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Irrigation Development Projection in the Nile Basin Countries: Scenario-based Methodology Technical Report

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Document Sheet

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The purpose of the technical report series is to support informed stakeholder dialogue and decision making in order to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the shared Nile Basin water resources.

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ABBREVIATIONS

ARP	Agricultural Revitalization Program
BaUScen	Business as Usual Scenario
CRGE	Climate Resilient Green Economy
DNIMP	Draft National Irrigation Master Plan (DNIMP)
DRC	Democratic Republic of the Congo
ENTRO	Eastern Nile Technical Regional Office
FAO	Food and Agriculture Organization of the United Nations
GERD	Grand Ethiopian Renaissance Dam
GTP	Growth and Transformation Plan
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
IWRMDP	Integrated Water Resources Management and Development Plan
JICA	Japan International Cooperation Agency
LVNCA	Lake Victoria North Catchment Area
LVSCA	Lake Victoria South Catchment Area
MALR	Ministry of Agriculture and Land Reclamation
MoIC	Ministry of Planning and International Cooperation
NIMP	National Integrated Master Plan
NB	Nile Basin
NBI	Nile Basin Initiative
Nile-Sec	Nile Basin Initiative (NBI) Secretariat
PLANScen	Planned Development Scenario
SADS	Strategy for Sustainable Agricultural Development
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
SWRA	Strategic Water Resources Analysis
UN DESA	United Nations Department of Economic and Social Affairs

SUMMARY

The Nile Basin Initiative (NBI) Secretariat (Nile-Sec) conducted a Strategic Water Resources Analysis (SWRA) in 2015 with the aim of developing sustainable options to meet the growing water needs of the Nile riparian countries, and subsequently to mitigate current and future water stress. Nile-Sec acknowledged that its previous SWRA study had gaps in the datasets, particularly a lack of integration of economic modeling of water use in terms of assessing the value of irrigation water. Another limitation of that first-phase assessment was that the impact of increased water productivity on food security and water utilization had not been analyzed across the Nile Basin (NB). It also had not analyzed the impact of optimal planning of cropping patterns on specific climate and soil conditions. Therefore, this second-phase study was tasked with refining the current estimates and projections of agricultural water demand/use. The outputs of this study will contribute to sustainable and efficient investment planning to meet growing water demands commensurate with the Nile-Sec plans. It is envisaged that options for water savings in agriculture, such as adoption of improved irrigation technologies, optimization of cropping patterns across the basin and other measures, could result in substantial gains across the NB.

The phase II study has six components. This report pertains to component II of the project, which focuses on developing alternative future irrigation projection scenarios, which contribute to improving the baseline irrigation water demand and actual use in the basin. Several studies and datasets were reviewed and analyzed as inputs for this scenario development.

A review of policy and strategy documents, master plans and programs indicates that almost all upper riparian countries of the NB want to expand irrigation to enhance food security and foster economic growth and transformation. Egypt's policy is focused on improving productivity and water-use efficiency rather than expansion of irrigated land. Sudan on the other hand shows renewed interest in irrigation expansion due mainly to the loss of oil revenue as a result of the secession of South Sudan in 2011 and recognizing the recent positive advances of liberalization and income generation activity brought to Sudan. It should be noted that all countries except Burundi and the Democratic Republic of the Congo (DRC) have submitted their future irrigation development plans to the NBI. However, the planned irrigation schemes shown in the respective master plans and documents of these countries are different from what were submitted to the NBI and verified thereafter. The basis of scenario development for this study is the NBI-validated data and the baseline existing irrigation data compiled under this project of Technical Report I.

A fundamental consideration in this study is that irrigation growth in many NB countries (or for that matter many sub-Saharan African countries) cannot be fully explained in terms of external drivers such as socioeconomic, technological and climatic change. Analyses indicate that it is more fully explained by the implementation capacity of each country's institutional, human, and financial resources and the existence of an enabling environment. Hence, this study follows an implementation-based approach rather than a scenario based on the functional relationship between irrigation development and external drivers. The implementation-based scenario amplifies the capacity of NB countries to implement their irrigation development plans. As a result, future development projections are based within the scope of the national plans supplied by the countries to NBI. We caution that this may not reflect all the future plans made in the respective countries: the master plan development schemes show much higher irrigation designs than the plans supplied to NBI.

This study proposed two possible implementation-based irrigation development projection scenarios, with two variants in each: Business as Usual Scenario (BaUScen) and Planned Development Scenario (PLANScen). These scenarios are intended to evaluate the likely impacts of future projections on the water resources of the NB system using river basin models. According to the scenarios:

- The BaUScen of variant I extends the basin irrigation area from its current 6.6 million hectares (Mha) to 8.9 Mha by 2030 and to 10.8 Mha by 2050. This is within the limit of the potential irrigation-suitable land but exceeds the potential irrigable land assessed by FAO in 1997.
- The BaUScen of variant II extends the basin irrigation area from its current 6.6 Mha to 7.4 Mha by 2030 and to 8.6 Mha by 2050. It is within the limit of both potential irrigation areas.
- The PLANScen of variant I extends the basin irrigation area from its current 6.6 Mha to 7.5 Mha by 2030 and to 9.2 Mha by 2050. It is within the limit of both the potential irrigation areas.

- The PLANScen of variant II extends the basin irrigation area from its current 6.6 Mha to 8.3 Mha by 2030 and to 10.0 Mha by 2050. It is within the limit of both the potential irrigation areas.

The results of this projection support the evaluation of the impact of irrigation expansion on water demand. The results need to be evaluated systematically with and without considering the proposed water-saving scenario. Based on the results of the final modeling, strategic policy recommendations will be developed and presented to the stakeholders.

