2008a); (Droogers and Immerzeel, 2010). In addition, Jonker et al. (2012) formulates the main goal of the system as *"to support informed, scientifically based, rational cooperative decision making to improve the overall benefit from harnessing the Nile River, and to develop economically efficient, equitable and environmentally compatible and sustainable strategies for sharing benefits."*

Values that can be observed in these goals and objectives are:

- Science - ”analytical capacity”, ”informed” and ”scientifically based, rational”
- (International) cooperation - ”shared knowledge base”, ”basin wide information exchange”, ”co-operative planning and management”, ”opportunities for cooperative development”, ”transboundary opportunities”, ”supporting stakeholder interaction”
- Inclusiveness - ”agreed upon tool”, ”accepted and used by all riparians”
- Equity - ”equitable” and ”strategies for sharing benefits”
- Efficiency - ”increase the overall efficiency” and ”economically efficient”
- Environment - ”environmentally compatible and sustainable strategies”

These values show a difference in attributes, either belonging to evaluation of water resources strategies (equity, efficiency, environment), credibility and legitimacy of information (science, inclusiveness) or international cooperation. Notable absent in this list is a reference to induce socio-economic growth, which is one of the governing themes in most of the sources that were part of the discourse analysis. One could argue that ”improve the overall benefit from harnessing the Nile River” refers to multiple benefits, of which one could be socio-economic growth. Nevertheless, this is not considered a clear reference.

7.1.2. Focus areas and related decisions

The NBDSS covers eight key thematic focus areas:

- Water resources development
- Optimal water resources utilisation
- Coping with floods
- Coping with droughts
- Energy development (hydropower)
- Rainfed and irrigated agriculture
- Watershed and sediment management
- Navigation

In addition, climate change and water quality are considered to be cross cutting issues, relevant for each focus area. The NBDSS is expected to produce output helping to take decisions regarding these themes. Sample decisions (Fedra et al. (2008a); p. 100-102) can be summarised to the following four categories:

- Selection of (investment) alternatives
- Optimisation (e.g. dam operation for navigation, irrigation schemes, basin level operation, hydropower production)
- Determination of scale and configurations of solutions
- Prioritisation (e.g. areas for intervention, irrigation development)

Values that are regularly associated with water are economy, society, environment and culture. In these themes and decisions, economic themes are definitely discussed (e.g. references to sectors such as agriculture, energy and navigation and decisions on ”investment alternatives”), while certain themes can be associated to society (e.g. coping with floods and droughts). Both topics watershed and sediment management and water quality can be linked to the environment, although aspects related to biodiversity would not be strange here. No clear reference to culture is found.

The type of decisions all entail a range of alternatives to be organised in a certain preference structure. For optimisation, this process happens in a slightly different manner than for the other three decision types, because it finds the best set of values out of a range of all potential values. This range of potential values is not limited by predefined alternatives, which is the case for the other three decision types. Nevertheless, optimisation indeed aims for an organisation (one best solution, other less performing

solutions), using predefined optimisation objectives that contain are based on a preference structure. The term ”preference” implicitly points to the relevance of values for each of the decision types, including all challenges related to embedding values.

7.1.3. Output, indicators and criteria

The produced output can be divided into 1) output of the model component: model generated scenarios / results and 2) output of the evaluation tools: ranking of alternatives for specific decision problems according to the user defined preference structure. These output types 1 and 2 match with the steps in the workflow as shown in Figure 7.2

Figure 7.2: The link between output type 1 and 2 and the NBDSS workflow steps

Indicators and associated criteria are used to rank scenarios, which therefore can be seen as the link between modelling and evaluation. Choices of indicators are partly based on values associated with the way alternatives should be evaluated. The system provides a list of 44 indicators, divided over three categories social, environmental and economic, which can be divided into indicator themes respectively. These themes are presented in Table 7.1, the full list of indicators is provided in Appendix A. Indicator values are calculated using predefined scripts that either use simulation output or an external type of input, such as spreadsheets containing data, to calculate indicator values. The predefined indicators are the result of consultation meetings and workshops during the development stage of the NBDSS, and were marked as key indicators. In addition, the NBDSS allows to define new indicators in line with the decision at hand, which again should be associated to either model output or external data.

Table 7.1: Summary of the themes associated with each indicator category. These themes are not equal to the indicators, but are clustered based on scope.

Society	Economy	Environment
• Health • Safety • Natural resources • Productive land use • Fish production • Recession agriculture • Displacement • Water availability	• Energy • Navigation • Water losses • Food damage • Food production	• Environmentally sensitive areas • Hotspots • Carbon • Fish production • Ecological stress • Wet season • Water quality • Floodplain inundation • Wetland inundation

Initial criteria list found in Fedra et al. (2008b), containing indicative examples and separated in bio-physical/environmental and socio-economic criteria. The example list for bio-physical and environmental criteria is based on water availability, flow rates, and supply and demand rates. No environmental criteria are explicitly formulated, but rather terms of water quantity that can be related to certain environmental requirements. All socio-economic criteria are denoted in monetary terms. References to measure equity can be found in the criteria, as supply/demand ratios and benefit/cost ratios can be calculated for the entire basin, sub-catchment, countries or economic sectors, allowing to display distributional aspects.

7.1.4. Models & Data

Fedra et al. (2008b) mentions five models that should constitute the core of the DSS. These are a water resources network model (including a bsaic dynamic water budget model, economic evaluation, reservoir management and hydropower generation), rainfall-runoff models, water quality models and an irrigation water demand model. The document complements these models with data requirements, which can be summarised to hydrological characteristics (rainfall, temperature, soil), spatial characteristics (sizes, lengths and coordinates of reaches, reservoirs etc), human induced data (reservoir characteristics, pollution, crop types), water demands, land use and economic data (costs for investment and operation, benefits for satisfied demands, cost/benefits for compliance/violation of constraints).

In addition, the indicator scripts show the required data to produce the desired output, including spatial data on environment (sensitive areas, hotspots, vegetation) and society (maps of households and structures, malaria incidence), and various rating curves (fish production, black fly rating, macrophyte growth).

Besides the system core, there are multiple models that can be connected to the DSS. Fedra et al. (2008a) addresses these models and related data. Topics not or partly included in the DSS include urban and industrial water demand (activity based, based on socio-economic growth, water distribution and sanitation), groundwater flow, water quality in lakes/reservoirs, wetlands (only addressed as a demand node), sediments (only basic processes are part of the core), biodiversity (only empirical relationships at the moment of design) and regional development and demographics (covering socio-economic driving forces, related to water demand and water quality).

The data requirements imply values related to economy, society and environment, corresponding with the indicator groups. However, major socio-economic models and data related to development, demographics and urban/industrial activity are not a part of the core system. The exclusion of certain models and associated data can be attributed to a desire for usability (demanding low complexity) and scientific excellence (requiring thoroughly developed models). Nevertheless, the level of depth in irrigation demand models, which are based on multiple parameters and data such as crop types, efficiency and return flows, over e.g. wetlands, simply modelled as a demand node, or urban and industrial demand, suggests a relative importance of this sector over the others.

7.1.5. Users

Two groups, namely users who use the produced information for decision making and planning, and users who interact with the DSS in order to accomplish a certain task in their working routine (Jonoski and Seid, 2016). This research classifies these two groups broadly as 1) producers of information (e.g. hydrologists, GIS specialists, modellers) and 2) users of information for decisions (e.g. decisions makers, members of NBI governance and ministries) . Both groups are spread over all basin countries. In terms of output, user group 1 can best be associated with models and modelling results (output type 1), while user group 2 is mainly concerned with the output from the evaluation tools (output type 2).

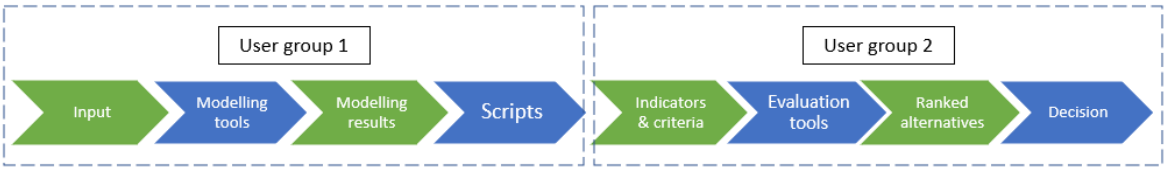

Figure 7.3: Main domains of user groups 1 and 2 with respect to the workflow steps. User group 1 is mainly concerned with models and model output, while user group 2 focuses on evaluation tools and the final decisions.

The category of interest for this research is the second category, as these were involved in thematic scope, focus areas and high level user requirements to come to decisions. The first category is more engaged in lower level system requirements, e.g. the tools, features and software provided by the DSS and its possibilities for modelling and analyses. In the design process, this opposition can be comprised

to concept versus details, where group 2 determines *what* should be the output of the system, while group 1 identifies *how* this output can be produced.

Value implications: Considers both direct interactors as users of results for decisions. Decision makers are not expected to dive into the technical parts of the system, while modellers are not expected to take decisions. Might arise value conflicts between the two user groups, leading to concessions in design.

7.1.6. Basic design principles

The design principles mentioned in Fedra et al. (2008a) can all be related to three main values: Trust, Usability and Sustainability. These relations are shown in Figure 7.4. The principles flexibility and transparency are linked to two of these values. Flexibility both ensures the easy scaleability (usability) and adaptation to changes in users and user requirements (sustainability). Transparency refers to openness in model steps and data assumptions (trust), but as well to production of understandable documentation and manuals (usability). In addition, two design principles are left out of this hierarchy, namely modularity and compatibility, which are seen as design requirements to ensure the other principles, in particular flexibility.

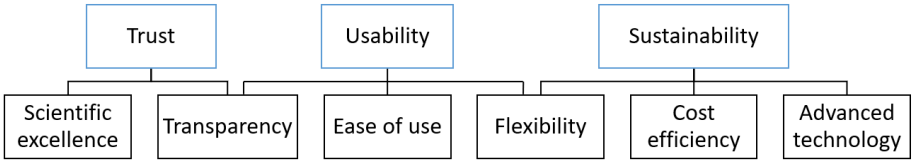

Figure 7.4: Values that form the core of the NBDSS design principles.

Table 7.2: Explanation of the eight design principles presented in Fedra et al. (2008a)

Principle	Relates to
Scientific excellence	Access and openness of data assumptions and methods, documentation, state-of-the-art models and tools, validation
Transparency	Availability of data, assumptions and processes; backtracking of results
Ease of use	Diverse group of stakeholders that should be able to use the system
Flexibility	1) Continuous change of users and user requirements 2) Scaleable from local to basin wide applications
Cost efficiency	All costs for development, training, implementation and operation, compared to the utility of the system
Advanced technology	The complement to scientific excellence in terms of usability; a forward looking strategy on technical possibilities.

7.1.7. Identified values

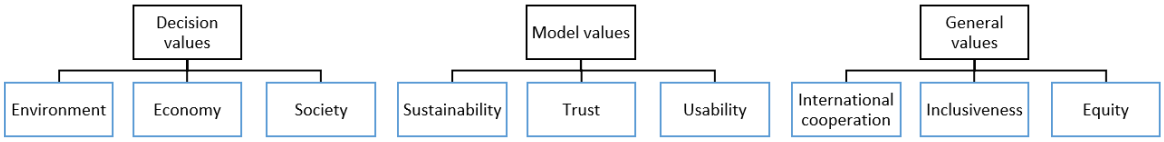

Figure 7.5: Values deduced from the design analysis. Three distinctive sets of values are found, which are called model values, decision values and objective values.

The identified values can be divided into three groups, namely model values, decision values and objective values. *Model values* relate to the model structure and preferences in operation of the model

components. These values are mainly associated with output and user group 1. These values are mainly deducted from the design principles. *Decision values* relate to themes that are embedded within the evaluation tools, and can be associated with output type 2 and user group 2. Decision values mainly appear within the choices on indicators and evaluation criteria. *General values* are not embedded within the NBDSS, but relate to key objectives the NBDSS should contribute to. These can be seen as main areas of impact, and are mainly referred to at the more abstract level of objectives and decisions to be supported.

The groups of values obviously interact. The connection between model components and evaluation tools within the system automatically leads to interactions between model and decision values. In addition, both system components are the result of a single design process, incorporating a single range of values. Because these groups of values differ in terms of user type and goal (produce information vs. produce decisions), a potential for value conflicts arises. The trade off between simplicity and flexibility was pointed out by Giupponi and Sgobbi (2013).

The initial exclusion of a biodiversity component in the shape of a simple empirical relationship because of its lack of thoroughness is an example of a value conflict between environment (a decision value related to the impact on biodiversity) vs. trust (a model value related to the lack of scientific foundation for the relationship). The documentation (e.g. Fedra et al. (2008a)) suggests that this indicator is therefore entirely left out.

8

Discourse analysis

This chapter contains the quantitative and qualitative results of the discourse analysis. The first section presents an analysis of the scores for the different themes. The results demonstrate the existence of two different discourses for each country and the consequent need for distinction between sources describing a domestic and an international focus on water resources. The second section derives values for each country, thereby distinguishing between shared values and country specific values. Finally, the third section elaborates on potential conflicts and synergies between the countries.

8.1. Two discourses: regional vs. domestic focus

This section explains the separation into two discourses based on the quantitative results of the discourse analysis. These two discourses can be separated based on themes related to international relations. The distinction shows a discourse focusing on transboundary aspects of water resources management and one focusing on the domestic aspects.

8.1.1. Analysis of quantitative results

Table 8.1 presents the theme scores for each separate source and the total average score per country. International Relations (IR) shows highest scores in all three countries, based on total scores. This suggests a discourse focusing on the international aspects of water resources management. The scores per source indeed show high IR scores for particular sources, but also low IR scores for others. This hints to a division in sources based on the score for IR. This thesis acknowledges the potential existence of multiple discourses meant for national or international audience, as found by van Roon (2020) in his thesis on water diplomacy in Central Asia. The theme IR is thought to provide a suitable separator between the two groups, using a threshold value of 20% on IR to distinct separate sources into IR and Non-IR.

Table 8.2 shows new total normalised scores based on the two separate source groups. For each country, three columns are presented. One presenting the scores for the IR source group, one the non-IR source group, and one presents total scores. This enables analysis along two dimensions: 1) between source groups: IR and non-IR; and 2) between countries.

Appendix D shows the most occurring subthemes for each source group for each country, including a total which is equal to the sum of the scores for the ten most occurring subthemes. Note that the scores do not necessarily add up to the score in Table 8.2, due to overlap in labels. The former are calculated based on the occurrence of subthemes; every time the label of a certain subtheme is detected, the count of this subtheme increases with 1. The latter is calculated based on the occurrence of theme groups; every time a label of a subtheme is detected that belongs to this subgroup, the count of this theme group increases with 1. However, in case the same part of the text receives multiple labels that belong to the same theme group, the count still increases with 1 to account for overlap. Therefore, the sum of subtheme scores belonging to a theme in Appendix D can be higher than the theme scores in Table 8.2. Consequently, both type of results are treated separately.

(a) Scores for Ethiopia

	ET-1	ET-2	ET-3	ET-4	ET-5	ET-6	ET-7	ET-8	TOT
C	3	8	4	18	7	9	13	8	9
EC	28	15	11	23	0	18	13	25	17
EN	14	0	0	5	7	9	13	14	8
IR	3	62	52	9	73	55	38	22	39
K	14	8	11	9	13	0	13	6	9
NG	8	0	0	14	0	0	0	11	4
S	29	8	22	23	0	9	13	14	15

(b) Scores for Sudan

	SU-1	SU-2	SU-3	SU-4	SU-5	SU-6	SU-7	TOT
C	0	2	0	10	2	0	22	5
EC	0	31	0	19	22	12	11	14
EN	33	16	25	5	21	6	0	15
IR	33	6	25	57	7	29	22	26
K	0	12	0	5	9	18	11	8
NG	0	10	25	0	6	18	22	12
S	33	22	25	5	33	18	11	21

(c) Scores for Egypt

	EG-1	EG-2	EG-3	EG-4	EG-5	EG-6	EG-7	EG-8	TOT
C	33	33	21	4	1	0	0	17	14
EC	0	0	4	22	33	58	10	50	22
EN	0	0	4	11	18	0	3	17	7
IR	67	44	54	11	4	0	48	17	30
K	0	11	3	19	10	42	15	0	12
NG	0	0	0	15	12	0	8	0	4
S	0	11	13	19	21	0	18	0	10

Table 8.1: Normalised results for each theme within each source, separated per country. Values are percentages (%).

Table 8.2: Normalised total average scores for each country, separated in domestic (DM), international (IR) and total (TOT) source group.

	Ethiopia			Sudan			Egypt		
	DM	IR	TOT	DM	IR	TOT	DM	IR	TOT
C	10	8	9	2	8	5	5	22	14
EC	25	14	17	27	8	14	41	4	22
EN	11	7	8	12	16	15	12	2	7
IR	12	50	39	4	34	26	8	53	30
K	10	8	9	12	4	8	17	7	12
NG	11	2	4	15	12	12	7	2	4
S	22	11	15	28	19	21	10	10	10

8.1.2. Distinction in two source groups

The **IR source group** is dominated by IR-subthemes. This can be seen in Appendix D, showing the most occurring subthemes that belong to the IR source group for each country. IR-subthemes score high, especially in Ethiopia and Egypt. Using the theory, this indicates a strong value for international relations within these sources. Scores for Sudan show a slightly flatter, more scattered pattern. The

tables show higher total top 10 scores compared to those for the non-IR source group. This indicates a stronger concentration of high scoring subthemes and a relatively low spread. This pattern is visible over all countries.

The **non-IR source group** contains sources that score between 0 and 17 % on IR and consists of only eight sources, with remarkable similarities in type and audience. In general, national policy documents (EG-5, ET-1, SU-2, SU-5) denote lowest scores. Slightly higher scores are observable for publications via ministerial web pages (EG-4, EG-8, ET-4), addressed to the national public. Finally there is one source that reports a score of 0: EG-6. The latter is an interview on causes and solutions of water scarcity in Egypt. Most remarkable differences with the IR source groups are the higher scores for Economy (EC), visible in Table 8.2, and the high scores for Agriculture, visible in the subtheme scores in Appendix D.

8.1.3. A regional focus vs. a domestic focus

The results suggest a separation between a national, socio-economic discourse and a international relations discourse. In general, economic values play a more significant role within domestic sources, while international relations play a more significant role in international sources. These differences can be explained by the type of source. One may expect more attention for topics such as international cooperation and international laws and policies in sources that belong to platforms for international negotiation such as the United Nations compared to policies that focus on domestic challenges regarding water resources. Similarly, social and economic values may be expected in domestic sources that focus on national development through water, as the purpose of these documents is to improve the country socially and economically. Nevertheless, the distinction between the two suggests a clove between international and national discourse, or, more importantly, a clove between international cooperation on one side and national socio-economic development on the other. The size of this clove is debatable, but the existence of different visions in national and international sources is evident from the results.

This distinction is acknowledged by other authors. Tawfik (2016) mentions the increase in consumptive use of water (besides hydropower production) in the national water policies of Sudan and Ethiopia for irrigation, increasing withdrawals and therefore reducing the available water resources for Egypt, and the lack of response to these new developments that reduce water resources available to Egypt in the countries water policy NWRP 2005-2017. Instead, its focus on increasing efficiency and reuse of drainage water is primarily meant to enable development of new irrigation schemes and land reclamation (Tawfik, 2016). However, the newer version of the NWRP (2017-2037) acknowledges the potential impact of upstream developments, and highlights the potential for outcomes with mutual benefits:

> *"Diplomacy and bilateral cooperation are directed at imitating development activities that provide win-win outcomes [...]"*

This suggests a change in discourse and vision over the years, where the two separate discourses come closer to each other. This change might be attributed to the GERD, which is nationally seen as one of the major challenges facing Egypt today (EG-4). The policy documents analysed for Sudan and Ethiopia date from 1999 and are relatively old. However, these policy documents already show willingness towards cooperation:

> *"Foster meaningful and mutually fair regional cooperation and agreements on the joint and efficient use of transboundary waters with riparian countries based on "equitable and reasonable" use principles"* - ET-1

> *"Cooperation and coordination between countries sharing the same water resource should be encouraged."* - SU-2

Nevertheless, the domestic discourse does not contain any concrete cooperative approaches. In addition, countries primarily focus on the benefits of cooperation for own socio-economic development. The main difference between the two discourses is therefore the regional perspective in the international discourse, focusing on themes that relate to international relations, and the national perspective in the domestic discourse, focusing on socio-economic development, which are clearly separated.

8.2. Values

The separation of discourses and related scores allow for derivation of values for each country. Country scores allow to identify potential patterns and recognise similarities and differences between countries. This section focuses on the meaning of these scores to arrive at a definition of both shared and country specific values. Table 8.3 presents an overview of the country specific information, based on significantly high or low scores for each theme or subtheme. The following subsections explain the mutual values and country specific values based on Table 8.3 for each country respectively.

Table 8.3: Notable codes (high or low) based on scores of the discourse analysis for each country. The second column for each country indicates whether the code is a theme (T) or subtheme (ST).

	Ethiopia		Sudan		Egypt	
	Code	T/ST	Code	T/ST	Code	T/ST
Low			Int. Relations	T	Society	T
High	Energy	ST	Environment	T	Economy	T
	National Pride	ST	Society	T	Identity	ST
	S.E. Development	ST	Livestock	ST	Agriculture	ST
			Nat. Government	ST	Technology	ST

8.2.1. Mutual values

Agriculture denotes highest score within the domestic discourse for each country. This matches the agricultural focus of the countries for their economies. National Water Plans however give priority to domestic and industrial water rather than agricultural consumption, mostly in terms of drought.

Cooperation plays an equal role in each of the three countries from a quantitative perspective. Within the IR-discourse, all countries value cooperation by mentioning its importance and potential and focusing on their own willingness to cooperate. Sudan focuses on its own role within cooperation, without really downgrading the role of the other parties. On the other hand, Ethiopia and Egypt are playing a ”we... they...” game: They emphasise their own willingness and point towards the other parties for preventing cooperation. Here, Egypt puts specific emphasis on the unilateral character of upstream development projects. This term is not mentioned once in Ethiopian sources. In addition, the three parties propose different means. Ethiopia brings up energy trade as a potential for cooperation, Sudan uses its own role as a stimulation of cooperation and Egypt creates a common identity through the Nile to foster cooperation. However, the theme is hardly described in the domestic discourse.

Laws & Policies and **Equity** are other commonly described values in the international discourse. These themes are defined differently and are therefore discussed under Section 8.3.2.

8.2.2. Country specific values: Ethiopia

The scores in Table 8.2 are not remarkable in comparison to the other countries. On the contrary, the results for subthemes in Appendix D demonstrate some interesting high-scoring values.

Energy scores high in both source groups. This valuation of energy production is evident given the mountainous nature and the associated hydropower potential of the country. Hydropower is described as one of the key priorities to unlock socio-economic development, including both national social benefits and regional economic trade. The description does not depend on the source group, as both groups contain references to national and regional importance.

Example from ET-3, demonstrating the social value of hydropower generation:

> *”Some 65 million people in Ethiopia are without electricity. You cannot imagine this much people are sleeping in darkness.”*

Example from ET-2, indicating the economic value of hydropower for the region.

"The GERD [...] will provide electricity not just to Ethiopia but to Egypt, Sudan, and other neighbouring countries."

National Pride mainly explains the relatively high score for Culture in Table 8.2. A strong sense of pride of national achievements in the field of water resources development is noticeable within the Ethiopian sources, with the GERD as main example. This seems to be an ideal value, used to judge and justify behaviour, and is reflected in suggestions of patriotism and a common Ethiopian identity that is connected with water resources, and developments in the field of hydropower and agriculture.

Example from ET-6, demonstrating the pride for the Ethiopian identity:

"[...] I will lead and work tirelessly, hand in hand with the hard-working men and women in the sector and outside the sector, to serve our country where its current and future citizens are reliant and proud of our achievements."

Socio-economic Development is described as a national goal. Water resources developments are one of the main means to reach this goal. The analysed sources show that Ethiopia uses its pursuit of socio-economic development as support for its infrastructural developments, demands for funding and position in GERD talks. This shows the ideal value of socio-economic development to Ethiopia.

Example from ET-7, showing the ideal value of socio-economic development to justify their infrastructural developments:

"Ethiopia's main aspiration is to lift our people out of poverty. [...] The central element of our vision for sustainable development includes building infrastructure and harnessing our national resources."

8.2.3. Country specific values: Sudan

Environment is valued both intrinsic and instrumental. The former is similar to the value attributed by other countries, although more prominently present within the analysed sources for Sudan. The latter is unique to Sudan, and seems to be the major reason for the difference in score with other countries. The awarded instrumental value is mainly related to agricultural yields and provisions for livestock, depending on quality of the environment.

Example from SU-2, demonstrating the instrumental value of the environment.

"The natural environment is the resource base from which we obtain water; there are many factors which affect the environment and hence the water resources."

Scores for Sudan demonstrate the appreciation for **social** themes. These themes include 1) social water uses such as drinking water, health and sanitation and livestock; 2) social consequences of water resources flaws such as internal conflicts, displacement and food insecurity; and 3) social aspects that can either be a cause or a solution to water resource issues, such as (lack of) participation and public awareness. In general, Sudanese sources describe certain themes as important factors limiting the productive capacity of the country, but other themes as consequences of this limited productive capacity. Therefore, societal themes are valued in two ways: for their respective (un)desirability of the value and for their positive effects on national development. The former can be associated with relational values related to water, as water is valued for its effects on relations between people. The latter implies the instrumental value that can be awarded to these social uses of water, in order to achieve socio-economic development.

Example from SU-2, demonstrating the instrumental value of social water uses such as sanitation:

"[...] basic sanitation services are required to ensure personal and public health. They are also needed to protect water sources so as to minimize water-related diseases which are a major cause of poverty, under-development and poor quality of life."

Example from SU-6, demonstrating the relational consequences related to water resources issues such as droughts:

"Consecutive droughts is a direct cause for displacement and migration from rural to urban areas, placing additional pressures on declining food production. Herders are of-

ten forced to seek alternative sources of food and water for their animals, which can create competition over meagre natural resources that can results in conflict between mobile pastoral and settled farming communities."

Sources as well describe relations between environmental and social values, where decrease in natural resources due to environmental degradation is the cause of social issues such as conflicts. This is nicely described by the following example from SU-1:

"The conflict in Darfur, which started with disputes between herders and farmers was a clear demonstration of the direct link between drought, desertification, environmental degradation and conflicts, especially in Africa."

Livestock is highly valued on itself as well, besides being one of the main reasons for awarding instrumental value to the environment. The high score for livestock can be explained by the size of the Sudanese livestock sector, both in economic and social terms. Livestock is qualified as a social value, as it is mostly discussed in social terms within the analysed sources. The economic significance of the livestock sector is addressed less extensively. Furthermore, the subtheme is only present in the domestic sources, but not at all part of the international discussion.

Example from SU-5, demonstrating the social value of livestock.

"The livestock sector constitutes the rural livelihood gear for food production, credit, savings, and nutrition for vulnerable households, and therefore, should be the focus for water interventions."

The **National Government** is mentioned relatively often in Sudanese sources. The history of internal conflicts and recent formation of the transitional government have impact on this valuation, and provide a reason for the sense of obligation to provide a good image of government.

Example from SU-7, demonstrating the admiration for own government.

"While the road ahead is filled with many pitfalls, the government has renewed its commitment to fulfill the objectives of freedom, peace and justice, the bilomatic slogans that have ensured a wave of change."

The theme **International Relations** is quantitatively less dominant in the IR-discourse than in other countries, both in terms of scores for theme (see Table 8.2 and subtheme (Appendix D). The latter indeed shows that other values, such as those discussed above, receive attention in the international discourse as well. This is different for Egypt and Ethiopia, which are dominated by IR subthemes. It is difficult to point out one clear reason for this difference. Possibly the Sudanese history of internal conflicts and national instability stimulated the country to a more national focus, which is reflected in the value for National Government as well. The recently formed transitional government probably influences these scores even more, focusing at their positive impact and "commitment to fulfill the objectives of freedom, peace and justice" (SU-7). This connects to a suggestion by Onencan and Enserink (2014) that countries struggling with legitimacy issues at the national level are the least willing to cooperate, although Sudan scores very well on subtheme International Cooperation. Nevertheless, the following example from SU-10 shows the desire to increase national legitimacy:

"Closing the access gap is a key government priority not only to ensure provision of basic services, but is also a key tool to rebuild the fragile social contract between government and communities, which decays of conflict and civil strive have created."

These findings suggest that Sudanese governmental legitimacy issues do not result in unwillingness to cooperate with other countries, but rather in generally less interest in International Relations. Note that these statements apply to the Blue Nile countries in a relative manner, where "less" does not necessarily mean "little". That would contradict with the results of the discourse analysis.

8.2.4. Country specific values: Egypt

Economy scores remarkably high within domestic sources, especially compared to scores for social themes. This is reflected in the scores for subthemes in Appendix D, showing relatively high scores for Agriculture, Economy and Efficiency.

This high theme score is obviously related to the dominance of **agriculture** within the domestic discourse. The score of 24% for the subtheme indicates that almost a quarter of the analysed sources contains a reference to agriculture or irrigation. The value for the agricultural sector and associated water consumption is evident, and the overwhelming attention for the topic suggests a prioritisation of agriculture over other demand sides. This is however contested in the sources, stating that agricultural water supply is subordinate to domestic and industrial supply. Agriculture, being the largest water consumer, is the most important sector for rationalisation of consumption. This as well partly explains the high score for **Water Quality**, which is mostly discussed in terms of reuse of irrigation water. See the following example from EG-5, highlighting the desire for rationalisation of agricultural consumption:

> *"[...] the agricultural sector is the recipient of water that is not diverted for domestic and industrial use [...]. At the same time, the objective also requires the agricultural sector to produce more crop per drop and to generate more cash per splash."*

The high score for **Technology** connects to the latter part of this quote that focuses on increasing the production and efficiency. Modernisation of irrigation schemes and application of new and advanced technologies in the agricultural sector are seen as important means to reach these objectives. Look at the following example from EG-6 of the stimulation of a new technology over traditional approaches within the agricultural sector:

> *"Ghanem [spokesman for the Ministry of Water Resources and Irrigation] pointed out farmers used to rely on their own experience in determining when to perform the irrigation process and when to complete it, but this device [the moisture meter] can determine this very precisely."*

The subtheme **Identity** is mostly present within the international discourse. The theme comes back in two different ways: A shared identity with other basin countries, and a historical and existential connection with the river. The former seems to be inconsistent with existing literature, that emphasise the historical segregation between Arab and Sub Saharan identity and a perceived feeling of distrust between them. On the other side, the perceived distrust might actually provide an explanation for the observed common identity that is claimed by Egypt. It seems to be a move in a negotiation process, thereby trying to enforce their position. See the following quote from EG-3:

> *"This reflects our unshakeable belief in our common destiny as Africans and confirms our conviction that the Nile River is not the exclusive property of Egypt or of any riparian State, but the common heritage and sacred trust of all our peoples."*

The other appearance of identity is shaped in a cultural sense of existence, a deeper connection with the river that means the difference between life and death. Other authors describe values attached to the Nile by Egyptians in a similar way, but mention their function in the securitisation[1] of water allocation issues (e.g. Grandi (2021); Arsano (2007); von Gienanth (2020)). Using the definition of securitisation, the existential identity that Egyptians attach to the Nile is an ideal value, justifying the position in international negotiations.

Example from EG-2 and EG-3 respectively, demonstrating the framing of the Nile as a source of life:

> *"[..] for Egypt the water of the Nile is a matter of life and existence [...]"*

> *"This harsh reality compels us to inhabit no more than 7 per cent of our territory along a slender strip of green and a fertile delta teeming with millions of souls [...]"*

Society scores noticeably low in the domestic source group. Only subthemes Participation, Society and Equity (National) are mentioned in two sources. All other subthemes can be found in only one or even none of the analysed sources. The absence of themes related to drinking water and sanitation were expected, as their status is significantly better in Egypt compared to the other countries, both qualitatively and quantitatively. Other aspects such as trust and justice are apparently not valued by Egyptian decision makers. The known authoritarian regime is expected to play a role in this ab-

[1] Securitisation can be defined as "The promotion of an issue to a national security concern, thereby legitimising counter-measures [...]" (von Gienanth, 2020)

sence. One explanation for the low appreciation for social values can be that the focus in the analysed sources is on ways to safe water, rather than on the benefits of these water savings. This rationalisation is already necessary without additional social water demands. The following example from EG-5 formulates this even stronger:

> *"The objective reads 'is securing' rather than 'has secured'. This indicates that Egypt [...] will achieve a sufficient level of control, while water scarcity itself remains a fact of life."*

8.3. Potential value conflicts, interest conflicts and value synergies

The derived values can be divided into different groups. There are common, uncontested values that are shared by all countries. Examples of this category are the values related to International Relations, such as cooperation, equity and laws & policies, but as well the value of knowledge and participation. Such values are difficult to disagree with; they are generally in line with the Sustainable Development Goals, the main guiding framework for global development. This group as well includes values such as economy, environment and society, and, according to this research, the value of agriculture is uncontested as well. The other group consists of complex, contested values that are specifically relevant to a certain country. Examples found during discourse analysis are the cultural-ideological values identity and national pride and the social theme livestock. Such values are not characteristic to one party and may therefore conflict with a value of another.

Additionally, there is a third group. This group consists of values that seem to belong to the uncontested group if looking at them superficially. However, by taking a closer look, it turns out that differences in definition arise between the countries on the same value. An example is the definition of equity.

This section uses the theory from Section 4.3.4 to identify potential value conflicts, interest conflicts and value synergies that might arise between countries because of differences and similarities in values. This section makes a distinction between inter value conflicts, such as identity vs. pride, intra value conflicts, such as the conflict around the definition of equity, and interest conflicts, such as the potential conflict due to the shared value for agriculture.

8.3.1. Egypt's identity vs. Ethiopia's pride

Egypt and Ethiopia both show different high scores on a value which I have called Culture. The difference The two narratives are constructed around a value which I have called Culture. However, the understandings of these cultural values related to the Nile differ over the Blue Nile countries. This research identified two current prevailing ideal values: The cultural sense of identity and existence in Egypt, and the cultural sense of pride and nationalism in Ethiopia. Grandi (2021) acknowledges both discourses and calls them "incompatible", as they fundamentally differ on the topic of upstream developments. This incompatibility suggests an intra-value conflict between two interpretations of what "culture" means in relation to the water resources development on the Nile.