1. INTRODUCTION

Agricultural expansion, including irrigated agriculture, will remain a phenomenon of the developing world in the twenty-first century. Alexandratos and Bruinsma (2012) estimated that nearly all agricultural expansion in the world (irrigated and rainfed) will take place in the developing countries. The overall arable land development is projected to increase by an additional 107 million hectares (Mha) (i.e., from 968 Mha during the reference period of 2005-07 to 1,075 Mha in 2050), which is an increase of 11%. The bulk of this projected expansion is expected to take place in sub-Saharan Africa (SSA) (51 Mha) and Latin America (49 Mha). Many of the Nile Basin (NB) countries are located in SSA (except Egypt) and have high population growth and food demand. Hence, irrigation expansion is anticipated to grow more rapidly in this region than in other parts of the world. The Nile Basin Initiative (NBI) Irrigation Assessment Report for the Nile equatorial countries (NBI 2012) shows an increase in irrigated area of 579,000 hectares (ha) in the Democratic Republic of the Congo (DRC), 42,000 ha in Burundi, 338,000 ha in Kenya, 1,012,000 ha in Tanzania, 1,151,000 ha in Uganda and 628,000 ha in South Sudan. Except Egypt, irrigation has shown expansion in Ethiopia and Sudan as well (NBI 2020a, Section 4.1, Table 7). This study also indicated an average increase of 10% and 16% in cropped and equipped irrigation areas, respectively, in the NB part of these countries since 2015.

To assess the increasing water demand situation in the basin, the NBI Secretariat (Nile-Sec) launched its Strategic Water Resources Analysis (SWRA) in 2015, and completed the first phase of the study in 2016. The SWRA is aimed at sustainably developing water resources infrastructure and management options to meet the growing water demand in the NB and reducing the mounting stress on the river system; and also minimizing tensions relating to water allocation among the riparian countries.

The first phase of the analysis, which focused on water supply and demand assessment, yielded initial estimates on water availability and water demand/use for the base year 2014, and projections up to 2050 as well. Furthermore, a NB water resources model was developed that took into account the existing water infrastructure and the planned water infrastructure investments to be implemented in the 2050 time horizon. The first phase of the SWRA also estimated the water savings achievable under various scenarios of irrigation efficiency improvement.

Despite these efforts to understand the irrigation water demand/supply situation within the basin, the phase I study acknowledged the existence of gaps in the datasets, limitations in the valuation of irrigation water uses and the impact of increased water productivity on food security and water utilization.

In view of these gaps, Nile-Sec launched the phase II study in partnership with the International Water Management Institute (IWMI) to contribute to the generation of strategic options for more efficiently and sustainably meeting the water demands in the NB. The phase II study has six interrelated components:

- Component I: Refining the baseline irrigation water demand and actual use
- Component II: Projection of the future irrigation water demand
- Component III: Scenarios for water saving in irrigated agriculture
- Component IV: Economic value of water for irrigation
- Component V: Development of a basin-wide approach for benchmarking irrigated agriculture performance
- Component VI: Strategic recommendations for improved irrigation water management

The purpose of this report is to objectively assess the various possible irrigation development scenarios in the basin. It builds on the database of future irrigation projects prepared by NBI in the first phase of the SWRA and relies on additional information available from different sources (e.g., Food and Agriculture Organization of the United Nations [FAO], NBI studies, national master plans).

The first phase of SWRA showed that there would be considerable water shortfalls if all the agricultural crop expansion was to be irrigated from the Nile or its tributaries. Limited desk studies by NBI indicate that improved irrigation efficiencies can substantially, if not totally, reduce the water shortfalls. This needs to be explored further in terms of whole packages of practices and technologies and policy elements that improve not only irrigation efficiency but also irrigation water productivity.

The objective of this report, component II of the phase II study dealing with future irrigation water demand scenarios, is to contribute to the discovery of more efficient and sustainable strategic options for meeting the growing water demands in the Nile Basin through (a) developing scenario-based modeling; and (b) assessment of the possible irrigation expansion pathways in the basin. Through a review of past irrigation development in the basin, a fundamental consideration has been taken into account: irrigation growth in Nile Basin countries (or for that matter many SSA countries) is a complex phenomenon that cannot be fully explained in terms of external drivers such as socioeconomic, technological and climatic change; we need to also consider the implementation capacity of the country's institutional, human and financial resources and the existence of an enabling environment.

The main outputs of this component include a detailed description (technical report, database, maps) of the reference scenario for irrigation expansion together with up to three variants that shall be used to refine irrigation water demand projections in the Nile Basin. The key tasks assigned to this component were to:

i) Review available information (FAO, NBI Regional Agricultural Trade and Production [RATP] study, national master plans and other relevant sources) on the land area that is potentially suitable (as per FAO suitability classes) for irrigated agriculture (based on land, rainfall, and soil suitability) in all NBI countries; and develop a georeferenced spatial database (including maps) of areas with irrigation potential together with likely cropping patterns. Preparation of the geospatial database shall be based on datasets available publicly or those that can be obtained on request;

ii) Analyze the national master plans or other planning documents of NBI countries and develop a comparative summary of the strategies adopted by NBI countries to achieve irrigation expansion (e.g., level of ambition, supplementary vs. full-scale, small-scale vs. large commercial farming, etc.);

iii) For each country, identify the historical trend of irrigation expansion in relation with projections made in the master plans or other planning documents (including graphical illustration of the trends and future trajectories);

iv) Assist the NBI in refining the reference scenario for irrigation in the 2050 time horizon based on national base plans. The basis for this task shall be the database of planned irrigation projects compiled by NBI and consultations with experts; and

v) Write a technical report describing future irrigation expansion while considering the following:

    1) Historical trend and likely future trajectories
    2) Comparative summaries of national strategies for irrigation expansion
    3) Analysis of potential irrigation land areas, related back to the planned expansion
    4) Scenarios of cropping patterns and irrigation technologies (component III)

2. REVIEW OF THE IRRIGATION SITUATION IN BASIN COUNTRIES

2.1 Irrigation Policies/Strategies/Plans

A review of the country documents shows that many of NB countries have documented irrigation development policies and strategies. Several of them are in an advanced stage of irrigation planning, as is demonstrated by their respective irrigation master plans, integrated water resources management studies and strategic and transformation programs. We summarize these plans and present them below in this section. The master plan studies of Burundi and DRC master were not available, and so were not included in this review. However, in common with many of the upper riparian countries, the policies of these two countries are quite likely to focus on improving food security and economic growth as well.