Egypt scores high on the theme Identity in two different ways: a shared identity with other basin countries, and a historical and existential connection with the river. Grandi (2021) extensively describes this sense of identity, stating that *"[t]he image of a river portrayed as essential for life is dominant in Egypt and explains the affection for the river so deeply rooted in the societies along its banks"*. Grandi adds that this image and its related sense of gratitude and pride have found their way to the political and economic domain. Cascão (2009b) (in Grandi (2021)) calls these values "traditional values", which have had an impact on recent policy making and discourse creation. Examples of these discourses are the successful emphasis on Egypt's absolute dependency on Nile water, its historically acquired rights of prior use to the Nile water, and the definition of water availability as a matter of national security (Cascão, 2009a). Zeitoun et al. (2017) and von Gienanth (2020) call these examples of hegemonic compliance-producing mechanisms, which relate to the domain of ideational power. The possession of ideational power allows the hegemon to shape the discourse in its favour, thereby ruling out other perspectives. Egypt's possession of ideational power has been one of the drivers for its position as a hydro-hegemon, which by deduction means that this sense of identity or "traditional values" has a

major impact on the hydropolitical situation in the basin. This identification is therefore valuable to be aware of in terms of decision making on water resources management.

On the other hand, Ethiopia shows high scores for National Pride, which is brought to life by the GERD in an extremely visible manner. The name Grand Ethiopian Renaissance Dam implies a certain sense of pride in itself. These feelings of pride and patriotism are mainly oriented towards development of water resources through infrastructure. According to Grandi (2021), these developments have a function beyond benefits through increased water supply and energy production; it serves as a necessary means to generate a *"general sentiment of nationalistic pride, expectations for a brighter future and widespread patriotism"* (Grandi, 2021), a new, positive discourse on hydrodevelopments that emerges from a historic hate-love relationship between Ethiopians and the Nile. Arsano (2007) and Grandi (2021) both describe the two opposite sides of the dilemma using quotes by multiple authors from poetry and old mythology. Both distinguish the Ethiopian view of rivers as "traitors", benefiting other nations while leaving their own country and people behind (Arsano, 2007; Grandi, 2021). This perception is still visible in the 1999 Ethiopian Water Resources Management Policy (ET-1):

> *"Much of the water however, flows across the borders being carried away by the transboundary rivers to the neighbouring countries."*

This new discourse can be seen as an important component in the construction of Ethiopia's counter-hegemonic position, using socio-economic development and national pride as a tool (von Gienanth, 2020). Both components become visible in the construction of the GERD, the epitome of Ethiopia's ambition for a bright future. The following quote from ET-8 demonstrates the role of the GERD in the creation of a sense of national pride and unity, as well as the desire for socio-economic development:

> *"[...] the GERD has become a very real and prominent symbol of national pride, a flagship project to efforts of poverty alleviation and the renaissance of the country"*

This sense of pride can be seen as an ideal value, a value to judge and justify behaviour. The ability to push a discourse is again related to the concept of ideational power. On a national level, this ideational power lays at the political rulers. National groups that do not conform to this vision of pride and prosperity, are rather silenced Grandi (2021). According to Veilleux (2013), the assessment of large infrastructures such as dams regularly overlooks the costs to local communities, with traditional livelihoods dependent on the river, and ecosystems. More specifically, local Ethiopian people see the river as *"the centre of their culture, identity and society"* (Veilleux, 2013), thereby bringing up yet another definition of cultural values associated with the Nile and, consequently, a intra-value conflict on national scale. The exclusion of such local values is one of the main limitations of this research, as it only focuses on the political debate. Nevertheless, von Gienanth (2020) has shown that the sense of pride and unity as well prevails amongst students and on social media when talking about the GERD, suggesting that the consensus for the observed political discourse is shared beyond the borders of the political domain. Besides the exclusion of certain values, the difference in distribution of ideational power and occurrence of intra-value conflicts between the national and regional scale demonstrates the complexity of water resources management with regard to scale, and poses some requirements for decision making as well.

8.3.2. The definition of spatial equity

The results show that the Blue Nile countries acknowledge the importance of equitable use and allocation of water in analysed sources. Rasul et al. (2010) distinguishes four elements of equity: 1) *spatial equity*, between people living in different regions or states; 2) *social equity*, between different groups of people living in the same location; 3) *gender equity*, between men and women in access and use of water and its benefits; and 4) *inter-generational equity*, between generations. The first three are prominently present within sources in all three countries; the fourth is attributed less importance. Here, spatial equity covers transboundary distributive justice, while social equity is about distribution between user groups within a country. In this thesis, spatial equity is framed in the IR subtheme International Equity, social equity in S subtheme Equity (National) and gender equity in the S subtheme Participation. The focus of this research is on transboundary water resources, so the focus of this section is on transboundary nature of spatial equity. Social equity is discussed in Section 8.3.3, gender equity in

Section 8.3.5.

The results show that the Blue Nile countries acknowledge the importance of spatially equitable use and allocation of water in analysed sources. However, they tend to give a different meaning to the concept of equity, matching their geographic location along the river. Two main topics dominate the discourse: the definition of equity in terms of ”reasonable use” and ”no significant harm”, and the validity and fairness of both existing and future agreements.

Ethiopia focuses its definition on benefits of upstream developments, thereby highlighting the principle of equitable and reasonable utilisation, while giving less attention to potential harm to other riparians. The country does not approve any agreement limiting their developments, either existing or yet to be created. Their perspective is based on extending the usage of water, demonstrated by the quote below:

> *”People should know that the River is adequate enough to address our needs provided that we use it equitably.”*

Sudan pays generally less attention to the theme than the other two countries. The two sources that contain references to equity emphasise both potential benefits and harms of upstream developments. Sources further emphasise the role the country plays in promoting cooperation, thereby pointing to its geographic location between upstream and downstream countries:

> *”The [...] geopolitical location of Sudan makes Sudan in a very good position to support cooperation in the region between the upstream and downstream countries. [...] [T]he Nile can be considered as [...] an avenue for cooperation among the Nile countries, for sharing the benefits and causing no significant harm.”*

Egypt finally mostly focuses on potential harms of upstream developments, and the dangers of upstream use for water supply available to the country. This matches the perception of downstream states to be vulnerable to upstream actions (Ashton, 2002), and corresponds to value of existence attributed to the Nile waters. Egypt vouches for agreements that strictly define the concept of significant harm, and projects the concept on historical agreements as well. Protection of the share of water is a central theme, which is visible in the following quote:

> *”Any other understanding or interpretation of this commitment would [...] reveal an underlying intention to impose an unacceptable fait accomli on downstream States and enforce the unilateral will of an upstream State on its co-riparians [...]”*

The concept of spatial equity is mostly used in negotiations on operation of the GERD, rather than as a basic principle for water resources management developments. This suggestion is strengthened by the observation that only Ethiopia uses the term in its national discourse. The concept therefore seems to function primarily as a means to reach ones objectives in international negotiation, rather than an operational design principle from national point of view.

The NBI mentions in its objective that *”the equitable utilisation of, and benefit from, the common Nile Basin water resources”* is the main means to reach sustainable socio-economic development in the region. However, a clear and functional definition, criteria and indicators for equitability lacks, which consequently results in difficulties with operationalisation of the concept (Yalew et al., 2021). In their paper, Yalew et al. (2021) use the Blue Nile countries Egypt and Ethiopia as an example to demonstrate the incompetence of the existing approaches, in particular those adopted by the UN Watercourse convention and SDG6.2, to really assess and monitor progress towards equity in transboundary basins. This connects to the findings in this research, that resemble the diverse range of interpretations and unconstructive use of the term spatial equity. Here, terms such as equity, reasonableness and fairness illustrate the subjective side of current approaches, but are simultaneously emerging as important elements in allocation of transboundary water (Yalew et al., 2021; Wouters et al., 2009).

Nevertheless, Yalew et al. (2021) as well point to opportunities, highlighting the potential of value optimisation techniques. These optimisation techniques use moral principles to quantitatively assess options in a morally informed manner, thereby facilitating negotiation and decision making. This would improve visibility of fundamental justice issues and result in indicators to monitor progress towards sustainable and inclusive transboundary water resource management. This would allow to capture the moral dimension rather than current available operationalisation approaches that focus on economic

efficiency and conservation (Yalew et al., 2021). However, one of the main challenges of integrating values in decision making is the operationalisation of moral values such as equity or distributive justice into measurable indicators and criteria, as identified in Section 4.3.4. This requires 1) explicit statement of values and 2) value judgements to select criteria and measurable attributes.

This suggestion resembles the theory in Section 4.2.2 applicable on decision support systems. The application of a DSS seems suitable to perform such optimisation techniques, involving multiple stakeholders and interests. Section 4.3.4 however already stated some requirements and challenges towards such applications, one being the operationalisation of such moral values into measurable indicators. This remains a challenge in the proposed approach, disregarding the optimisation strategy of choice. Currently, the NBDSS does not explicitly state any indicators or criteria to assess the equitability of solutions, but such indicator combinations should be determined based on context of the issue at hand. The absence of a structured approach for the calculation of one of the main objectives is expected to reduce effectiveness of the system. Determination of clear and accepted indicators and criteria is important to increase support for and trust in decisions of the NBDSS. The current economic and conserving definitions might not cover the full range of moral values that are at stake when making decisions on transboundary water resources, but can be seen as a step in the first direction. Usage of a participatory planning tool such as the NBDSS stimulates active discussion on values, which brings more explicit moral components to the decisions problem. These discussions can help to formulate additional, morally induced indicators, that complement the purely economic ones towards a more inclusive definition of equity.

8.3.3. Differences in values related to social themes

The attention for social subthemes differs amongst the countries based on the scores, with averages ranging from 21% for Sudan to 10% for Egypt, with Ethiopia in between. In addition, a brought range of codes was placed under the theme Society during coding, showing diversity over the countries as well. This indicates a difference in definition of what is considered social, both in terms of content and relevance. In general, the subthemes link to Society can be divided into four categories: 1) social water uses such as drinking water or health and sanitation; 2) social consequences such as conflict, displacement and food insecurity; 3) social solution strategies such as participation, public awareness and equity and 4) objectives such as social development and improved quality of life.

Ethiopia focuses on contribution to socio-economic development. The analysed sources contain plenty of references to the term ”socio-economic development”, but the social part of these developments are mostly framed as a necessity to generate more economic growth. That means that improvements in water uses or reduction of consequences are not a target on itself, but are framed in terms of their positive impact on development of the country. Ethiopia clearly states in its water policy that ”water shall be recognized both as an economic and as a social good”, but later on mentions that ”all water resources developments ought to be based on the ”economic value” of water”.

This differs from **Sudan**, where the social water uses drinking water, sanitation and livestock dominate the domestic discourse. Improvements on this level are key objectives of water sector policies. Drinking water and sanitation score high in the international discourse as well, highlighting their priority and absolute value. Additionally, the Sudanese international sources often mention internal conflicts, adding a consequence the list. As mentioned in Section 8.2.3, Sudanese history of internal fights and instability is reflected in this value.

On the contrary, **Egypt** pays little attention to social water uses and consequences. That does not mean they are not valued; Section 8.2.4 discussed the priority of domestic water consumption over agriculture, highlighting the inherent value of drinking water. The small livestock sector and relatively well established drinking water and sanitary connections make water uses of less interest compared to the other countries. The absence of social consequences might actually arise from the clustering of themes. Egypt obviously focuses on these consequences in the international discourse, but the value of existence was caught under Culture; the corresponding consequence as described in Egyptian sources is death. In addition, Egyptian sources do speak about participation (solution) and equity (objective). Furthermore, the subtheme Society scores high. This subtheme was invented to catch all references to society or social benefits without a concrete description of these benefits or impacts. The absence

of concrete examples of societal themes suggests a lack of sincere interest in these topics, and hints towards name dropping.

Participation could be observed through all countries and discourses as important aspect of water resources management. Financing the GERD is a clear example of participation of the Ethiopian people, while Egypt aims at rationalisation of water consumption at every layer of society including domestic use. Although the examples differ in participatory approach, the value of participatory approaches seem to match each other: Participation of user communities, women in particular, and the private sector in decision making and water management practices in order to make approaches more inclusive and increase support. This hints towards a value synergie, which can be translated into design features that are accepted by all parties, discussed in Section 8.3.5

8.3.4. Agriculture: Matching value, conflicting interests

The results point to a third type of conflict, different from the two types of value conflicts described above: a conflict of interests. Such a conflict arises in case different actors pursue the same value, but individual pursuit of these values affects other actors in their pursuit. This is especially applicable to situations involving common pool resources such as the available water resources in a river, where actors compete over the same finite resource in order to accentuate their specific value.

This can be illustrated using the value agriculture, valued by all three countries, as an example. The agricultural sector is water consuming; crop growth depends on evaporation which inherently results in water leaving the river system. The value attributed to agriculture is mainly an instrumental one, to achieve social and economic growth. Further accentuating this value would aim at increasing yields, which inherently comes with increasing consumptive use of water. However, the total amount of water and inherently the amount of water available to agriculture are finite. Even stronger, the water stocks of the Nile are already under pressure. Therefore, such an increase in water consumption automatically affects other demand sides. A battle for the common resource arises in case these other demand sides as well try to increase their consumption. This would become reality in case all three countries act towards their valuation of agriculture individually, although agriculture is mutually valued. The term ”individually” is particularly relevant because it results in competing demand sides and thereby conflicting interests. This example therefore shows the potential negative consequences associated with unilateral pursuit of values.

On the contrary, cooperative accentuation of such mutual values might provide opportunities beyond the instrumental nature of a value. Using the example of agriculture, this this would mean that the countries act towards their valuation of agriculture in a cooperative manner, thereby looking for differences in values rather than similarities to find win-win solutions. In addition, the accentuation of agriculture does not necessarily have to come with increased water consumption. Current technologies allow to increase yield using the same, or even less, amount of water. The Egyptian discourse focuses on such conservation practices (see Section 8.2.4). Such practices show the awareness of both finiteness and mutual dependency of water and provide solutions on the demand side.

8.3.5. Value synergies

Cooperation might seem a bit odd, in the context of a value synergy, as this whole thesis narrates the unwilling attitude of Blue Nile countries towards cooperation. However, the international discourse contains plenty of references to basin wide cooperation, which at least demonstrates the awareness of its importance. The framing of cooperation seems a classic example of an ideal value as opposed to an actual value, mainly because of its significance in the international discourse while limited in the domestic one. This raises concerns on the cooperative will in the countries.

Knowledge is valued by all actors in a similar manner. In general, countries show a desire for advanced technologies, data and monitoring devices to support evidence based decision making. These aspects provide room for cooperation. In addition, it shows the potential of the NBDSS, as it incorporates plenty of these knowledge related values.

Participation and inclusion are both described similarly in the national discourses. Participation of user communities, women and minorities in particular, and the private sector in decision making and

water management practices are valued for their potential to make both decisions and management more equitable and inclusive. The focus on women and minorities brings back two types of equity mentioned in Section 8.3.2: *social equity* and *gender equity* (Rasul et al., 2010). These obviously are two different aspects, requiring different approaches.

Economy and related interests seem are highly valued by all actors, which provides possibilities for economic cooperation and trade. Agricultural products and energy can both be part of such deals. Sources contain references to these type of regional interaction.

9

Value-based evaluation of the NBDSS

This chapter evaluates the capabilities of the NBDSS in considering all values. This evaluation is based on the four elements as mentioned in the method: design requirements, design values, actor values and value conflicts and synergies. The impact of the two separate discourses on the functioning of the NBDSS and vice versa is added to this list.

This evaluation reveals the potential of the system for assessment of water resources problems in economic and environmental terms, but as well shows that social and cultural values are excluded from NBDSS decisions.

9.1. Reflection on DSS requirements

In Section 4.3.4, five requirements for a DSS to contribute to value considerations were derived. These are transparency, participatory development, reasonable value judgements, flexibility and usefulness of information (see Section 4.4).

The developers of the NBDSS have acknowledged all five requirements in their development process. The main point of interest did not relate to the system design, but rather to the cooperative attitude of the actors involved now that the system is in use. The perceived lack of institutional transparency and little clarity on sharing of data in combination with phrases from the sources used for discourse analysis hint towards a lack of trust between the parties involved. Such mutual understanding and trust is essential for the legitimacy and, consequently, the success of a collaborative planning tool such as the NBDSS.

9.1.1. Transparency

The NBDSS is well designed with regard to transparency. It is equipped with a clear and structured system to store and retrieve used data, assumptions and other choices to come to specific decision information. It further incorporates proper data management through PostgreSQL, which allows to access various databases. However, interaction with the NBDSS revealed a couple of transparency issues that are related to management and governance rather than design of the system.

Access to the system can be requested through the NBDSS help desk online and requires licenses and software downloads. Transparency issues arose during installation, as manuals are outdated while software has been updated. Compatibility issues due to differences in version arose and were difficult to solve. In addition, the NBDSS is delivered as an empty shell. The downloaded software package is a general MIKE program, which ”becomes” the NBDSS by loading hydraulic, hydrologic and spatial data sets, script packages and indicator spreadsheets. Script packages were difficult to retrieve, as the download at the NBDSS platform was unavailable. The NBDSS training material comes with required data to do the exercises, but indicator spreadsheets were not encountered. Request through the help desk did result in a positive response, but eventually were never received. Data can be managed using PostreSQL databases, but it is unclear how data are shared amongst riparian countries. The identified gaps in the understanding of NBDSS could be easily filled during an interview with an expert on the system. However, this interview was cancelled, which ironically contributes to the perceived lack of transparency. These issues mainly reduce usability of the system, especially by outsiders of

the organisation, but might as well affect trust in the outcomes of applications by other actors due to a lack of data sharing.

That said, the NBDSS is not made to actually share data, but merely is an analytical tool to create knowledge and thereby facilitate decision makers. Data sharing however is key to the objectives of the NBDSS, namely a shared knowledge base and cooperative planning and management of the Nile waters. Proper sharing of data is therefore a precondition for the success of the NBDSS. Other initiatives exist to increase sharing of data over the basin countries, such as those guided by the Nile Basin Data and Analytics Services.

9.1.2. Reasonable value judgements

The question whether *value judgements* are reasonable is a subjective one. The evaluation of these value judgements requires active documentation of the applicable choices on inclusion or exclusion of values, criteria and measurable attributes, as well as trade offs between considered values. Such value judgements can partly be discovered within the analysed documents, but these mainly cover included values which resulted in the nine derived NBDSS values. Choices on which values to exclude are important to the development process as well. These are not properly documented, but this can be attributed to the lack of transparency as well.

One important section that provides insights into value judgements is the section ”External Models” in Fedra (2008). This section describes various external models that are not directly included into the NBDSS because they are regarded as *”not directly required as ”embedded” functions of the river basin simulation system”* (Fedra, 2008). Examples of excluded models include urban/industrial water demand, (extensive) water quality, wetlands, climate change, sediments, biodiversity and regional demographics. The core system does incorporate basic models for hydropower production, reservoir management, water quality and irrigation. Focus on irrigation and hydropower resemble the economic perspective observed in the sources focusing on domestic water resources management. The exclusion of other models seems to be a trade off between complexity and inclusiveness, as discussed in Section 9.1.5.

9.1.3. Participatory development

The NBDSS was created using *participatory development*, which is beneficial to the inclusiveness of the system. Additionally, it not only increases the perceived trust of participants in the NBDSS, but can as well create mutual understanding, thereby increasing mutual trust between parties and enhancing legitimacy. Involved participants included potential DSS users, development partners, interested parties and data supplying institutes from all Nile Basin countries, including regionally operating organisations. This already demonstrates a cooperative attitude, which was observed during the development phase as well by the lead consultant, who states *”expectations and interests of stakeholders are high, a very positive prerequisite for good progress [towards a joint DSS]”* (Abuzeid et al., 2007). This section reflects on design requirements, not on requirements for usage. The demonstrated cooperative attitude during the development phase therefore is thought to be sufficient to fulfil this criterion. Nevertheless, joint planning using the NBDSS obviously requires a sense of cooperation between the countries as well. Results of the discourse analysis and the identified NBDSS values suggest that the necessary cooperative attitude for implementation of the system on a transboundary scale is present, although these might be ideal values rather than actual ones. The latter seems especially the case due to the separation of international and domestic discourse, where nationally oriented sources hardly show any signs of cooperative will. More on this later.

9.1.4. Flexibility

The NBDSS is designed in a highly flexible manner. The system is compatible to different types of models and software, from which output can be combined in the NBDSS to calculate indicators for multicriteria or cost-benefit analysis. Model software can be connected by using so-called adaptors; specific adaptors exist for selected software packages, but it is possible to develop new ones for additional packages. In addition, the NBDSS allows for development of new criteria and indicators, next to

the predefined ones. This provides the system with the flexibility to cope with both value dynamics and proceeding knowledge, where indicators can be added to either represent new values or represent an already existing value in a different way. The spatial scope is as well flexible, from local to basin-wide scale.

9.1.5. Usefulness of information

The process of finding out what is considered to be ”useful information” amongst the different countries played a central role during development of the NBDSS. Interactive sessions in every country mainly focused on salience, seeking for key focus areas, decision types, criteria and indicators. The desire for applications on different scales (local vs. basin-wide) poses challenges to the salience of the delivered information. The interpretation of salience differs for both scales, as salience depends on legislative and political context but as well on values involved. The results of this thesis have shown that values related to domestic water resources management differ from those related to transboundary water resources management. The flexibility of selecting and adding indicators provides an outcome to make the NBDSS scalable. Credibility of information is ensured by the scientific standards for inclusion of indicators. Only scientifically proven relationships are used, either theoretically or empirically. This criterion limits the amount of environmental and social indicators available in the system, due to a lack of proven and measurable relationships. The developers have tried to ensure legitimacy of information through participatory development, documentation of the development process including design choices, cooperation with national entities and transparent data management tools. Issues related to transparency however are expected to affect perceived legitimacy as well. Finally, legitimacy of such a joint tool is not only determined by a feeling of trust in the design of the tool, but as well in other people that interact with it. The latter seems to lack based on the analysed sources.

As mentioned in Section 4.3.2, the three criteria for useful information conflict with each other, leading to trade offs amongst them. Choices for exclusion of certain modellable aspects such as demographic information imply a preference for reduction of complexity over monitoring of different demographic entities. Exclusion of the latter could lead to a biased outcome, mainly because of ignoring distribution of consequences over different social classes. This is an example of a trade off between salience (what information is chosen to be useful?) and legitimacy (does the information provide a fair picture?). For credibility reasons, biodiversity indicators were left out of the design because of their empirical nature. This again implies a preference for science over inclusiveness. Scientific credibility is associated with trust, and therefore with legitimacy. However, the exclusion of such aspects can reduce perceived legitimacy, for example for environmental groups. This example shows that legitimacy of the NBDSS is at stake in various ways. Again, transparent documentation on value judgements such as choices on inclusion or exclusion are essential to maintain legitimacy.

9.2. Coverage of actor values

Analysis of the inclusion of values in the NBDSS shows that mainly environmental and economic values are operationalised well. The tool further facilitates assessment of cooperatively, equitably or legally induced scenarios that can contribute to consideration of values associated with international relations. Identified social water uses are included to some extent, but the conceptualisation of livestock and domestic water use in the NBDSS does not reflect the value deducted from discourse analysis. In addition, social consequences and cultural or ideological aspects are not included in the system, while they have a demonstrated impact on water system, society and transboundary relations.

9.2.1. Economic, environmental and social values and indicators

Table 9.1 shows the most relevant social, environmental and economic values and their respective incorporation in or exclusion from indicators in the NBDSS. The operationalisation of economic and environmental values in NBDSS indicators covers the most important values identified during discourse analysis. Economic indicators are calculated based on extensive scripts, with proven relationships. In addition, efficiency can be calculated using water availability indicators, such as Water Conservation

and Water Availability. The fact that evaporation losses are denoted as being economic parameters indicates an economic vision of water resources in general. On the other hand, environmental indicators are generally calculated based on empirical relationships, using rating curves or predefined footprint data. Nevertheless, the important environmental values, water quality and natural resources, are covered in the NBDSS. It can therefore be concluded that the NBDSS allows for consideration of these values in the decision making process.

Social values however are operationalised differently. This can be deduced from Table 9.1, which shows certain identified values that are not reflected in the social indicators. In addition, the definition of indicators does not always meet the expectations. This actually links to the diffusive character of social values as discussed in Section 8.3.3, lacking a clear definition of what is considered to be social. Included indicators primarily focus on food security, displacement, health and safety. In terms of the separation of ”social” into uses, consequences, solution strategies and objectives, the NBDSS focuses on uses (food security, health, water availability) and to a lesser extent on consequences (displacement) and objectives (safety).

Obviously, social values such as conflict and participation are difficult to embed in a DSS. Even stronger, seven of the total of fifteen social indicators are proxies, emphasising the absence of proven natural or even empirical relationships between the physical system of the Nile (e.g. flow or inundation height) and social values. Nevertheless, it should still be possible to consider such values during a decision making process. Relevance of inclusion has been demonstrated by the discourse analysis and the usage of a computerised tool should not lead to exclusion of values that are difficult to quantify.

Table 9.1: Comparison between economic, environmental and social actor values and their operationalisation in terms of indicators in the NBDSS, demonstrating the difference in operationalisation of society.

Value category	Actor value	Indicator
Economy	Agriculture	Yes
	Efficiency	Yes
	Energy	Yes
Environment	Natural resources	Yes
	Water quality	Yes
Society	Drinking water	Yes
	Health and sanitation	Yes
	Participation	No
	Conflict	No
	Social equity	No
	Livestock	Yes

The indicator Water Availability

Both drinking water and livestock are caught under one indicator Water Availability (see Appendix A). The NBDSS allows to create multiple demand sides, reflecting either domestic consumption or livestock. In this way, distributional issues between the sectors can be modelled, although the indicator description[1] suggests one demand side that covers domestic, livestock and recession agriculture water demand. In addition, the description suggests the water available for domestic and livestock purposes to be a ”left-over”. This does not reflect the priority status awarded to domestic consumption of water in National Water Plans.

Livestock in the NBDSS

The usage of one indicator for both domestic and livestock consumption emphasises the social view of livestock in the NBDSS. However, this indicator does not cover the relevance of the value of livestock, primarily for Sudan. This has two reasons. First, the indicator only allows to model livestock as a demand side, consuming water without any production. However, the Sudanese livestock sector contributes 55% to the agricultural GDP and provides employment to 40% of the population, indicating

[1] The change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock, see Appendix A

the significance of the sector. The conceptualisation of livestock as being a purely consuming sector does not cover the economic benefits of this consumption. The extensive calculations of agricultural and energy production indicators show the economic orientation of other sectors, highlighting the exclusion of the livestock sector in economic terms. Secondly, the relational values related to livestock (e.g. problems related to migration and associated conflicts) are not reflected in the indicator, but can actually have a major impact on water demands, in particular on urban water demands due to migration towards cities. The exclusion of such an important national aspect within the NBDSS suggests that minority values might be excluded from the final design. This exclusion affects regional decisions, but is particularly relevant for application of the NBDSS on a smaller scale within Sudan. In general, the exclusion of national values in the system limits the applicability of a DSS on a national scale.

9.2.2. Scenario modelling for international values

International cooperation, equity and laws and policies are all valued in each of the countries. These values are not included in the indicators, but can function as guiding concepts in scenario development. Smit (2021) used scenarios to test the impact of the legal debate on strategic allocation of the Nile waters; Verhagen (2020) formulated different cooperative scenarios to study the potential benefits and impacts of water resources collaboration along the Nile. Similar scenarios could be developed for the NBDSS. In addition, these examples show the potential of scenario development to test international aspects of transboundary water resources, including transboundary equity. Such scenarios would facilitate decision making from a regional perspective by giving insights into both benefits and consequences of certain approaches. The development of different scenarios to test the various definitions of spatial equity could help in formulation of standards on equitable distribution and in definition of what equity actually is.

9.2.3. The NBDSS as a an artefact embodying knowledge and participation

The value for reliable data, evidence and information highlights the potential and relevance of the analysed support system. This tool actually embodies the desire for evidence based decision making, as it is the direct functionality of the system. The NBDSS itself therefore reflects this value of knowledge, producing information and evidence to support decision makers. Analysed sources as well show disagreements on reliability of data and measurements as well as different interpretations of model outcomes. A complete, inclusive and accepted design of the NBDSS could definitely contribute to a solution for these disputes by providing credible, accepted information and stimulate discussion beyond positions. The question remains whether the system is up to the current standards of knowledge, that is, whether it incorporates all possibilities of today's technologies and science. An example is the absence of biodiversity models because of their limited scientific relevance back at the start of development in 2008, while newer decision support systems currently make use of flow-ecology relationships to relate fish community response to water quantity and quality, thereby providing a measure for biodiversity indicators. This could be integrated into the design of the NBDSS as well.

Participation is one of the shared values amongst all countries. The sources mainly describe participation in terms of participation of user communities, women and minorities in water resources practices and active participation of the private sector in water resources management. These types of participation are actually not facilitated by the NBDSS when making decisions from a regional point of view. Such participatory approaches take place at a smaller scale, e.g. locally. Nevertheless, the NBDSS is as well meant for implementation on local or national scale, thereby providing room to include women, minorities and local user communities in the process. This simultaneously allows for development of a better understanding of local residing values, that can be incorporated in the negotiations on the transboundary scale. However, transboundary decision making involves state actors linked to the Ministries of Water Resources. In this context, the participants are therefore different from the participants described within the sources. The inclusion of these groups in regional decision making is therefore desirable, although it is not feasible to provide everyone with a spot around the negotiation table. Such efforts are there even a prerequisite to inclusive decision making. More on this in Section 9.4. The tool still embodies participatory and inclusive decision making, but this might in practice be complicated due to limited access to the decision making process.

9.2.4. The exclusion of culture and national governance

Both cultural and national governance aspects are generally not included in the NBDSS. The exclusion of important identified cultural aspects such as identity and pride makes sense given the complications with quantification of the interactions between such feelings and water management practices. However, effects of water infrastructure development on such cultural aspects have been described for dam projects in all countries in a qualitative manner. Mohamud and Verhoeven (2016) describe the aspirations of Sudanese regime to use dam programmes as key assets in order to create a new nation characterised by newly formed relationships between peoples. They conclude that Sudanese dam-building nationalism failed in multiple aspects, one of which being the exclusion of pastoralists, non-riverine populations and displaced populations. Menga (2016) explored the symbolism and emotional significance of dams at national level and the effects of such nationalistic perceptions on both domestic and transboundary level, using the GERD in Ethiopia and the Rogun Dam in Tajikistan as examples. Mitchell et al. (2002) describes a range of negative consequences, including physical, social and economic ones, of the Egyptian Aswan High Dam, all ignored because of the dam being ”the centerpiece of postwar nation making in Egypt”. Apparently, cultural and ideological interests impact decision making processes to such an extent that they affect water system (Egypt), society (Sudan) and international relations (Ethiopia). The Aswan High Dam case highlights a new value conflict between modelable, rational features such as salinisation, displacement of people and loss of water due to evaporation on one side and ideological, mostly emotional, values on the other. Exploration of such value conflicts is necessary to avoid similar failures.

9.3. Capabilities in addressing value conflicts

The NBDSS is more capable to explore certain conflicts and synergies than others. This section describes the applicability of the NBDSS in contributing to resolving such conflicts. Conflicts and synergies involving economic or environmental values highlight the strengths of the NBDSS, while cultural and social conflicts show its limitations.

Potential conflicts involving economic and environmental values

The operationalisation of values in the previous section showed that agriculture, energy and environment are well established in the NBDSS. Therefore, the system is expected to be very appropriate to explore the potential inter value conflict between Ethiopian energy, Sudanese environment and Egyptian agriculture and the conflict of interests based on agriculture. Comparison of the two can even show the benefits of focusing on different values and therefore turn a potential value conflict into a value synergy, providing room for cooperation.

Definition of spatial and social equity

The NBDSS should provide insights in the equitability of different scenarios to contribute to the resolution of this intra value conflict. Prevailing discussion includes disagreement on existing and future water sharing agreements and on the meaning of concepts of ”no significant harm” and ”reasonable use”. Therefore, it is unclear what exactly is meant by the NBI’s objective of *”equitable utilisation of and benefit from the common Nile Basin water resources”*. Provided manuals on the NBDSS do not provide a clear and structured approach to assess equity, although the fact that equity is a key objective of the NBI suggests the value of such an approach.

Distributional aspects of use of and benefits from water can be modelled using various demand nodes. Analysis of the distribution of benefits and harms over different types of water users can provide insights into social equitability; these demand sides should be distributed amongst multiple countries in order to assess spatial equitability as well. The NBDSS is limited in the level of detail in these analyses. According to Rasul et al. (2010), equity should be ensured between conflicting water users, including socially differing groups such as rich and poor people or urban and rural population. The latter can be modelled based on urban and rural water consumption and indicators for urban and rural pollution, both primarily spatially determined. The NBDSS however does not incorporate such demographic data, preventing proper analysis of impact on different social groups. Nevertheless, certain measures specifically affect certain groups, such as increased water pricing. Multiple authors highlight the potential impact of too

high water prices on the poorer fraction of the population and associated social consequences (e.g. Neal et al. (2014)). Assessment of the consequences requires separation in income groups in relation to the existing water infrastructure and management systems. Another example would be the differences between men and women (gender equity), requiring division of the population based on gender. The exclusion of such information in the main system restricts the contribution the NBDSS can deliver towards social equitable solutions.

A possibility could be to monitor gender equity after a decision is implemented. This requires the selection of measurable attributes, such as representation of women in water management functions or their access to knowledge and education on health and sanitation. Monitoring of such attributes could give insights into the status of gender equity, disregarding the project at hand. In case monitoring shows that inclusion of women should be stimulated, project plans should incorporate measures to do so and could be evaluated based on a yes/no criterion.

The analysis of spatial equity requires less detail, as this covers distributional aspects over upstream and downstream communities and countries. The NBDSS allows for division of benefits and harms in economic, environmental and social terms. These indicators provide measurable subcriteria that at least indicate relative movement towards final objective of transboundary equity Joubert et al. (1997).

values related to social themes

The NBDSS incorporates social values in terms of social water uses, such as domestic water consumption and livestock. This definition mostly links to the Sudanese image of society and are easily quantifiable. Other identified social values such as participation and conflict cannot be modelled. This limits the applicability of the NBDSS in Egypt, as their concretely formulated social values are not yet operationalised in the NBDSS. However, the integrated MCA-module facilitates the development of criteria such as ”public acceptance” (see (Nile Basin Initiative (NBI), 2014a)), in the shape of a score card. Each alternative receives a score (1-5 or up to another arbitrary scale), and higher scores mean a larger desirable result based on public opinion. Such methods could provide outcome to values that lack a specific relationship with e.g. water availability, but data collection requires a certain standard to limit subjectivity. Different methods for collection of data on public acceptability exist, such as surveys or interviews. It is more difficult to give a score to effects of an alternative on the formation of conflict. However, as plenty of social indicators are already established using proxies, values such as conflict and migration could be qualitatively related to their physical or environmental counterparts. An example of such a qualitative relationship could be the connection between the loss of natural resources on one side and migration and associated conflict on the other. An increase in lost natural resource would mean an increase in migration and conflict, while a decrease in lost natural resources would mean a decrease in migration and consequently, a decrease in conflict. In this way, such values could be operationalised qualitatively in the NBDSS, using + or - signs instead of a number scale. This would contribute to make the NBDSS socially more inclusive.