Egypt

Egypt has a 'Strategic Framework for Economic and Social Development Plan' with a time horizon of 2022 that aims at poverty reduction. It provides guidance for different policy formulations, including agriculture and food security. In this document, it is evident that Egypt's future desire for irrigated agriculture is shifting toward improving sustainability, productivity and water efficiency (e.g., MoIC 2012). As stated in this framework, the 'National Water Resources Plan of 2005' aims at improving overall water-use efficiency in agriculture, improving allocation and distribution of the Nile water, preventing or reducing emissions, and treatment of wastewater.

In 2009, a Strategy for Sustainable Agricultural Development (SADS) was developed by the Ministry of Agriculture and Land Reclamation (MALR 2009). Today, it stands out as one of the significant strategies developed by the ministry. It aims at modernizing Egyptian agriculture through efficient use of development resources, utilization of geopolitical and environmental advantages, and exploitation of the comparative advantages of the different agroecological regions of Egypt. The country's strategic objectives for 2030 focus on (i) sustainable use of natural agricultural resources; (ii) increasing the productivity of both land and water units; (iii) raising the degree of food security of strategic food commodities; (iv) increasing the competitiveness of agricultural products in local and international markets; (v) improving the climate for agricultural investment; and (vi) improving living standards among the rural population and reducing the poverty rate in rural areas. Therefore, Egypt's policy toward long-term expansion is limited and, as such, focuses on improving productivity and water-use efficiency. However, in its country communication to NBI, Egypt has indicated it plans to have an irrigation area of about 502,196 ha in the future (see Section 4.5, Table 11).

Ethiopia

Led by a Climate Resilient Green Economy (CRGE) strategy of achieving middle-income status by 2025, Ethiopia embarked on a Growth and Transformation Plan (GTP) with a five-year cycle with the main policy objective of economic growth and poverty reduction. The first phase of GTP was completed fairly successfully in 2015 (NPC 2016). The next phase of GTP – GTP II – was launched in 2016 and will run through to 2020. The objective of GTP II is to ensure rapid, sustainable and broad-based growth by enhancing productivity of agriculture and manufacturing; and by improving the quality of production and stimulating competition in the economy. Though GTPs are intended to stimulate economic growth, food security is one of the pillars of the transformation. Ethiopia planned to develop more than 940,000 ha by implementing medium and large-scale irrigation schemes; and over 1.6 Mha by using small-scale irrigation schemes (through the Ministry of Agriculture and Natural Resources) during the GTP II period. Ethiopia is one of the countries pursuing irrigation development vigorously as part of its strategy of food security and economic growth. The NBI-verified irrigation plan for Ethiopia would cover approximately 1.43 Mha (see Section 4.5, Table 11).

Kenya

Kenya has set itself a national irrigation development goal of 1.2 Mha by 2030 to strengthen its agricultural sector so that it can contribute more to the national economy. The development target includes large-scale (public), small-scale (smallholders) and private irrigation schemes. The country's

2013 Master Plan identifies a catchment-based area with irrigation potential and a newly updated irrigation development area, which incorporates a water balance study. For the Nile Basin part of Kenya, the irrigation development plan is divided into two components, the Lake Victoria North Catchment Area (LVNCA) and Lake Victoria South Catchment Area (LVSCA), as shown in Table 1. Accordingly, Kenya is planning to develop 277,764 ha of irrigable land in the Nile Basin part of the country by 2030. However, this extent of planned area is higher than the data verified by NBI, which is about 66,682 ha (see Section 4.5, Table 11).

Table 1. Irrigation development target in the Nile Basin part of Kenya as per the national irrigation development goals specified in the plan Kenya Vision 2030.

Irrigation development target	Lake Victoria North Catchment Area (LVNCA)	Lake Victoria South Catchment Area (LVSCA)	Total
Provisional target area (ha)*	90,786	186,978	277,764
Possible new irrigation area (ha)**	168,913	113,206	282,119
Total	259,699	300,184	559,883

Source: JICA 2013.

Notes:

*Assumed values for the Kenya Vision 2030 targets based on data on potential agricultural area proposed by Ministry of Agriculture before water balance study.

**Maximum possible area for new irrigation development based on water balance study.

Tanzania

The national agriculture policy of Tanzania (JICA 2018) recognizes irrigation development as an effective approach to achieve food security and poverty reduction as it improves crop productivity and assures stable expansion of agricultural production. The Government of Tanzania (GoT) began to focus on irrigation development at the government level in 1994 and formulated the National Irrigation Development Plan (NIDP) to achieve more efficient irrigation development by 2014. In 2004, Tanzania developed the National Integrated Master Plan (called NIMP2002) with 2017 as its target year. The major objective of NIMP 2002 was to realize sustainable irrigation development by effectively mobilizing national resources, which would in turn contribute to the achievement of goals set in the Agricultural Sector Development Strategy (ASDS). The master plan proposed to develop 626 irrigation schemes with a total irrigated area of 405,000 ha. By 2015, national irrigation development in Tanzania grew from 200,000 ha in 2004 to 460,000 ha, which was above the targeted development for 2017. This is a growth rate of almost 10% annually over the total irrigated area in 2004. The revised NIMP 2018 sets out the national irrigation development targets for 2025 and 2035. Table 2 shows the estimates for targeted irrigation development in the Nile Basin part (the Lake Victoria catchment) of Tanzania as presented in NIMP 2018 (JICA 2018) and the Integrated Water Resources Management and Development Plan (IWRMDP). Both studies estimate the planned irrigable area for 2025 and 2035. However, the NIMP 2018 study explicitly considers water allocation, and significantly varies from the IWRMDP study, as is evident in Table 2. The NIMP 2018 planned irrigation area shown in Table 2 (45,140 + 27,460 = 72,600 ha) is higher than the NBI-validated planned irrigation area, which is 50,677 ha (see Section 4.5, Table 11).