Conflicts involving cultural or ideological values

The explainable exclusion of cultural and ideological values in the models of the NBDSS limit the role of the system in the resolution of this value conflict. The explicit statement of these values might help to create operational ”ideal” value-based scenarios. These would be based on narratives around the ideological values of pride and unity on one side and identity and existence on the other and could be modelled using the NBDSS. Analysis of model results and relationships with the values and narratives that underlay these scenarios can provide insights into potential benefits and harms of these different ”ideal” scenarios, thereby facilitating value-based decision making. The information provided by the NBDSS is limited to its capabilities. This means that potential social or political consequences similar to those discussed under Section 9.2.4 cannot be simulated, although results of the discourse analysis show the valuation of such consequences, especially for Sudan.

The above strategy allows to explore conflicts between two culturally induced values. However, Section 9.2.4 showed the potential conflict between non-modelable ideological values and modelable values, for example economic or environmental ones. A trade off between these two might result in a decision that is not supported by the outcome of the NBDSS in case the ideological values are dominant or the produced information is not considered useful. Awareness of such ideological values can therefore contribute to the understanding of positions that oppose the outcome of the NBDSS. In addition,

the explicit consideration of such values in the evaluation of options can prevent silent, nontransparent processes that contradict scientifically based information and might result in unexpected negative consequences. Consideration of values obviously starts with awareness of their existence. The identification of prevailing ideological values such as the Ethiopian sense of pride facilitates this awareness. This clove between the non-quantifiable ideological preferences on one side and quantifiable ones on the other demonstrates both the limits of the NBDSS and the value of qualitative approaches such as discourse analysis.

It should be mentioned that such cultural-ideological conflicts as described under Section 8.3.1 are almost impossible to solve due to their deep roots in society and institutions. It therefore is only beneficial for the development of desirable outcomes if such values are not included in the NBDSS. Inclusion could lead to narrow-mindedness that would lead to every discussion or proposal be pinned down to this discussion covering the upstream development perspective versus the downstream conservative perspective. Instead, it is better to acknowledge this conflict and interpret generated outcomes in the light of potential consequences associated with this conflict.

9.4. Reflection on two discourses

The results of the discourse analysis demonstrate the existence of two discourses, differing in scale of interest. On one side there is a transboundary one, that focuses on international relations and contains a regional perspective of water resources. On the other there is a discourse focusing on the domestic aspects of water resources, that pays more attention to national socio-economics. These cover two decision making scales, namely nationally and regionally, and therefore relate to two different instruments of power. The distinction in values between both discourses was found to be significant, but nevertheless, these discourses have a strong connection because they involve the same actors. States are the primary actors in both national and transboundary decision making. For the latter, states generally operate in ”the national interest” (Earle and Neal, 2017). The state is represented by ministries, with the national Ministries of Water Resources as principle ones. However, the transboundary discourse belongs to the domain of international diplomacy and negotiation, which as well involves an active role for the Ministry of Foreign Affairs. Following Earle and Neal, diplomatic efforts primarily pursue national interest as well, suggesting a strategic role for the discourse on transboundary water management.

9.4.1. The national interest dominates both discourses

The focus on socio-economic interests and absence of themes related to a transboundary perspective or international relations in the domestically oriented texts is in line with other authors. Earle and Neal (2017) mention that national interests and socio-economic imperatives drive the political agenda of individual states. They add that framing transboundary water management and cooperation efforts in terms of national interest could contribute to their uptake on the national scale.Hirsch et al. (2006) observe policies of national interests that make governments claim sovereignty over their own stretches of the Mekong, thereby preventing transboundary water governance. This predominantly domestic orientation was as well observed during development of the NBDSS. The Final Inception Report of the consultancy states *”the demand for support on issues predominately important for national decision making was more evident than transboundary challenges”* (Abuzeid et al., 2007). As a result, the authors concluded that interest in the NBDSS will fade if national priorities are not served in the short and medium term, and therefore proposed an adaptive strategy for development of the NBDSS. This strategy should allow to gradually shift objectives from national interests towards regional decision making issues.

The supposed strategic nature of the transboundary oriented discourse matches van Roon (2020), who concluded that governments shape messages for an international audience in such ways that they correspond to the desires of international donor parties, while sources with a domestic audience show other messages. The distinction identified in this thesis is not based on audience, because all sources are meant for an international audience. In this case, the spatial scope separates the two. Here, the transboundary oriented sources primarily focus on international cooperation and equity. These values

are as well adhered by international parties such as the United Nations, the World Bank and the NBI and were as well guiding principles for the Nile Basin Trust Fund (The World Bank, 2016). Following van Roon's line of reasoning, the dominance of these values in the transboundary discourse might as well arise from a desire to attract donors for the national interest. The different framings of the term *equity* by Egypt and Ethiopia provide another example of strategic attempts in the transboundary oriented discourse, thereby protecting the national interest as well.

9.4.2. Implications for value considerations

The strategic nature of the transboundary discourse and the associated international negotiations imply a strategic function for the derived values too. Things that are said not actually have to be meant, and values referred to in such a strategic context might serve a convincing and justifying purpose rather than reflecting an actual actor value. Alam et al. (2009) refer to this as a distinction between the rhetoric of cooperation and water management in practice. They state that countries often unilaterally develop water resources within their geographical boundaries while simultaneously joining in international treaties or basin organisations. An example is the NBDSS itself, which was agreed upon by all basin countries, but is only occasionally used for the purpose of transboundary decision making. This does not mean that these values are not relevant nor that they are invalid. They however do not necessarily reflect the real or actual values actors have outside these negotiations, but are primarily valid for the context they are used in, namely that of transboundary water resources management. This is linked to Schwartz (1992) actual and ideal values (see Section 4.1), the latter meant to judge and justify behaviour while actual values are enacted in practice and embodied in institutions and artefacts. Both discourses serve a strategic purpose to a certain extent, therefore covering mainly ideal values. Nevertheless, the sources focusing on domestic water resources provide a better reflection of the actual country values, as this discourse is aimed at people that presumably share the same values and interests.

However, the concept of "national interest" fails to address the diverse range of interests within each state (Hirsch et al., 2006). As interests and values are closely related, so are national interest and national values (see the definition used in Chapter 4). The discourse analysis of the political discourse in this thesis focused on national values for each country, thereby simultaneously resulting in a definition of what these national interests are constituted of. These as well cover the interests protected in the transboundary discourse. Nevertheless, the actual range of interests is larger and more complex. This intrinsically comes with a challenge in translating decisions taken at the national or international level into socially, economically and environmentally outcomes across levels, all the way down to the local level. This links to social and distributive justice across scales. The local scale is outside the scope of this research, but it should be noted that specific local or even national values are often not part of transboundary decision making processes executed by ministers Hirsch et al. (2006) Earle and Neal (2017).

9.4.3. Challenges and opportunities for the NBDSS

Main challenge for success of the NBDSS that arises due to these value implications was already identified by Abuzeid et al. (2007): the interest for regional and cooperative planning is subordinate to national needs and priorities. Consequently, countries will emphasise their sovereignty to legitimise water resources developments in their own national interests, rather than focus on mutual benefits and regional development. These national interests are linked to the national values derived in this research. Luckily, the NBDSS itself can contribute to reverse these effects towards a shift in focus from national to regional interest. In fact, that is one of the main objectives of the system. Alam et al. (2009) and Earle and Neal (2017) present two different perspectives on promoting regional interests, for which the NBDSS could both be of value.

Alam et al. (2009) see the road towards regional interests and the associated collective action as "sovereignty bargains", where countries exchange autonomy[2] for negotiated future benefits. The NBDSS could provide insights into the resulting benefits and their spatial distribution and so create a vision

[2] "independence to act" (Alam et al., 2009)

of what the effects of management approaches from a basin perspective would entail. In this way, the trade off between sovereignty and shared benefits can be quantified for each country, providing countries with evidence to convince them towards a more structural form of transboundary water governance. These two aspects are currently clearly separated into two discourses; sovereignty is concerned with the domestic orientation while benefit sharing is the domain of the transboundary orientation. Here, the NBDSS would facilitate a gradual shift from national towards regional interests, and therefore function as a bridge between the two discourses. This vision mostly links to that of the NBI and its desire for decision making from a regional perspective.

However, this approach as well indicates that all three basin countries gradually exchange their national interests for those of the region. The current status quo in the GERD talks actually demonstrates the unwillingness and issues of trust that prevent such a shift from happening. Egypt's domestic interests have dictated the international discourse for years, formulating "the regional perspective" mainly in terms of water conservation for downstream purpose and thereby preventing upstream countries from development. This perspective on upstream developments should change in order for the NBDSS to make a contribution to effective cooperative development. In fact, using the NBDSS in a transboundary environment will contribute to create mutual understanding on what such a regional perspective should entail and what kind of interests and values are associated to upstream developments for all countries.

Earle and Neal (2017) use a different approach, that is constructed around reframing transboundary water management and cooperation efforts into terms of national interest in order to improve their uptake. This approach does not aim for a shift away from national interests, but rather promotes the adoption of cooperative approaches into national decisions. This approach offers a way to convince countries that are hesitant towards exchanging national for regional interests. In this case, the NBDSS could be used to test multiple transboundary strategies in order to align them with the national interests of the country under consideration. Researches such as this thesis can help to define what these "national interests" are constituted of. The proposed strategy assumes a country that is unwilling to participate. Of course, a more desirable strategy holds in case all countries are actively involved but not yet ready to think from a regional perspective. In this case, the participants would make their national values and interests explicit before the decision making process. The different transboundary management options could then be evaluated and altered accordingly, in order to shape them in such a way that they would align with national interests. Here, the NBDSS facilitates the search for win-win strategies without formulating a clear regional perspective, but rather operates as a tool to explore potential strategies favourable to all national interests around the table. The two discourses therefore remain separated, but the tool can contribute to make national values and interests clear and explicit in the transboundary domain.

Abuzeid et al. (2007) suggest to first focus on national objectives in order to keep countries interested in the tool. This could increase trust in the NBDSS and simultaneously familiarise actors with the available modelling and evaluation tools. However, this research has shown the diverse range of values and interests for each specific country. The DSS is not able to address all individual concerns as a result of scoping choices and modelling capabilities, which is a known limitation of modelling tools (e.g. Abuzeid et al. (2007)). The specific value for livestock in Sudan for example cannot be addressed properly in the NBDSS. The applicability of the same decision support system for decision making both on national and transboundary scale therefore seems to be questionable. A suggestion could be to develop "fixed" national versions of the system as well, similar to the predefined shell that is present within the NBDSS. These versions could be distributed through the technical offices of the NBI and be used for domestic analyses. However, the absence of such nationally residing values in an internationally used information system also restricts such parties from becoming part of the regional decision making process. This adds to the already discussed inability of governments to cover the diverse range of nationally prevailing interests. Internationally negotiated solutions might therefore not reflect values of those excluded groups.

Implementation of the NBDSS across multiple levels of scale (e.g. locally, nationally and regionally) could provide part of the solution, given that outcomes and acquired knowledge is shared effectively and acted upon. Local deployment of the tool could contribute to identification of locally residing values and interests, thereby contributing to a more complete picture of what "the national interests" should

cover. This picture could be tested, evaluated and modified by application of the NBDSS on a national scale. Following Earle and Neal (2017), national decision makers could then take these new insights on national interest to the international negotiation table in a search for strategies that are mutually beneficiary, e.g. win-win solutions that would cover a wider range of nationally prevailing values and interests. This strategy could increase trust and interest in using the NBDSS by focusing on the national interest, while complementing the understanding of national interest with more local values and interests can prevent situations where ”national interest [...] represents, privileges and legitimises the exclusive interests of one [or more] sector[s]” (Hirsch et al., 2006).

The NBDSS can definitely contribute to make the shift towards sharing benefits and consequences in an equitable manner, but these approaches are mainly based on the willingness of countries to participate in such endeavours. Usage of the tool requires active participation and cooperation, which consequently requires mutual understanding and trust. Both trust and understanding are increased through the NBDSS, providing a structured approach to participatory planning and actively stimulating discussion on values and interests. Nevertheless, the success of the system is mainly restricted by the attitude of the projected participants.

9.5. Can the NBDSS be successful from a value perspective?

The evaluation in this chapter revealed some additional requirements, limitations and recommendations to ensure successful implementation of the NBDSS. This thesis understands successful implementation to be in line with the objectives for both development and usage, where usage of the NBDSS should:

1. Implementation of the NBDSS should increase the overall benefit of usage of the Nile Basin water resources from a regional perspective;
2. Usage of the NBDSS should lead to transboundary cooperative developments and strategies for water resources management;
3. These strategies should be value-inclusive, which includes the distribution of benefits over different groups that adhere different values.
4. ”Success” should be monitored and evaluated upon, which involves active monitoring of distribution of benefits and harms both spatially and between groups.

This evaluation identified five main issues that prevent the NBDSS from reaching this status of successful implementation. The first issue is related to trust, which entails both the required trust in the NBDSS as well as trust in other countries, required for the creation of mutual understandings. The second issue is related to decision makers operating in ”the national interest” and the associated lack of inclusiveness in regional decision making by governmental actors who fail to bring the diverse range of national values and interests to the table. Thirdly, the monitoring of equitable distribution of benefits and harms, both spatially and between groups, is proven to be difficult due a lack in definition and the according absence of clear, measurable attributes. Fourth, values that are not quantifiable are difficult to account for in decision making using a modelling tool such as the NBDSS. Finally, there is a key difference in operationalibility between contested and uncontested values.

Implementation of the NBDSS at different scales (e.g. local, national and regional) can increase trust in the system nationally, as well as provide regional decision makers with insights into locally residing values, thereby contributing to the inclusiveness of transboundary decision making.

It is important to know the limitations of a DSS to ensure all values to be considered in decision making. These limitations include the impossibility to integrate measurable decision variables into the system. Complex values that are contested in terms of definition (e.g. spatial equity) or relevance (e.g. certain social themes) should therefore first be made uncontested in order to operationalise them in an agreed upon manner. Additionally, non-operationalisable values (e.g. identity) should be considered by interpreting DSS output from a value perspective. This requires explicit value statement prior to the evaluation process.

10 Discussion

This thesis yielded two main results: a list of values associated with water resources for each Blue Nile country and an evaluation of the NBDSS from a values perspective. The selected methods and scope pose two main limitations to the results. This section discusses both value and validity of the research, and pays attention to the perceived dominance of the GERD in the analysed sources.

10.1. Value of the research

The identified values were derived using discourse analysis, a particular form of qualitative analysis. These types of methods are often associated with a sense of subjectivity and an inability to come up with clear policy recommendations or optimal allocation schemes. However, this thesis demonstrated subjectivity of decision making, even when using a decision support tool such as the NBDSS. Verhoeven (2013) adds that subjectivity itself plays a major role in wrong decisions, making it an interesting subject of research itself to contribute to addressing value trade offs. This thesis dives into the discursive nature of water resources in the Blue Nile, in order to clarify the subjective context to a presumably objective decision support tool.

One main subjective aspect of the research is the deduction of values based on my own interpretation of sources, framings and discourses. Such interpretations are susceptible to my own values and perceptions, and might therefore have an impact on the results. This impact is limited by keeping away as match as possible from stating judgements during derivation of values but rather state observations. In addition, the identified values were verified in terms of their validity with other studies and reports. Finally, countries were compared with each other instead of an individual judgement or comparison with my own values. The explicit statement of reasoning contributes as well. Nevertheless, the influence of own values and perceptions cannot be prevented, but was limited as far as possible. Impact could further be reduced by testing the identified values through interaction with actors. This fell out of scope due to practical reasons, but is highly recommended for future research.

This outsider perspective might provide benefits as well. The analysis of a value-laden discussion such as the current international discourse on the Blue Nile requires a distant view to the topic, independently of deeper rooted feelings and emotions connected to the discussion.

The proposed list of values for each country is not meant to be final, nor is it meant to be exclusive or exhaustive. The identifications presented here are meant to contribute to a discussion on values between the different actors, in order to more explicitly formulate these and consequently open up possibilities to take them into account in decision making. This increases awareness of different perspectives, provides insights into other points of view and the values that support these, and might stimulate the search for collective ground. In addition, it arguably allowed the identification of improvements for the NBDSS, highlighting the value of the results.

The assessment of the NBDSS was performed in a triangular way, by analysing documents, attend a course to play with the software and compare results to findings derived from literature. As said, it would have been fruitful to have an interview on the capabilities of the system with experts. That would allow to fill some gaps in the analysis and provide a fourth perspective enabling a more complete picture of the system. On the contrary, the hesitant attitude towards such an interview raises concerns about transparency of the NBDSS. This hesitant attitude might be attributed to me being an outsider,

which therefore again limits the research to a certain extent. Nevertheless, the outsider perspective provides opportunities in analysing the NBDSS as well. The introduced potential ”group-think” associated with participatory approaches is easier to observe for someone outside of this group. In addition, this outsider perspective provides a more critical attitude towards the concerned model.

10.2. Validity of the discourse analysis

To start of, the selection of sources is generally limited to sources available in English. These sources are primarily meant for international communication, because all three countries have their own language. Sources in national languages are primarily expected to describe the domestic discourse. In addition, sources for an international public might be easier to acquire than national sources, provided the open access of for instance the United Nations database or interviews with international academic institutions. The international character of the content might therefore be a product of the colourised selection of sources, which might explain the significantly larger part of the sources belonging to the transboundary discourse. Including sources written in national languages might lead to changes in the results, particularly to the domestic discourse as these sources are expected to primarily cover national interests. van Roon (2020) identified a significant difference between sources in English and those in regional language in Central Asia. These differences reflect the distinction between ideal and actual values obtained from Schwartz (1992), where the English sources contain more ideal values that are in line with international actors to increase the potential to receive funds, while the sources in national language, meant for national audience, contain more actual values. For the Blue Nile countries that could mean the NBDSS mainly reflects ideal values, while excluding certain actual values. It would be interesting to study these domestic discourses in the Blue Nile countries more in depth in order to test this statement.

Language as well have played a role in the limited number of analysed sources. This number allowed for a thorough analysis and deduction of values, but may not be sufficient to completely ban the dominance of a single source. To prevent such dominance, sources have been normalised to the total amount of quotations in order to allow comparison. In addition, the selection aimed to include sources based on their topics related to water resources in a range as wide as possible, but in the end was restricted by availability. The wide range of themes and thorough qualitative analysis allow for a reliable interpretation of the obtained sources.

Secondly, the results only describe the discourses and values identified in the political debate on water resources, that is openly accessible. These identified values can be associated with national governments rather than with any individual speaker in the analysed sources. Additionally, they will not be representative for values and discourses of the whole population, but that was not the aim of this research. The results cover values adhered by decision makers, but do not distinguish between any decision making entity. Of course, different sectors exist nationally that have own views and objectives. Lastly, these values are deducted from analysis of the international discourse on water resources in the Blue Nile, which is thought to be highly strategic. These values definitely play a role in negotiations on the Blue Nile level, but they do not necessarily reflect the real values apart from this context.

Derived values are country specific, which means they are not translatable to other countries in the basin, or in other basins. Complementing of the list with values for the other eight Nile basin countries would give an even more elaborate description of the interactions in the basin. This could be the subject of further research. For now, the Blue Nile dispute seems to dominate the public discourse, which means this thesis described the interactions in the most relevant part of the basin.

The discourse analysis was performed using evolutionary coding on a subtheme level, but at the theme level these codes were predefined. Although they did change after reading the first five texts, the presupposed coverage of all aspects by these seven themes might lead to missing themes and, consequently, missing values or to interpretations of texts that conform the proposed themes. A thorough qualitative interpretation of sources was used to prevent this, in combination with an extensive link to context to validate the obtained values.

It needs to be noted that the age of the analysed sources plays a role in these findings. Dates of international sources start from 2013, while two of the analysed national policy documents date back

to 1999. These policies still seem to be in use, but their age might have impact on the validity of the results, especially due to the growing attention for international cooperation that came with the establishment of the NBI and the potential underrepresentation of domestic sources in the discourse analysis. Nevertheless, the results show the relevance of awareness of potential differences within the national and international discourse. In addition, this highlights both a challenge and opportunity for usage of the NBDSS.

10.3. Influence of the GERD

The relative young age of most of the source have led to a significant presence of the GERD within the discourses, both domestic and international. The new dam indeed is the main topic of controversy in the basin. Additionally, big dams have a clear foreign dimension, since such infrastructures alter natural flows of rivers that can have far reaching effects on downstream areas, thereby causing tensions between riparians Menga (2016). The aforementioned dominance of international discourse in English sources focuses on this transboundary dimension and, consequently, such large infrastructures are a logical topic of interest. The GERD, being the newest of these huge infrastructure projects and leading to a lot of tensions in the region, is therefore significantly present within the discourse. Arsano and Tamrat (2005) and Grandi (2021) seem to provide evidence that the GERD is a tangible agent of a more general change in cultural value. Indeed, there is a reason why the GERD is so prominently present in the discourse on water resources in the Blue Nile. The whole debate on the GERD in a way embodies the present value conflict of upstream and downstream ideology.

Important to note is that this thesis aims to describe current discourse and underlaying values. The fact that this discourse is dominated by a large dam does not mean the discourse is not reliable. It merely shows the dynamics of discursive aspects such as water resources. In addition, However, the controversies on the dam might prevent

10.3.1. Suggestions for future research

Future research could focus on adding more depth to the analysis of values. Such studies could include validating and updating the presented list of values by means of interviews or other active participatory approaches, or supplementing the list with a focus on actual values rather than ideal (political) values. Another suggestion would be to supplement the list with actor values of other basin countries, such as the White Nile countries.

It would be interesting to translate the identified value conflicts and synergies into scenarios and test these using the NBDSS. This could provide insights into value-induced national interests and validate transboundary strategies accordingly, thereby providing insights into the value of cooperation. This would give additional results on the possibilities of the NBDSS in doing so.

Lastly, an extensive analysis of the decision making processes from a governance perspective could add to this analysis in formulating clear and effective governance strategies that fit the context of the Blue Nile. A closer look at the impact of donor parties on the discourses that are used could help to construct a picture of how these discourses are shaped to mobilise financial means.

11

Conclusions & recommendations

This thesis tried to identify the potential role of the Nile Basin Decision Support System in considering all values in decision making on the Blue Nile level. To this end, the NBDSS was evaluated based on identified design requirements, design values, actor values and value conflicts and synergies.

11.1. Conclusions

The actual role of the NBDSS turns out to differ from both its potential and its desired role. Literature study showed that the potential contribution of a DSS to include values in decision making is restricted by five requirements. The DSS should be transparent, flexible and developed in a participatory manner, which requires a cooperative attitude. In addition, such systems should provide useful information and should be based on reasonable value judgements. Failure to meet these requirements can result in final decisions that lack support or favour certain actors' values over others. This can have influence on power relations between actors. Nevertheless, properly designed decision support systems can contribute to explicit statement, discussion and consideration of values, thereby facilitating participatory processes and increasing trust and transparency.

Document analysis revealed nine values that are included into NBDSS during development: Trust, Usability, Sustainability, International cooperation, Inclusiveness, Equity, Environment, Economy and Society. These values are seen as drivers of the final design and functioning of the system, but in some cases mutually conflict. The final system design is therefore based on trade offs between Trust on one side and Usability and Inclusiveness on the other and between Usability and Inclusiveness. These trade offs have resulted in an non-inclusive NBDSS. On the other hand, the ranking and evaluation functionalities of the NBDSS allow to gain insights in consequences of other value trade offs within water resources decision processes, particularly between environment, economy and society.

Analysis of the political discourse on water resources in Ethiopia, Sudan and Egypt resulted in identification of both common and differing values associated with water resources. In addition, the results showed a significant difference in accentuated values between domestic and international sources, observable for each country. These results indicate the existence of two discourses. One discourse focuses on the transboundary nature of water resources management and accentuates values related to international relations, such as cooperation, equity and laws and policies. The other focuses on the domestic aspects of water resources management, highlighting the national economic and social values, with a strong focus on agriculture. Other identified similarities were the attention for participation and knowledge. Despite these main similarities, the analysis yielded values specific to each country individually as well. Within these discourses, Ethiopia particularly values energy, national pride and socio-economic development. For Sudan, environment, society, livestock and national government are of particular importance in these discourses. Egypt mainly demonstrates a value for agriculture, technology and identity.

These similarities and differences provide potential for both conflict and cooperation. An already observable inter value conflict can be attributed to Ethiopia's value of pride and Egypt's value of identity. Other potential conflicts include intra value conflicts due to differences in definition of spatial equity and society and a conflict of interests due to the mutual valuation of agriculture. Such conflicts complicate transboundary decision making and can result in slow processes and little support for the final decision.

On the other hand, mutual valuation of cooperation, knowledge, participation and economy provide possibilities for fruitful interaction and point to design features with significant support and related potential impact.

The identified values belong to three different groups. They are either uncontested and mutually shared, contested in terms of definition or complex with local or national contexts or contested in terms of validity. Additionally, not all identified values can be operationalised into a quantitative decision support system such as the NBDSS. As a result, the NBDSS does not incorporate all identified values in its decision outcomes. Environmental and economic values are relatively uncontested and operationalised in a scientifically sound way. Sudanese particular value for livestock could be operationalised, but is not included. Both spatial equity and society have been integrated in design values of the NBDSS, but their definitions are not agreed upon or do not reflect the attributed value from the discourse. Participation and knowledge are two shared values that have been translated into design features for the NBDSS. Finally, cultural-ideological values are not incorporated into the NBDSS, while the research has shown their significance for transboundary decision making. The exclusion of such contested, non-quantifiable values might be beneficial to the potential outcomes of the DSS, by preventing narrow-mindedness on unsolvable topics.

The NBDSS is developed to contribute to an increase in overall benefit of usage of the Nile Basin water resources from a regional perspective and to promote transboundary cooperative developments and strategies. These strategies should be value-inclusive and should distribute benefits and harms in an equitable manner.

The role of the NBDSS in developing these regional, value-inclusive strategies is multifaceted. It can provide insights into national interests and values and test transboundary management strategies accordingly, in order to create mutual understanding and shape strategies that would align with national interests. Here, the regional perspective would be constructed from win-win solutions based on the diverse national values. Secondly, the NBDSS can facilitate a gradual shift from national towards regional interests by analysing the trade off between exchanged sovereignty and negotiated benefits for each country. However, both approaches require countries to be willing to consider values of other countries, which asks for the acknowledgement of mutual dependencies and trust between actors.

Implementation of the NBDSS at different scales (e.g. local, national and regional) can increase trust in the system nationally, as well as provide regional decision makers with insights into locally residing values, thereby contributing to the inclusiveness of transboundary decision making. Insights from local and national use should be brought to the international negotiation table in a search for mutually beneficiary strategies. The primary focus on the national interest could capture countries' trust and interest in the system, before gradually shifting towards a more regional perspective of benefits.

The NBDSS seems particularly capable of assessing scenarios based on economic and environmental values. The system therefore is very appropriate to assess potential conflicts and synergies between economic and environmental values. The trade off between Ethiopian energy, Sudanese environment and Egyptian agriculture and the conflict of interests between agriculture in the three countries are examples of testable interactions.

Limitations for the consideration of values relate to operationalisation of social and cultural-ideological values. Such values should be considered in a qualitative manner by indicating positive or negative effects. Values that cannot be awarded a score are still to be incorporated in decision making. To this end, it is good to be aware of the limitations of the NBDSS and the values that constitute its outcomes. Explicit consideration of non-quantifiable values increases transparency of decision making. However, even if value interactions, their significance for decision making and the associated limitations are fully understood, the role the NBDSS can play in considering all values is mainly limited by actor attitude. Implementation of the NBDSS can only be effective in case both both transparency and cooperative attitude are increased. This shows that the limitations of a technological asset such as the NBDSS to be primarily human induced, demonstrating the value of this thesis.

11.2. Recommendations for NBDSS and decision making

To start off it would be recommended to implement the NBDSS at different scales (e.g. locally, nationally and regionally). Local deployment of the tool could contribute to identification of locally residing values and interests. In case such knowledge is properly communicated towards the national representatives in the transboundary decision making process, this would allow them to pursue a more inclusive version of ”the national interest”. It would further lead to an increased trust in the system because of the focus on national interest, and local and national capacities as a result of the increase in application.

Secondly, the awareness of the limitations of the NBDSS should be taken into account when using it for decision making at every level. Complications with operationalisation shoud not lead to exclusion of values in decision making. These values, such as cultural-ideological ones, can play a major role in decisions that undermine NBDSS outcomes. Awareness of such values and potential value conflicts and of the capabilities and limitations of support provided by the NBDSS is essential in understanding the interactions between these outcomes and non-operationalisable values. Explicit statement of such values is a first step towards active consideration.

Thirdly, it is wise to develop a clear protocol to monitor both spatial and social equity. Equitable distribution of harms and benefits is one of the main objectives of implementation of the NBDSS. Measurement of key objectives should not be based on a subjective interpretations, but monitored in a structured and agreed upon way. Current documentation on the NBDSS lacks such a definition, but this is an issue that reaches further than only the NBDSS. For now, prevailing legislation and definitions do not provide outcome, but attributes that measure equity can be selected based on the specific content of the Blue Nile content. The inclusion of demographic data would improve such measurements. Selected attributes could guide choices on data to collect and include. Again, awareness of the capabilities and limitations of NBDSS outcomes is essential to interpret the outcomes of such monitoring systems, especially in the light of the multifaceted nature of equity. It would be better to involve multiple parties to agree on measurable attributes to monitor (spatial) equity, that do not necessarily focus on the NBDSS environment but rather on a measure of equity in general. Other monitoring organisations can play a role in such practices as well.

Fourthly, it might be wise to first focus on shared values, in order to create mutual trust and understanding. First cooperative efforts should therefore focus on knowledge, economy and participation. Cooperation on knowledge could include the establishment of a system for collection, management and sharing of data. Participation would mainly entail the participation of women and user communities in decision making, as well as invite the private sector to participate. Because such practices would be new, transboundary coordination could contribute to implementation of such measures.

Finally, transparency of the NBDSS can be improved. The identified issues mainly relate to governance of the system, rather than the system design. Improvements therefore require a change in governance and supervision of the system, as well as a change in attitude. Main identified points of improvement are clarity on the initial shape of the NBDSS as an empty shell, version compatibility and download locations of NBDSS attributes. In addition, open access to databases and indicator sheets would benefit transparency and hence regional decision making. Such databases can be made publicly available through the NBDSS platform. Lastly, an open attitude towards external interested parties will contribute to level of trust and can even yield valuable insights for further development of the system.

Bibliography

Abd El-Haliem, E., Soliman, E., and Atta, N. (2016). Impacts of climate change on hydropower production in blue nile sub-basin. *Advances in Environmental Biology*, 10(7):256–271.

Abuzeid, K. M., Blumauer, A., Fedra, K., Hartveld, A., Riddell, P., Seidelmann, R., and Tamrat, I. (2007). Nile basin decision support system final inception report - main report. Technical report, Hydrophil.

Alam, U., Dione, O., and Jeffrey, P. (2009). The benefit-sharing principle: implementing sovereignty bargains on water. *Political Geography*, 28(2):90–100.

Aramo-Immonen, H. and Vanharanta, H. (2009). Project management: The task of holistic systems thinking. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 19(6):582–600.

Arsano, Y. (2007). *Ethiopia and the Nile: Dilemmas of national and regional hydropolitics*. ETH Zurich.

Arsano, Y. and Tamrat, I. (2005). Ethiopia and the eastern nile basin. *Aquatic Sciences*, 67(1):15–27.

Ashton, P. J. (2002). Avoiding conflicts over africa's water resources. *Ambio*, pages 236–242.

Beck, R., Meisch, S., and Potthast, T. (2012). The value (s) of sustainability within a pragmatically justified theory of values: considerations in the context of climate change. In Potthast, T. and Meisch, S., editors, *Climate change and sustainable development*, pages 49–54. Springer.

Bingham, G. (1986). *Resolving environmental disputes: A decade of experience*.

Black, P. and Stockton, T. (2009). Basic steps for the development of decision support systems. In *Decision support systems for risk-based management of contaminated sites*, pages 1–27. Springer.

Boardman, A., Greenberg, D., Vining, A., and Weimer, D. (2017). *Cost-benefit analysis: concepts and practice*. Cambridge University Press.

Bohanec, M. (2003). Decision support. In *Data mining and decision support*, pages 23–35. Springer.

Bradley, M., Fisher, W., Dyson, B., Yee, S., Carriger, J., Gambirazzio, G., Bousquin, J., and Huertas, E. (2016). *Application of a Structured Decision Process for Informing Watershed Management Options in Guánica Bay, Puerto Rico*. National Health and Environmental Effects Research Laboratory, Office of ….

Cardwell, H., Cole, R., Cartwright, L., and Martin, L. (2006). Integrated water resources management: definitions and conceptual musings. *Journal of contemporary water research & education*, 135(1):8–18.

Cascão, A. (2009a). Changing power relations in the nile river basin: Unilateralism vs. cooperation? *Water Alternatives*, 2(2).

Cascão, A. (2009b). *Political economy of water resources management and allocation in the Eastern Nile River Basin*. PhD thesis, University of London.

Cash, D., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., and Jäger, J. (2002). Salience, credibility, legitimacy and boundaries: linking research, assessment and decision making. *Assessment and Decision Making (November 2002)*.

Citeau, J., Steve, C., et al. (2016). Baro akobo sobat multipurpose water resources development study project inception report v.4 february 2016. Technical report, BRL Ingenierie and Aurecon.

Deelstra, Y., Nooteboom, S., Kohlmann, H., Van den Berg, J., and Innanen, S. (2003). Using knowledge for decision-making purposes in the context of large projects in the netherlands. *Environmental Impact Assessment Review*, 23(5):517–541.

Diaz, S., Pataki, G., Roth, E., Watson, R., Al-Hafedh, Y., Ahn, S., Amankwah, E., Asah, S., Balvanera, P., Breslow, S., Bullock, C., Cáceres, D. M., Chobotová, V., Daly-Hasen, H., Dessane, E., Figueroa, E., Golden, C., Gomez-Baggethun, E., Islar, M., and Spierenburg, M. (2014). Preliminary Guide regarding diverse Conceptualization of Multiple Values of Nature and its Benefits, including Biodiversity and Ecosystem Functions and Services. Technical report, Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES).

Droogers, P. and Immerzeel, W. (2010). Preliminary data compilation for the nile basin decision support system. Technical report, Nile Basin Initiative (NBI).