Table 2. Estimates for targeted irrigation development (ha) in the Lake Victoria catchment of Tanzania as presented in the country's National Integrated Master Plan (NIMP 2018) and Integrated Water Resources Management and Development Plan (IWRMDP).

Basin	2025		2035	
	IWRMDP	NIMP 2018	IWRMDP	NIMP 2018
Lake Victoria	131,560	27,460	261,288	45,140

Source: JICA 2018.

Uganda

Given the immense potential that improved rainfed agriculture has for food security and the high investment costs associated with irrigation development in Uganda, that county's irrigation development policy is aimed at poverty alleviation and economic growth. For sustainable realization of its irrigation potential, while mitigating the likely effects of climate change and contributing to the transformation of society from a peasant to a modern and prosperous country, Uganda is keen to expand irrigation development in the country.

Past studies have given varying figures for Uganda's irrigation plans and potential. As shown in the National Irrigation Master Plan study, which was conducted by PEM Consult (2011), the estimates for potential irrigation area in Uganda have ranged from 170,000 ha to 566,466 ha. The PEM Consult study indicates that this wide range is due to the fact that the estimates followed the Draft National Irrigation Master Plan (DNIMP). The DNIMP study appeared to project irrigation area on the basis of a certain annual increment expressed as a percentage of the total potential arable land, which was estimated at 4.4 Mha (PEMConsult2011). Table 3 shows the potential and planned irrigation area projections until 2035. It should be noted that the NBI-validated irrigation area for Uganda is 4,048 ha (see Section 4.5, Table 11), which is far below the master plan's estimate of 33,750 ha (Table 3). It is clear that irrigation expansion is expected to be more than 4,048 ha by the end of 2050. This value may require further validation and updating.

Table 3. Projections for planned irrigation area vary significantly for the Nile Basin in Uganda.

	Potential irrigable (ha)	Planned irrigation (ha)
Type A land (wetlands)	243,500	24,000
Type B land (uplands)	272,000	9,750
Total	515,000	33,750

Source: PEMConsult 2011.

South Sudan

The Republic of South Sudan commissioned an Irrigation Development Master Plan (IDMP) study in 2015 with the goal of achieving sustainable irrigated agriculture and other productive uses of water in order to improve food security and resilience, reduce poverty and contribute to economic growth and sustainable development. The study charted out irrigation development for 2021, 2027 and 2040 (Table 4). The total planned irrigation area until 2040 adds up to 582,928 ha in this master plan (Table 4) against the NBI-validated value of 226,930 ha.

Table 4. Projections for planned irrigation area in South Sudan.

Type of scheme	Planning horizon		
	2021 Area (ha)	2027 Area (ha)	2040 Area (ha)
Small scale (100 ha)	33,800	81,500	207,628
Medium scale (250 ha)	6,250	31,250	145,250
Large scale (750 ha)	2,250	12,750	62,250
Total	42,300	125,500	415,128

Source: JICA 2015.

Rwanda

Rwanda developed an Irrigation Master Plan (IMP) in 2010. The primary objective of the IMP is to develop and manage water resources; to promote intensive and sustainable irrigated agriculture; and to improve food security. The plan aims at full, efficient and sustainable exploitation of surface water (runoff, rivers and lakes) and underground water resources.

The history of irrigation development in Rwanda goes back to the 1940s although progress has been slow. About 300 ha of swamp land was brought under rice cultivation at two places in 1964 with Taiwanese aid. An additional 100 ha of swamp land was prepared for irrigation in 1968. Irrigation development efforts continued through many partner interventions until 1986. In 2003, the Government of Rwanda embarked on a swamp reclamation program under the Rural Sector Support Project (RSSP) funded by the International Development Association (IDA), with a focus on large-scale rice production. By the end of 2006, almost 11,000 ha of swampland had been reclaimed and used for rice production. As part of a detailed joint master plan study by the Ministry of Agriculture and Animal Resources, Ebony Company Limited and World Agroforestry (ICRAF) identified 589,712.7 ha of irrigable land area in Rwanda. Almost 20% of this area (125,627 ha) is intended to be developed by the World Bank in building small reservoir storage. However, the NBI-validated planned area in Rwanda is only 4,447 ha. It is clear Rwanda has more land that can be brought under irrigation than has been validated by NBI. This value, however, requires further validation and updating by studies in Rwanda.

Sudan

Furthermore, IMF (2013) recommended providing poor people whose livelihoods depend on land, water, forests and biodiversity secure access to these assets and creating circumstances under which they can manage the resources sustainably. Similarly, initiatives like the Agricultural Revitalization Program (ARP), Green Mobilization Program (GMP) and Revitalizing Sudan's Non-Oil Exports all contribute toward revitalizing agriculture in Sudan.

Therefore, given the decline in agricultural growth over the past two decades, the secession of South Sudan in 2011, the consequent loss of oil revenues and the subsequent downturn in the country's economy (FAO 2015a), Sudan's policy on irrigation development is likely to move toward expansion, encouraged by the recent positive efforts in liberalization and income generation activity. Furthermore, completion of the Grand Ethiopian Renaissance Dam (GERD) and its steady flow may present an additional opportunity to Sudan's farmers to engage more in irrigation activities.

In terms of the actual irrigation plan, the report 'Multipurpose Development of the Eastern Nile: One System Inventory Report on Water Resource Related Data and Information -- Sudan' (Ahmed 2006), submitted to the Eastern Nile Technical Regional Office (ENTRO), estimates the total extent of available irrigable land in Sudan to be of the order of 12,283,500 ***feddan***[1] (5,159,100 ha) (Table 5). As this data was collected before South Sudan seceded, it cannot be considered Sudan's plan alone. The NBI-validated planned irrigation area submitted by Sudan is of the order of 1.1 Mha (see Section 4.5, Table 11).

[1] 1 feddan = 0.42 hectares

Table 5. Planned irrigation area in Sudan.

No.	Summary of sub-basins	Cultivated area in 1000			Available
		2005	2015	2025	(potential)
1	The Blue Nile available area is 6,271.5 million feddan	3,107	5,061	5,224	6,271.5
	Revised for summation error (feddans) - no error	3,107	5,061	5,224	
	Revised area in 1,000 ha	1,304.9	2,125.6	2,194.1	
2	The White Nile available area is 1.791 million feddan	282	772	1,492	1,791
	Revised for summation error (feddans)a	830	1,397	1,896	
	Revised area in 1,000 ha	348.6	586.7	796.3	
3	Atbara available area is 1.361 million feddan	700	1,147	1,596	1,361
	Revised for summation error (feddans)b	492	982	1,742	
	Revised area in 1,000 ha	206.6	412.4	731.6	
4	Others—available area 2.860 million feddan	311	1,071	1,860	2,860
	Revised for summation error (feddans)c	311	1,071	1,860	
	Revised area in 1000 ha	130.6	449.8	781.2	
	Grand total area (feddans)	4,740	8,511	10,950	
	Revised grand total (feddans)d	4,740	8,511	10,722	12,283.5
	Revised grand total in 1,000 ha	1,990.8	3,574.6	4,503.2	5,159.1

Source: Ahmed 2006.

[a] The summation of the total planned irrigation in this row was not correct; therefore, revised and corrected.
[b] The summation of the total planned irrigation in this row was not correct; therefore, revised and corrected.
[c] The summation of the total planned irrigation in this row was not correct; therefore, revised and corrected.
[d] The summation of the total planned irrigation in this row was not correct; therefore, revised and corrected.

3. SUMMARY OF PHASE-I IRRIGATION DEVELOPMENT PROJECTION STUDY

3.1 NBI Future Irrigation Development Projection Study

The phase I study presents a combined scenario formulated for modeling of future development using a combination of a selected set of infrastructure development and climate change scenarios and levels of irrigation improvement represented by a percentage increase (see Table 2, NBI Technical Note IV). The approach for scenario definitions was developed in collaboration with the National Experts Group. As shown in Table 6, the irrigation part of the scenario takes into account the 'Full Development Scenario' and its variants (25%, 50% and 75% of Full Development) based on the future infrastructure projections supplied by the NBI member countries. A range of percentages of the 'Full Development Scenario' along with climate change and efficiency improvements considered in the phase I study are shown in Table 6. The basis of the variants of the projects are not explained, however. As part of this study NBI requires development scenario-based irrigation projections.

Table 6. Phase I projection scenarios Source: NBI 2015b, Technical Note IV.

Scen*	Climate	Infrastructure	Irrigation efficiency	Label
1	Baseline ensemble	Full development	Current level	future_00
2	Baseline ensemble	Full development	Current for existing + 50% New System	future_01
3	Baseline ensemble	Full development	Increased level 50% for all	future_02
4	RCP 4.5 and RCP 8.5	Full development	Current level	future_03
5	RCP 4.5 and RCP 8.5	Full development	Current for existing + 50% New System	future_04
6	RCP 4.5 and RCP 8.5	Full development	Increased level 50% for all	future_05
7	RCP 4.5 and RCP 8.5	25% development	Current level	future_06
8	RCP 4.5 and RCP 8.5	50% development	Current level	future_07
9	RCP 4.5 and RCP 8.5	75% development	Current level	future_08
10	Baseline ensemble	25% development	Current level	future_09
11	Baseline ensemble	50% development	Current level	future_10
12	Baseline ensemble	75% development	Current level	future_11

Notes:
*Scen = Scenario number; RCP - Representative Concentration Pathway.

4. PHASE II SCENARIO-BASED IRRIGATION DEVELOPMENT METHODOLOGY

4.1 Existing Irrigation Development and Baseline Data

The phase I study (NBI Technical Note II) indicated that the total area equipped for irrigation in the Nile Basin is about 5.37 Mha (NBI 2015a). The basis for this assessment was the baseline data used for irrigation projection in the phase I study. The baseline data has been updated as part of Technical Report I of this project (NBI 2020a). A summary of the 2018 baseline data is provided in Table 7 along with the 2015 NBI baseline data. The detailed country-specific data are presented in Annex A-1 through A-9 of the Technical Report I (NBI 2020a).

To improve upon the data presented in Technical Report I (NBI 2020a), a significant effort has been made to supplement the data so that it provides a sufficient base for the development of scenarios and future agricultural water demand in the Nile Basin. The use of very recent information – some of it as recent as 2018 – and various sources to verify previously available information makes the findings the best available information at the NBI's disposal to estimate water demands in the Nile Basin.

As shown in Table 7, the new cropped and irrigation-equipped area is about 8.7 Mha and 6.6 Mha, respectively, which represents a 37% (cropped) and 23% (equipped) weighted average increase over the 2015 data. This increase is consistent with global studies on irrigation growth in sub-Saharan Africa (FAO 2011). Such an increase over a three-year period is significant. However, this increase has not actually been verified through a field survey or any other means. It could just be due to improved data collection and reporting. The new baseline data have been used as the basis for future irrigation projection in the Nile Basin. The existing irrigation data for eastern DRC is not available and, as such, DRC was not included in the analysis.

Table 7. Data on cropped and irrigation-equipped area in the Nile Basin.

	2014/15 baseline data Area ('000 ha)		Updated 2018 baseline data Area ('000 ha)		Change from 2015 baseline (%)	
	Cropped	Equipped	Cropped	Equipped	Cropped	Equipped
Burundi	14.96	8.7	14.9	8.8	(0.50)	1.18
DRC		-	-			
Egypt	5,021	3,447.2	6,529.6	3,823.7	30.0	10.9
Ethiopia	134	91	455.4	547.4	239.9	501.5
Kenya	20	47.8	33.2	61.3	65.8	28.2
Rwanda	7	7	7.7	8.9	10.0	26.7
South Sudan	0.15	0.5	265.1	111.4	176,653.8	22,171.0
Sudan	1,146.7	1,764.63	1,381.3	Country	20.5	14.7
Tanzania	6	19.75	32.2	33.4	435.9	69.1
Uganda	9.7	9.7	14.7	21.2	51.7	118.5
Total	**6,359.51**	**5,396.08**	**8,734.1**	**6,639.8**	**37.3**	**23.0**

Source: Technical Report I: The Baseline Report (modified with data from the 2018 Baseline Report - component I of the project, NBI 2020a).