Earle, A. and Neal, M. J. (2017). Inclusive transboundary water governance. In *Freshwater governance for the 21st century*, pages 145–158. Springer, Cham.

Fairclough, N. (2003). *Analysing Discourse: Textual Analysis for Social Research*. Psychology Press.

Fedra, K. (2008). Needs assessment and conceptual design of the nile basin decision support system consultancy: Final analysis and dss design report. *Hydrophil. Vienna. Austria*.

Fedra, K., Brown, D., Riddell, P., Seidelmann, R., Eder, G., and Schuen, R. (2008a). PART II DSS Conceptual Design - Main Report. Technical report, Nile Basin Initiative.

Fedra, K., Brown, D., Riddell, P., Seidelmann, R., Eder, G., and Schuen, R. (2008b). PART II DSS Conceptual Design ANNEX B: DSS Design Specifications. Technical report, Nile Basin Initiative.

French, S., Maule, J., and Papamichail, N. (2009). *Decision behaviour, analysis and support*. Cambridge University Press.

Gastélum, J. R., Valdés, J. B., and Stewart, S. (2009). A decision support system to improve water resources management in the conchos basin. *Water resources management*, 23(8):1519–1548.

Geertman, S. (2006). Potentials for planning support: a planning-conceptual approach. *Environment and planning B: Planning and Design*, 33(6):863–880.

Georgakakos, A. (2007). Decision Support Systems for Integrated Water Resources Management with an Application to the Nile Basin. In *Topics on System Analysis and Integrated Water Resources Management*, chapter 5, pages 99–116. Elsevier: Amsterdam, The Netherlands.

Giupponi, C. and Sgobbi, A. (2013). Decision support systems for water resources management in developing countries: Learning from experiences in africa. *Water*, 5(2):798–818.

Grandi, M. (2021). Images of the nile: How competing narratives frame water disputes. In *Split Waters*, pages 176–193. Routledge India.

Gregory, R. and Keeney, R. (2002). Making smarter environmental management decisions 1. *JAWRA Journal of the American Water Resources Association*, 38(6):1601–1612.

Groenfeldt, D. (2019). *Water ethics: A Values Approach to Solving the Water Crisis*. Routledge.

Hamid, S. (2013). The impacts of planned ethiopian dams on the blue nile system in sudan using the nbdss. Technical report.

Hammond, J., Keeney, R., and Raiffa, H. (1999). *Smart Choices: A Practical Guide to Making Better Decisions*. Harvard Business Review Press.

Hermans, L. (2005). *Actor Analysis for Water Resources Management: Putting the Promise into Practice*. Eburon Uitgeverij BV.

Hermans, L. and Thissen, W. (2009). Actor analysis methods and their use for public policy analysts. *European Journal of Operational Research*, 196(2):808–818.

Hewitt, R. and Macleod, C. (2017). What do users really need? participatory development of decision support tools for environmental management based on outcomes. *Environments*, 4(4):88.

Hill, G., Kolmes, S., Humphreys, M., McLain, R., and Jones, E. (2019). Using decision support tools in multistakeholder environmental planning: Restorative justice and subbasin planning in the columbia river basin. *Journal of Environmental Studies and Sciences*, 9(2):170–186.

Hirsch, P., Jensen, K. M., Boer, B., Carrard, N., FitzGerald, S., and Lyster, R. (2006). *National interests and transboundary water governance in the Mekong*. Australian Mekong Resource Centre, in collaboration with Danish ….

Jacobs, S., Martín-López, B., Barton, D., Dunford, R., Harrison, P., Kelemen, E., Saarikoski, H., Termansen, M., García-Llorente, M., Gómez-Baggethun, E., et al. (2018). The means determine the end–pursuing integrated valuation in practice. *Ecosystem services*, 29:515–528.

Jonker, V., Beuster, H., Sparks, A., Dobinson, L., Mullins, D., Palmer, R., and Tuncok, K. (2012). Data compilation and pilot application of the nile basin decision support system (nb-dss): Work package 2: Stage 2 synthesis report: Integrated nile basin. Technical report, Aurecon Centre.

Jonoski, A. and Seid, A. (2016). Decision support in water resources planning and management: The nile basin decision support system. In *Real-World Decision Support Systems*, pages 199–222. Springer.

Jørgensen, T. B. and Vrangbæk, K. (2011). Value dynamics: Towards a framework for analyzing public value changes. *International Journal of Public Administration*, 34(8):486–496.

Joubert, A. R., Leiman, A., de Klerk, H. M., Katua, S., and Aggenbach, J. C. (1997). Fynbos (fine bush) vegetation and the supply of water: a comparison of multi-criteria decision analysis and cost-benefit analysis. *Ecological economics*, 22(2):123–140.

Junier, S. (2017). *Modelling expertise: experts and expertise in the implementation of the Water Framework Directive in the Netherlands*. PhD thesis, Delft university of Technology.

Kangas, A., Kangas, J., Kurttila, M., Hujala, T., and Eyvindson, K. (2015). *Decision support for forest management: Second edition*. Springer.

Keeney, R. (1994). Creativity in decision making with value-focused thinking. *Sloan Management Review*, 35:33–33.

Keeney, R. (1996). Value-focused thinking: Identifying decision opportunities and creating alternatives. *European Journal of operational research*, 92(3):537–549.

Keeney, R. L. and Gregory, R. S. (2005). Selecting attributes to measure the achievement of objectives. *Operations Research*, 53(1):1–11.

Kroes, P. and van de Poel, I. (2015). Design for values and the definition, specification, and operationalization of values. *Handbook of ethics, values, and technological design: sources, theory, values and application domains*, pages 151–178.

Langsdale, S., Beall, A., Bourget, E., Hagen, E., Kudlas, S., Palmer, R., Tate, D., and Werick, W. (2013). Collaborative modeling for decision support in water resources: Principles and best practices. *JAWRA Journal of the American Water Resources Association*, 49(3):629–638.

Liu, J., Dorjderem, A., Fu, J., Lei, X., Macer, D., Qiao, Q., Sun, A., Tachiyama, K., Yu, L., and Zheng, Y. (2011). Water ethics and water resource management.

Lynam, T., De Jong, W., Sheil, D., Kusumanto, T., and Evans, K. (2007). A review of tools for incorporating community knowledge, preferences, and values into decision making in natural resources management. *Ecology and society*, 12(1).

Marcomini, A., Suter II, G., and Critto, A. (2008). *Decision Support Systems for Risk-based Management of Contaminated Sites*, volume 763. Springer Science & Business Media.

Mason, S. (2004). *From Conflict to Cooperation in the Nile Basin: Interaction Between Water Availability, Water Management in Egypt and Sudan, and International Relations in the Eastern Nile Basin*. ETH Zurich.

McNie, E. C. (2007). Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental science & policy*, 10(1):17–38.

Mellor, M. (2007). Ecofeminism: Linking gender and ecology. *The SAGE handbook of environment and society*, pages 66–77.

Menga, F. (2016). Domestic and international dimensions of transboundary water politics. *Water Alternatives*, 9(3):704–723.

Miller, J. K., Friedman, B., Jancke, G., and Gill, B. (2007). Value tensions in design: the value sensitive design, development, and appropriation of a corporation's groupware system. In *Proceedings of the 2007 international ACM conference on Supporting group work*, pages 281–290.

Mitchell, T. et al. (2002). *Rule of Experts: Egypt, Techno-Politics, Modernity*. Univ of California Press.

Mohamud, M. and Verhoeven, H. (2016). Re-engineering the state, awakening the nation: Dams, islamist modernity and nationalist politics in sudan. *Water Alternatives*, 9(2).

Mostert, E. (2015). Children's books as a historical source: Flooding in 20th century dutch children's books. *Water History*, 7(3):357–370.

Mostert, E. (2018). Values in water management. *Hydrology and Earth System Sciences Discussions*, pages 1–20. unpublished.

(NBI), N. B. I. (2015). The nile basin decision support system: Best national application cases 2015. Technical report, NBI.

Neal, M. J., Lukasiewicz, A., and Syme, G. J. (2014). Why justice matters in water governance: some ideas for a 'water justice framework'. *Water Policy*, 16(S2):1–18.

Nile Basin Initiative (2012). State of the river nile basin report. Technical report, Nile Basin Initiative: Entebbe, Uganda.

Nile Basin Initiative (2015). How can the dss be used to make decisions? `http://nbdss.nilebasin.org/support/solutions/articles/4000041676-how-can-the-dss-be-used-to-make-decisions-`.

Nile Basin Initiative (NBI) (2014a). Analysis manager training module. Technical report, NBI.

Nile Basin Initiative (NBI) (2014b). Database manager utility and the system manager training module. Technical report, NBI.

Nile Basin Initiative (NBI) (2014c). Dss modeling tools training module. Technical report, NBI.

Onencan, A. and Enserink, B. (2014). The nile basin by 2050: Strategic foresight on the nile basin water governance. *Nile Basin Discourse: Entebbe, Uganda*, 28.

Opricovic, S. and Tzeng, G. (2004). Compromise solution by mcdm methods: A comparative analysis of vikor and topsis. *European journal of operational research*, 156(2):445–455.

Pierce, S. A. (2006). *Groundwater Decision Support: Linking causal narratives, numerical models, and combinatorial search techniques to determine available yield for an aquifer system*. The University of Texas at Austin.

Postel, S., Carpenter, S., et al. (1997). Freshwater ecosystem services. *Nature's services: Societal dependence on natural ecosystems*, 195.

Raiffa, H. (1994). The prescriptive orientation of decision making: a synthesis of decision analysis, behavioral decision making, and game theory. In *Decision theory and decision analysis: Trends and challenges*, pages 3–13. Springer.

Rasul, G., Chowdhury, A. J. U., et al. (2010). *Equity and social justice in water resource management in Bangladesh*. JSTOR.

Ravesteijn, W. and Kroesen (2015). Design for values in water management. In *Handbook of Ethics, Values, and Technological Design*, pages 847–867. Springer, Dordrecht.

Russo, J. and Carlson, K. (2002). Individual decision-making. In *Handbook of marketing*, pages 371–409. Sage Publications Ltd.

Schwartz, S. (2011). *Values: cultural and individual*, page 463–493. Cambridge University Press.

Schwartz, S. H. (1992). Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. In *Advances in experimental social psychology*, volume 25, pages 1–65. Elsevier.

Seid, A. (n.d.). Presentation: Introduction to the nile basin decision support system (nb dss). Unpublished.

Sileet, T., El Shamy, M., and Sharaky, A. (2014). Downstream impact of blue nile basin development. *Nile Basin Water Sci Eng J*, 7(1):16–33.

Sileet, T. M., El Shamy, M., Abdel Aty, M., and Sharak, A. (2013). The development of the baro-akobo-sobat sub basin and its impact on downstream nile basin countries. *Nile Water Science & Engineering Journal*, 6(2):51–208.

Smit, W. (2021). The nile water dispute: Legal integration in quantified allocation. Master's thesis, Wageningen University.

Sowińska, A. (2013). A critical discourse approach to the analysis of values in political discourse: The example of freedom in president bush's sate of the union addresses (2001-2008). *Discourse & Society*, 24(6):792–809.

Steen, M. and Van de Poel, I. (2012). Making values explicit during the design process. *IEEE Technology and Society Magazine*, 31(4):63–72.

Taebi, B. (2017). Strategies for dealing with value conflicts. `https://www.delftdesignforvalues.nl/fundamentals/`.

Tawfik, R. (2016). The grand ethiopian renaissance dam: a benefit-sharing project in the eastern nile? *Water International*, 41(4):574–592.

Teodosiu, C., Ardeleanu, C., and Lupu, L. (2009). An overview of decision support systems for integrated water resources management. *Environmental Engineering & Management Journal (EEMJ)*, 8(1).

The World Bank (2016). The nile basin trust fund. `https://www.worldbank.org/en/programs/cooperation-in-international-waters-in-africa/brief/nile-basin-trust-fund`.

UN (n.d.). Indicator 6.5.1 "degree of integrated water resources management implementation (0-100)". `https://www.sdg6monitoring.org/indicator-651/`.

Van Daalen, C. E., Dresen, L., and Janssen, M. A. (2002). The roles of computer models in the environmental policy life cycle. *Environmental Science & Policy*, 5(3):221–231.

Van de Poel, I. (2015). Conflicting Values in Design for Values. In van den Hoven, J., Vermaas, P., and van de Poel, I., editors, *Handbook of Ethics, Values and Technological Design*. Springer, Dordrecht.

van de Poel, I. (2018). Design for value change. *Ethics and Information Technology*.

van Delden, H., Seppelt, R., White, R., and Jakeman, A. J. (2011). A methodology for the design and development of integrated models for policy support. *Environmental Modelling & Software*, 26(3):266–279.

Van Meensel, J., Lauwers, L., Kempen, I., Dessein, J., and Van Huylenbroeck, G. (2012). Effect of a participatory approach on the successful development of agricultural decision support systems: the case of pigs2win. *Decision Support Systems*, 54(1):164–172.

van Roon, V. (2020). Government Attitudes to the Central Asian Water Crisis and Third-Party Water Diplomacy. Master's thesis, Delft University of Technology.

Veilleux, J. C. (2013). The human security dimensions of dam development: the grand ethiopian renaissance dam. *Global Dialogue*, 15(2):1–15.

Verhagen, J. (2020). Spatially explicit wef modelling in transboundary river basins. Master's thesis, Delft University of Technology.

Verhoeven, H. (2013). The politics of african energy development: Ethiopia's hydro-agricultural state-building strategy and clashing paradigms of water security. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 371(2002):20120411.

von Gienanth, E. (2020). "#itsmydam": An analysis of ethiopian and egyptian discourses surrounding the grand ethiopian renaissance dam. Master's thesis, University of Amsterdam.

Walker, D. H. (2002). Decision support, learning and rural resource management. *Agricultural systems*, 73(1):113–127.

Williams, C. and Fang, L. (2019). A value-focused multiple participant-multiple criteria (mpmc) decision support approach for public policy formulation. *Group Decision and Negotiation*, 28(1):99–126.

Wong, F. (1997). Decision support systems for integrated environmental management: anticipating and interrogating bias. In *Proceedings, MODSIM 97, International Congress on Modelling & Simulation, Hobart, Tasmania*, volume 2.

Wouters, P., Vinogradov, S., and Magsig, B.-O. (2009). Water security, hydrosolidarity, and international law: A river runs through it.... *Hydrosolidarity, and International Law: A River Runs Through It*, pages 97–134.

Yalew, S. G., Kwakkel, J., and Doorn, N. (2021). Distributive justice and sustainability goals in transboundary rivers: Case of the nile basin. *Frontiers in Environmental Science*, 8:281.

Zack, M. H. (2007). The role of decision support systems in an indeterminate world. *Decision Support Systems*, 43(4):1664–1674.

Zeitoun, M., Cascão, A. E., Warner, J., Mirumachi, N., Matthews, N., Menga, F., and Farnum, R. (2017). Transboundary water interaction iii: contest and compliance. *International Environmental Agreements: Politics, Law and Economics*, 17(2):271–294.

A

List of predefined indicators

Table A.1: Economic indicators

Sub-category	NB-DSS Indicator Name	Description
Navigation	Navigation	Number of days above baseline flow threshold or change relative to baseline
Energy	Average Energy	Average energy generated at specific hydropower node over a specified period
	Average Energy System	The system wide average annual energy
Water Conservation	Evaporation Loss	The average annual evaporation from a dam, wetland or lake
	Evaporation Loss System	System wide average annual evaporation
Floods	Flood Damage	Flood damage based on damage-depth relations for different land use types
Food Production	Food Production Single	Food production of new irrigation schemes
	Food Production	The potential reduction in crop yield of existing irrigation schemes due to upstream developments
	Production Income Single	Actual crop income of new irrigation schemes
	Production Income	Change in crop income of existing irrigation schemes due to upstream developments.