4.2 Identification of Potential Irrigation Area

The land suitability and mapping component of this study identified the maximum possible land suitable for irrigation based on established criteria. The suitability analysis and mapping are presented in detail in a separate technical report (Technical Report 2b; NBI 2020b). The report also compared the potential suitability data with other earlier data sets. As shown in Table 7, the differences in estimates of potential are mainly attributed to differences in the assessment methodology. Some studies consider only land resources, others consider land and water resources, and some others consider additional aspects such as economic viability and environmental characteristics as well. As elaborated in Technical Report 2b (NBI 2020b), the FAO (1997) assessed the 'physical irrigation potential' of Africa by evaluating the land and water resources along with irrigation water requirements. The current land suitability classification avoids eliminating land that is permanently unsuitable for reasons other than water supply. Technical Report 2b also presents the categories of suitable land that are currently under agriculture and non-agriculture purposes. Table 8 provides a comparison of the potential irrigable land and potential suitable land in the Nile Basin.

Table 8. Potential irrigable land and potential suitable land in the Nile Basin.

Country	Potential irrigable land (FAO 1997)	Potential suitable land (This Study, Technical Report 2b; NBI 2020b)
Burundi	80,000	162,909
DRC	0	487,817
Egypt	4,420,000	3,377,971
Eritrea	150,000	154,632
Ethiopia	2,220,000	7,969,455
Kenya	180,000	1,927,607
Rwanda	150,000	464,665
South Sudan		3,580,578
Sudan	2,750,000	20,086,802
Tanzania	30,000	4,273,263
Uganda	202,000	7,308,534
Total	10,192,000	49,794,233

Source: Technical Report 2b, NBI 2020b.

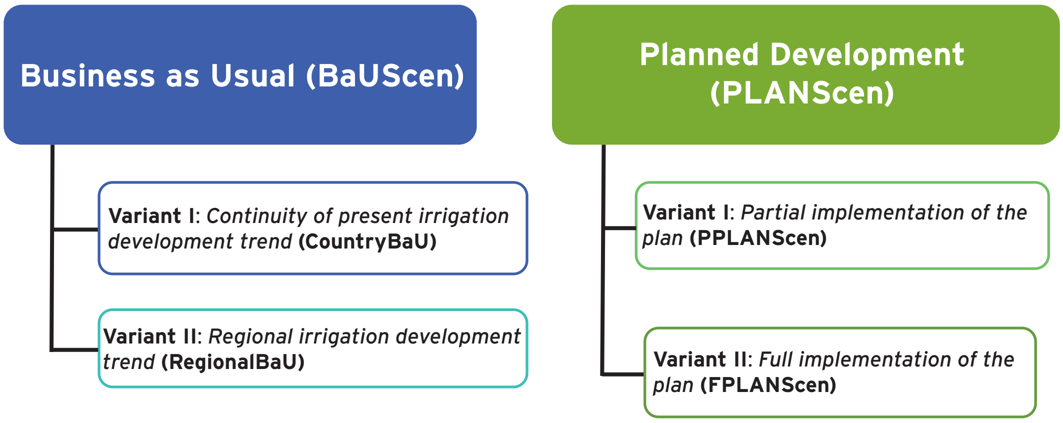
4.3 Description of Scenarios: General Conceptual Framework

Many Nile Basin (NB) countries have irrigation master plans, a fact that underscores their desire for future irrigation expansion to achieve food security and economic growth. Data compiled for Technical Report I of this project (NBI 2020a) indicate that many NB countries have already embarked on programs to expand irrigation. As shown in Section 4.1 above (Table 7), cropped and irrigation-equipped area expanded by 37% and 23%, respectively, over the 2015 base level. In terms of historical magnitude, the irrigation area of the upper Nile countries expanded from 50,404 ha in the 1980s to 823,173 ha in 2017/18 (Table 9), while the lower riparian countries Sudan and Egypt showed expansion from about 5 Mha to around 7.9 Mha. It appears that irrigation expansion will remain a key development direction for the NB countries, especially the upper riparian countries (see Section 2.1). However, in view of the political and socioeconomic history of the basin countries, the path and speed of irrigation development is uncertain and inconsistent.

Scenario analysis comprises a systematic approach to determine possible alternative future outcomes of the impact of socioeconomic growth, technology or development interventions. It is a prerequisite for preparedness and averting potential risks. Different fields of study provide slightly varying definitions of scenario analysis. Balaman (2019) summarizes scenario analysis as an approach conducted to analyze the impacts of possible future events on the system's performance by taking into account several alternative outcomes, i.e., scenarios, and to present different options for future development paths, resulting in varying outcomes and corresponding implications. The role of scenario analysis and planning is to look at various future states of a system operating under uncertainty and generate strategies to meet potential management challenges (Peterson et al. 2003). Scenario analysis can be used to estimate the behavior of the system in response to an unexpected event, and may be utilized to explore the changes in the system's performance in a theoretical best-case (optimistic) or worst-case (pessimistic) scenario. That is to say that the major objective is to analyze the results of the more extreme outcomes (with high probability and/or more severe impacts) (Bekessy and Selinske 2017). Stewart et al. (2007) identifies identify scenario analysis as the consequences of interactions among boundary conditions, driving forces and system components. Some of the important drivers at the center of scenario analysis are changes in policies, socioeconomic conditions, technology and the international trade regime. For instance, IPCC (2000) generates future greenhouse gas (GHG) emissions scenarios on the basis of plausible assumptions of socioeconomic driving forces such as demographic development, economic development, and technological change. Knox et al. (2018) considered the socioeconomic scenario drivers in their effort to develop future irrigated agriculture narratives for one watershed in the United Kingdom.

In the context of the Nile Basin (NB) countries, it is believed that rapid changes in socioeconomic drivers, especially in the upper riparian countries, have not significantly affected agricultural productivity or irrigation. Despite five-fold population growth in the NB since the 1950s (UN DESA 2015), cereal productivity over the last 20 years or so has almost stalled. Except for Egypt, where cereal yield has been steadily increasing and reached more than 7 tonnes/ha, cereal productivity in all other riparian countries has been in the range of 0.6-2.2 tonnes/ha (Omiti et al. 2011; World Bank 2020). Similarly, population increase and drought in the basin have acted as constraints to significant irrigation expansion or improved food security in the NB countries. For instance, the droughts of the 1980s and 2003 in Ethiopia have not led to enhancement of irrigation development activity. As of 2015, only 3% of the crop production in Ethiopia came from irrigated agriculture (FAO 2015c). The NB countries are the lowest in the Global Food Security Index ranking and have a significant food shortfall (The Economist Intelligence Unit 2018). Siderius et al. (2016) indicate that the contribution of irrigated agriculture to food security in many upper riparian countries is almost nil. This phenomenon is related to the question of affordability and the lack of irrigation technology. Hence, socioeconomic drivers, advancement of technology, climate change or other drivers have not significantly contributed to irrigation expansion compared to the magnitude of the expansion of the impacts of these drivers. Expansion of rainfed agricultural land that still has low productivity has been the main response to the growth of socioeconomic drivers in these countries. This study focuses not on driver-based scenario projections but on implementation-based scenario analysis. As discussed in Section 2, the Nile Basin countries have nationally planned irrigation master plans/programs which for the most part are based on their implementation capacity and the enabling environment. Furthermore, IWMI and NBI agreed to develop implementation-based scenario analysis for irrigation projection in the Nile Basin based on practical considerations that were discussed with the stakeholders. Thus, this study proposes two possible implementation-based irrigation development projection scenarios to be used for the evaluation of the likely impacts on the water resources of the NB system. Figure 1 depicts the two scenarios with variants – the Business as Usual Scenario (BaUScen) and the Planned Development Scenario (PLANScen). The two scenarios are evaluated using the regional water resources modeling system, with and without water saving considerations. The water saving scenario analysis is presented as component III of the project.

Figure 1. Schematic flow diagram illustrating the proposed irrigation development projection scenarios and their variants.



4.4 Business as Usual Irrigation Development Scenario (BaUScen)

The Business as Usual Scenario[2] (BaUScen) is a scenario for future patterns of activity which assumes that there will be no significant change that will affect the current path of irrigation development. It attempts to construct the current irrigation development trend of Nile Basin countries based on their historical growth. Due to uncertainties in the nature of irrigation data, two variants of the BaUScen irrigation development projections are proposed (Figure 1):

i. Continuity of the present irrigation development trend, which is constructed on the basis of compiled existing irrigation data for each country; and

[2] Online Oxford Reference Dictionary – Available at https://www.oxfordreference.com/view/10.1093/oi/authority.20110803095538117 (accessed in March 2019).

ii. Regional Irrigation development trend, which FAO-Nile (FAO and NBI 2011) developed for each country based on past regional SSA analysis. The following section describes the facts and assumptions for these variants in detail.

4.4.1. Continuity of Present Country-Specific Irrigation Development Trend (Country BaUScen)

This variant assumes that the historical irrigation development trend in each basin country will continue in the sense of a long-term average, assuming that the ups and downs of development are lumped into an average computed trend. For this study, efforts were made to compile information on existing and past irrigation development trends from various reports and documents produced since 1989 (e.g., FAO and NBI 2011). Table 9 depicts historical and existing irrigation data for 1989, 1997, 2000, 2005, 2009, 2015 and 2018, including data generated by the current study. These data were used to calculate the rate of irrigation growth in each of the NB countries over the past 30 years. Though the data, which were compiled at different times, may have limitations as indicated earlier, they provide an indication of the progression of past irrigation development in these countries and in the region. The inconsistencies and credibility of this data in the light of current circumstances are discussed in Technical Report 1 (NBI2020a).

As it stands now, irrigation development, both in terms of the speed of expansion and the level of intensification, has not been homogeneous in the NB. In Technical Report 4, the irrigation water valuation study clustered the NB countries into four types: (i) Egypt intensive; (ii) Sudan semi-intensive; (iii) extensive highland; and (iv) extensive lake region. Against that background, for this variant NB countries are divided into two clusters[3], upper and lower riparian countries, mainly based on their past irrigation experience and prospects for future extension of irrigation development. Sudan and Egypt are included as the lower irrigation sub-region and the other the riparian countries are treated as the upper sub-region. The upper sub-region includes countries such as Burundi, DRC, Ethiopia, Kenya, Rwanda, Tanzania, Uganda; and the lower sub-region includes countries such as Sudan and Egypt. As shown in Table 9, the average rate of irrigation growth for Egypt and Sudan is less than 2.1%, and greater than 10% for the other countries. In both categories, the average rate of growth of irrigation development is considered in order to project future expansion. As can be calculated from Table 9, the average annual rate of irrigation growth for the upper riparian countries is of the order of 18% per annum. This is significantly high compared to the downstream countries Sudan and Egypt, which average 0.8%. The upper riparian countries start from a much lower base than Egypt and Sudan and as such the rapidity of their trend is to be expected.

The recently compiled existing irrigation areas in the Technical Report I (NBI 2020a) were taken as the baseline (2018) and used to project expansion of irrigation up to 2030. After 2030, similar to the case of Egypt, upper riparian countries are assumed to start focusing more on improvements in efficiency and water productivity. And irrigation development expansion is likely to be lower by half (FAO 2011) due to several factors. Surface water scarcity and rainfed agriculture productivity (discussed in Technical Report 3) enhancement are likely to be the drivers of this lowering of the rate of irrigation expansion. The decrease by half is not likely to happen sharply after 2030, but an average of the anticipated gradual decrease will take place at the beginning until expansion ceases toward 2050. Egypt has clearly stated that one of its strategies (Section 2) is to focus on irrigation modernization and efficiency improvement rather than expansion per se, and, as such, it is reasonable to assume that the annual land expansion rate of Egypt will be lower than that of Sudan after 2050. Therefore, the summarized annual irrigation development rate (Table 10) was used as BaUScen (variant I) to provide the indicative irrigation expansion in the NB.