Table A.2: Social indicators

Sub-category	NB-DSS Indicator Name	Description
Water Availability	Water Availability	The change in availability of water for riparian users: domestic consumption, subsistence agriculture and livestock
Community Health and Safety	Malaria Endemicity	The susceptibility of irrigation scheme areas to malaria based on WHO malaria incidence map for Africa
	Pest Disease Prevalence	The prevalence of diseases resulting from pest species
	Urban Pollution	The water pollution downstream major urban areas
	Households Flooded	The number of households within the 100-year flood line
	Drowning Risk	The drowning risk due to conveyance of water in an open canal
Food Security and Livelihoods	Formal Irrigation	The footprint are due to establishment of new irrigation schemes
	Recession Agriculture Flood Plain	The impact on recession agriculture due to floodplain inundation
	Recession Agriculture Bank Instability	The impact on recession agriculture due to bank instability
	Fish Production Dam	The change in fish productivity in a dam, lake or wetland
	Fish Production River	The change in fish productivity along a river reach
	Productive Land Use	The productive land use for crops, grazing inundated by dam or lost due to establishment of an irrigation scheme or a canal
	Loss Natural Resources	The change loss of access to natural resources due to inundation by dam or establishment of an irrigation scheme or a canal
Displacement	Physical Displacement	The physical displacement of population due to inundation by a dam, establishment of an irrigation scheme or construction of a canal
	Economic Displacement	The economic displacement due to disruption of access to natural resources (cattle, people, wildlife) as a result of a canal and/or a dam construction

Table A.3: Environmental indicators

Sub-category	NB-DSS Indicator Name	Description
Footprint Areas	Environmentally Sensitive Areas	The extent of Environmentally Sensitive Area within a dam, irrigation scheme or canal footprint
	Environmentally Sensitive Rating	The impact rating on environmentally sensitive area within a dam, irrigation scheme or canal footprint
	Hotspot Rating	The wetlands of international importance and Important Bird Areas that fall outside protected areas, but within primary impact zones.
	Carbon	The area of woody biomass and biomass carbon within dam footprint
	Fish Production	Fish production from a dam, lake or wetland
Downstream Areas	Floodplain Inundation	The floodplain area inundated compared to a baseline
	Wetland Area	The wetland area inundated compared to a baseline
	Ecological Stress Rating	Ecological stress rating from changes in key flow components and flow variability compared to a baseline
	Wet Season Duration	The wet season duration based on median monthly flows
	Black Fly Rating	Black fly rating from HP operation, changes in low flows and variability compared to baseline
	Bank Stability	Bank stability rating downstream of impoundment based on standard deviation of flows and predefined sinuosity
	Recovery Distance	Recovery distance based on median discharge from impoundment and distance to downstream tributary
	Wet Season Shift	Calculates number of weeks delay in the onset of wet season compared to a baseline
Water Quality	Phyto Plankton	The phytoplankton growth potential based on empirical relationship with retention time
	Aquatic Macrophyte	Aquatic macrophyte growth potential based on empirical relationship with nitrate concentration in irrigation scheme return flow

B

Known NBDSS application cases

Jonoski and Seid (2016) present three examples of cases in which the NBDSS was used:

- A multi-sector investment planning study in the Nile Equatorial Lakes region. A range of water resources development and management scenarios for projected future water demand was analysed and evaluated using the DSS, to select a preferred scenario based on agreed criteria.
- A study into potential lack of water resources as a result of planned development projects. In this study, Nile-SEC used the DSS to create projections for water demand and supply for 2050.
- Formulation of the national water resources management strategy in Uganda. The DSS was used to make a hydrological assessment of water resources development objectives, to assess possible trade-offs between HP generation, wetland and upland irrigation, and downstream flow and to finally compare the options in terms of pros and cons.
- Estimation of hydrological implications of the GERD and other planned dams in Ethiopia on Sudan, including changes in flow regimes, reservoir water levels and hydropower generation (see e.g. Hamid (2013).

Other examples that could be found on Google Scholar and the NBI knowledge hubs are:

- Baro-Akobo-Sobat (BAS) Multipurpose Water Resources Development Study Project (MWRDSP). Project documents retrieved from ENTRO's knowledge hub show proposals to use the NBDSS for scenario evaluation and optimisation for several project aspects, including water balance, water availability and allocation, irrigation, environmental and wetland management, reservoir filling and operations, hydropower and navigation (e.g. Citeau et al. (2016).
- An impact assessment of Blue Nile projects on both national and regional levels in order to minimise downstream negative impact on basin level Sileet et al. (2014)
- A study into the impact of climate change on hydropower production in the Blue Nile before and after construction of the GERD Abd El-Haliem et al. (2016).
- An assessment of positive and negative impacts of water resources development projects in the Baro-Akobo-Sobat sub basin on both national and regional levels (Sileet et al., 2013).

In 2015, the NBI organised the NBDSS Best National Application Awards. (NBI) presents the price-winning applications, including applications in Ethiopia, Kenya, Rwanda, Sudan and Tanzania. Out of this list, the Ethiopian and Sudanese application cover the Blue Nile. In Ethiopia, the impact of irrigation developments on hydropower, fish production, navigation and evaporation was investigated. The Sudanese case is an application that is similar to the one mentioned by Jonoski and Seid (2016). Here the impact of the GERD and other planned dams on the existing Blue Nile reservoir system in Sudan is studied.

The above mentioned projects and knowlegde hubs resulted in some interesting findings. Firstly, project documents on the BAS MWRDSP mention the NBDSS is used to model some of the aspects for which indicators and model tools are embedded in the system. However, the documents speak about usage of other model software "to investigate more localised water management issues related to water quality, flooding [...] and sediment control [...]" (Citeau et al., 2016), although indicators and associated scripts for water quality and flooding already exist in the NBDSS. This might indicate that incorporated scripts are not up to meet the necessary standards. Nevertheless, the model output would still be feeded into

the NBDSS.

Only a few descriptions of applications of the NBDSS could be found. Most of these applications date back to 2015 or before. After 2018, both the Nile Information System (Nile-IS), ENTRO's knowledge hub, Google Scholar and Scopus do not provide a single case described. The retrieved publications are mostly published by the NBI or written by authors with a link to the organisation. Little scientific publications on usage of the NBDSS could be found.

There are a few described cases with a relation to reservoir development and management. The (NBI) describes a study into impacts of upstream dam development (including the GERD) on the Sudanese Blue Nile reservoir system. This study used scenarios based on different dam configurations in Ethiopia to estimate peak flood reduction, low flow augmentation and total flow reduction. Results depended highly on reservoir operation policies. Results were calculated based on eleven environmental, four social and four economic criteria. The DSS already provided most of these criteria and scrips; only criteria for maximum and minimum flow ratio could not be deducted from the list in Appendix A. Results showed that the Ethiopian dams will have a distributional effect on floods, benefiting the relatively small irrigation reservoirs in Sudan.

Jonoski and Seid (2016) mentions impact assessments of storage reservoirs on flood control and reservoir sedimentation as part of the focus areas of the NBDSS. Flood control is indeed studied in the Sudanese case above, but no described applications on sedimentation was discovered. In addition, this claim feels contradictory to the quote from Citeau et al. (2016), stating that localised issues such as sediment management in this case ask for usage of different models. Finally, Seid (nd) states that the system offers ”a suite of models for simulating lake-river/reservoir systems.”

C

Sourcelist

C.1. Ethiopian sources

Source	ET-1
Title	Ethiopian Water Resources Management Policy
Speaker	Ministry of Water Resources
Forum	Official Policy document by the Ethiopian Government
Language	English
Date	1999
Link	http://www.fao.org/faolex/
Accessed	22/02/2021

Source	ET-2
Title	Civilisation and peace for who? Nile Basin is made up of 10 countries
Speaker	Fesseha Shawel Gebre, Ambassador of Ethiopia to the United Kingdom
Forum	Letter to the Editor of the Independent Newspaper
Language	English
Date	25/04/2020
Link	https://www.ethioembassy.org.uk/civilisation-and-peace-for-who-nile-basin-is-made-up-of-10-countries/
Accessed	19/04/2021

Source	ET-3
Title	Unlike Downstream Countries, Ethiopia Believes in Resolving GERD issues through negotiation
Speaker	Minister of Irrigation and Energy Sileshi Bekele
Forum	News paper article in ENA, summarizing an interview of the minister to Al Jazeera Arabic in English.
Language	English
Date	04/02/2021
Link	https://www.ena.et/en/?p=21224
Accessed	16/04/2021

Source	ET-4
Title	Message of the Minister
Speaker	Dr. Seleshi Bekele
Forum	Offical message of the Minister on the Ministerial web page
Language	English
Date	n.d.
Link	http://mowie.gov.et/message-of-the-minister
Accessed	05/03/2021

Source	ET-5
Title	Annex I to the letter dated 26 June 2020 from the Permanent Representative of Ethiopia to the United Nations addressed to the President of the Security Council
Speaker	Minister of Foreign Affairs, Gedu Andargachew
Forum	Offical letter to the United Nations Security Council
Language	English
Date	26/Jun/20
Link	https://undocs.org/S/2020/623
Accessed	24/02/2021

Source	ET-6
Title	The celebration of Nile Day
Speaker	The Ministry of Foreign Affairs
Forum	A week in the Horn, weekly journal of the Ministry of Foreign Affairs of Ethiopia
Language	English
Date	Mar/13
Link	https://www.yumpu.com/en/document/read/39834354/a-week-in-the-horn
Accessed	19/04/2021

Source	ET-7
Title	Address by the President of the Democratic Republic of Ethiopia, mrs. Sahle-Work Zewde
Speaker	mrs. Sahle-Work Zewde, President of the Federal Democratic Republic of Ethiopia
Forum	Speech at the General Assembly of the United Nations
Language	English
Date	26/09/2019
Link	https://undocs.org/en/A/74/PV.7
Accessed	24/02/2021

Source	ET-8
Title	The reality of the Grand Ethiopian Renaissance Dam (GERD)
Speaker	The Ministry of Foreign Affairs
Forum	A week in the Horn, weekly journal of the Ministry of Foreign Affairs of Ethiopia
Language	English
Date	17/02/2017
Link	https://www.ethioembassy.org.uk/a-week-in-the-horn-17-02-17/
Accessed	15/03/2021

C.2. Sudanese sources

Source	SU-1
Title	Statement by the Minister for Foreign Affairs of the Republic of the Sudan, mr. Eldirdiri Mohamed Ahmed
Speaker	Mr Eldirdiri Mohamed Ahmed, Minsiter of Foreign Affairs of the Republic of Sudan
Forum	Speech at the General Assembly of the United Nations
Language	Arabic, translated into English officially by United Nations
Date	01/10/2018
Link	https://undocs.org/en/A/73/PV.16
Accessed	24/02/2021

Source	SU-2
Title	Sudan National Water Policy
Speaker	Ministry of Irrigation & Water Resources
Forum	Official policy document of the Sudanese government
Language	English
Date	1999
Link	https://www.ircwash.org/resources/sudan-national-water-policy
Accessed	12/04/2021

Source	SU-3
Title	Statement by the Minister for Foreign Affairs of the Republic of the Sudan, mr. Ibrahim Ahmed Abd al-Aziz Ghandour
Speaker	mr. Ibrahim Ahmed Abd al-Aziz Ghandour, Minsiter of Foreign Affairs of the Republic of Sudan
Forum	Speech at the General Assembly of the United Nations
Language	Arabic, translated into English offically by United Nations
Date	23/09/2020
Link	https://undocs.org/A/72/PV.21
Accessed	24/02/2021

Source	SU-4
Title	Annex to the letter dated 2 June 2020 from the Permanent Representatitve of the Sudan to the United Nations addressed to the President of the Security Council
Speaker	Permanent Respresentative of the Sudan, Omer Mohamed Ahmed Siddig
Forum	Offical letter to the United Nations Security Council
Language	English
Date	02/Jun/20
Link	https://undocs.org/S/2020/480
Accessed	24/02/2021

Source	SU-5
Title	Sudan National Drought Plan
Speaker	National Council for Combating Desertification
Forum	Official Plan Document of the Government of Sudan.
Language	English
Date	21/11/2018
Link	http://extwprlegs1.fao.org/docs/pdf/sud197769.pdf
Accessed	14/04/2021

Source	SU-6
Title	Transscript speech Minister of Irrigation and Water Resources, Prof. Yasser Abbas, at the UN General Assembly on water
Speaker	Minister of Irrigation and Water Resources, Prof. Yasser Abbas
Forum	Speech at the UN General Assembly on water
Language	English
Date	19/03/2021
Link	https://www.unmultimedia.org/avlibrary/asset/2608/2608697/
Accessed	14/04/2021

Source	SU-7
Title	Transscript of interview dr. Yassir Mohammed, Minister of Irrigation and Water Resources in Sudan, with prof. Pieter van der Zaag (IHE)
Speaker	Dr. Yassir Mohammed, Minister of Irrigation and Water Resources of the Sudan
Forum	Interview with prof. Pieter van der Zaag (IHE)
Language	English
Date	Sep/19
Link	https://www.youtube.com/watch?v=J9w4JwFm3kA&t=12s
Accessed	16/04/2021

C.3. Egyptian sources

Source	EG-1
Title	Statement by the President of the Arab Republic of Egypt, Mr. Abdel Fattah Al Sisi, at the General Assembly
Speaker	Mr. Abdel Fattah Al Sisi, President of the Arab Republic of Egypt
Forum	The General Assembly of the United Nations
Language	Official translation by the United Nations, speech originally in Arabic
Date	2017
Link	https://undocs.org/en/A/72/PV.5
Accessed	24/02/2021

Source	EG-2
Title	Statement by the President of the Arab Republic of Egypt, Mr. Abdel Fattah Al Sisi, at the General Assembly
Speaker	Mr. Abdel Fattah Al Sisi, President of the Arab Republic of Egypt
Forum	The General Assembly of the United Nations
Language	Official translation by the United Nations, speech originally in Arabic
Date	2019
Link	https://undocs.org/en/A/74/PV.3
Accessed	23/03/2021

Source	EG-3
Title	Statement of the Minister for Foreign Affairs of Egypt, Someh Shokry, for the Security Council meeting on the Grand Ethiopian Renaissance Dam, 29 June 2020
Speaker	Minister of Foreign Affairs of Egypt, Sameh Shokry
Forum	Letter to the Security Council of the United Nations
Language	English
Date	2020
Link	https://undocs.org/fr/S/2020/617
Accessed	24/02/2021

Source	EG-4
Title	Egypt and the world celebrate the World Water Day
Speaker	Dr. Mohamed Abdel Aty, Minister of Water Resources and Irrigation
Forum	Publication on Ministerial web page
Language	English
Date	zd
Link	https://www.mwri.gov.eg/
Accessed	26/04/2021

Source	EG-5
Title	The National Water Resources Plan 2017-2030-2037
Speaker	Ministry of Water Resources and Irrigation, in person dr Mohammed Abd el Aaty, Minister of Water Resources and Irrigation
Forum	Official Policy document of the Ministry of Water Resources and Irrigation of Egypt
Language	English
Date	2017
Link	Available at author
Accessed	19/04/2021

Source	EG-6
Title	Irrigation Ministry spokx: Egypt faces water scarcity problem due to population increase, climate change
Speaker	Mohamed Ghanem, spokesman for the Ministry of Water Resoucres and Irrigation
Forum	Newspaper article citing the spokesman of the Ministry of Water Resources and Irrigation
Language	English
Date	2020
Link	https://www.egypttoday.com/Article/1/100904/Irrigation-Ministry-spokx-Egypt-faces-water-scarcity-problem-due-to
Accessed	30/04/2021

Source	EG-7
Title	Egypt's irrigation minister clarifies status of Ethiopian Dam crisis
Speaker	Minister of Irrigation and Water Resources Mohamed Abdel Aty
Forum	Newspaper article summarising most significant quotes of an interview by the Minister by Amr Adib in Al Hekaya Show (Egyptian Talkshow)
Language	English (original interview in Arabic)
Date	2021
Link	https://www.egypttoday.com/Article/1/100821/Egypt-s-irrigation-minister-clarifies-status-of-Ethiopian-Dam-crisis
Accessed	30/04/2021

Source	EG-8
Title	Nile Water
Speaker	Ministry of Water Resources and Irrigation of Egypt
Forum	Offical ministerial web page
Language	Arabic translated into English (Google translate)
Date	zd
Link	https://www.mwri.gov.eg/nile-river/
Accessed	04/05/2021

D

Results of the discourse analysis

Table D.1: Ten most occurring subthemes Egypt, non-IR sources

Egypt			
Rank	Theme	Subtheme	Score
1	EC	Agriculture	24
2	K	Technology	12
3	EC	Economy	6
4	EC	Efficiency	5
5	EN	Water Quality	5
6	IR	Equity	4
7	NG	National Government	3
8	EC	Fisheries	3
9	C EC EN	Identity Tourism Biodiversity	3
		Total top 10	68

Table D.2: Ten most occurring subthemes Egypt, IR sources

Egypt			
Rank	Theme	Subtheme	Score
1	IR	International Cooperation	20
2	C	Identity	13
3	IR	Equity	13
4	IR	Laws & Policy	12
5	IR	International Actors	10
6	IR	Conflict	5
7	K	Research	3
8	S	Socio-Economic Development	3
9	EC	Agriculture	2
10	K	Data	2
		Total top 10	84

Table D.3: Ten most occurring subthemes Sudan, IR sources

Sudan			
Rank	Theme	Subtheme	Score
1	IR	International Cooperation	16
2	EN	Environment Protection	11
3	NG	National Government	10
4	S	Drinking Water	8
5	IR	International Actors	8
6	S	Conflict	7
7	IR	Equity	6
8	IR	Laws & Policy	5
9	EC	Agriculture	4
10	C	Tradition	3
		Total top 10	79

Table D.4: Ten most occurring subthemes Sudan, non-IR sources

Sudan			
Rank	Theme	Subtheme	Score
1	EC	Agriculture	8
2	S	Livestock	5
3	EN	Environment Protection	5
4	S	Health & Sanitation	5
5	S	Drinking Water	4
6	S	Participation & Inclusion	4
7	EC	Economy	4
8	K	Capacity Building	4
9	EN	Water Quality	4
10	EN	Natural Resources	4
		Total top 10	45

Table D.5: Ten most occurring subthemes Ethiopia, non-IR sources

Ethiopia			
Rank	Theme	Subtheme	Score
1	S	Socio-Economic Development	7
2	EC	Agriculture	7
3	EC	Economy	6
4	S	Drinking Water	5
5	EC	Energy	5
6	S	Participation & Inclusion	4
7	C	National Pride	4
8	K	Data	4
9	S	Equity	3
10	EC K K S	Funding Capacity Building Technology Health & Sanitation	3
		Total top 10	48

Table D.6: Ten most occurring subthemes Ethiopia, IR sources

Ethiopia			
Rank	Theme	Subtheme	Score
1	IR	Laws & Policy	16
2	IR	Equity	13
3	IR	International Cooperation	12
4	IR	International Actors	6
5	EC	Energy	5
6	S	Socio Economic Development	4
7	C	Identity	4
8	S	Quality of Life	3
9	K	Research	3
10	EN	Natural Resources	3
		Total top 10	69