[3] The two clusters are intended to limit erroneous trends resulting from the treatment of one country as a cluster. The four clusters suggested in Technical Report 4 take Ethiopia, Sudan and Egypt each as one cluster intended for economic analysis.

Table 9. Data on irrigation area (ha) in the Nile Basin countries as compiled from different sources since 1989.

Country	1989 (FAO)+	1997 (FAO)	2000 (FAO)	2005 (FAO)+	2009 (NBI)+	2015 (NBI)	2018 (This study)	% growth/ annum
Burundi	0	0	50	3,158	14,625	14,960	14,885	24.3
DRC	0	0	80	0	0	0	-	
Egypt	3,078,000	3,078,000	292,320	39,27,039	2,963,581	5,021,000	6,529,614	2.06
Ethiopia	23,160	23,160	32,100	14,171	90,769	134.000	455,421	35.01
Kenya	6,000	6,000	9,800	41,693	34,156	20,000	33,168	10.00
Rwanda	2,000	2,000	3,300	15,637	17,638	7,000	7,698	12.83
South Sudan	NA	NA	NA	NA	NA	150	265,131	
Sudan	1,935,200	1,935,200	1,930,300	1,156,747	1,749,300	1,146,700	1,381,337	0.27
Tanzania	10,000	10,000	14,100	130	475	6,000	32,154	49.90
Uganda	9,120	9,120	9,100	33,203	25,131	9,700	14,717	37.1
Upper riparian Countries	50,404	65,404	68,530	112,135	182,794	191,810	823,173	18.9
Lower riparian Countries	5,013,200	5,013,200	4,853,500	5,083,786	4,712,881	6,167,700	7,910,951	0.8
Nile Basin	5,078,604	5,078,604	4,922,030	5,195,921	4,895,675	6,359,510	8,734,124	1.3

+Data from FAO and NBI (2011).

Table 10. Projected average annual growth rate (%) in irrigation development in the Nile Basin.

Countries	2005/07-2030	2030-2050
Lower riparian countries[4]		
Egypt	0.80	0.40
Sudan	0.80	0.40
Upper riparian countries	18.00	9.00

Two important issues to note that may encourage irrigation development in the NB are: (1) the global demand for agricultural land; and (2) private-driven irrigation development. The current demand for agricultural land to produce more food in developing Africa has been reported as significant (Friis and Reenberg 2015). Many countries, particularly in the Nile Basin, appear to venture in the global land deal. For instance, Friis and Reenberg (2015) report that 27 countries in Africa have had land dealings with foreign companies, and of them Ethiopia, Sudan, DRC, Tanzania and Uganda stand out as key players. Though evidently irrigation is a significant element of this phenomenon, there is not much information whether all or part of the leased land will be developed through irrigation. Furthermore, if national irrigation policies are revised to encourage private involvement in the form of public-private partnership and facilitate loans and land grants to private companies, it will likely act as a stimulant to irrigation growth, especially in the upper riparian countries where there are large parcels of potentially irrigable land. In such a scenario, a trend of high irrigation growth in the upper riparian countries may not be unrealistic after all.

4.4.2. Follow Regional Irrigation Development Trend (Variant I)

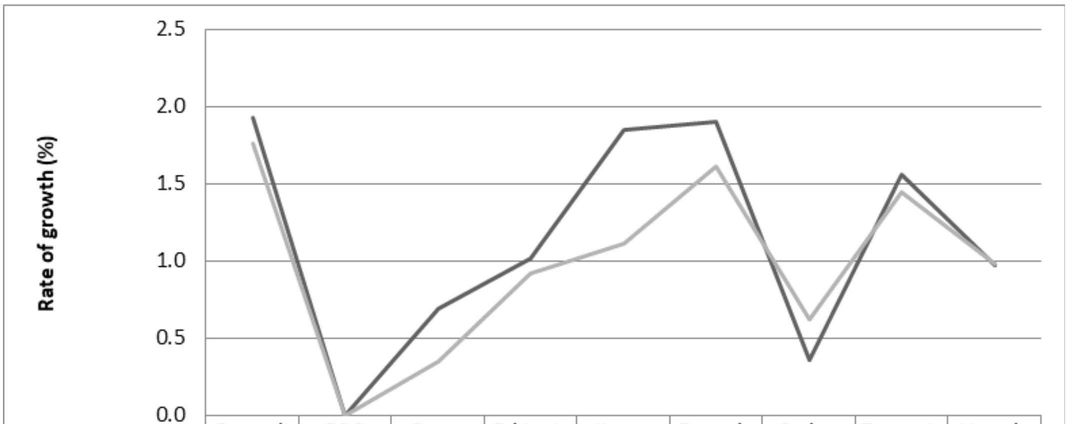
This variant of BaUScen assumes that irrigation development in the long run will continue to grow modestly, consistent with the current trend in sub-Saharan Africa. FAO and NBI (2011) presents irrigation development projections based on past growth trends, assuming that the baseline areas distributed across the basin will grow in line with the national projections done by FAO (the AT2030/50 project, 2006). That projection estimates an average basin irrigation growth rate of 1% per annum up to 2030 and 0.5% up to 2050,

[4] Note that irrigation expansion may be limited by water availability in the lower riparian countries specially Egypt.

consistent with sub-Saharan Africa projection estimates, with specific country variations which are shown in Figure 2. This does not necessarily mean that the growth trend will strictly accord to 1% and 0.5%, but it can be taken as a long-term average. Given the commitment of countries to reduce food insecurity and hunger (under Sustainable Development Goal [SDG] 2) by 2030, it is anticipated that rapid expansion of irrigation is likely to occur until 2030 and then slow down thereafter.

The FAO and NBI (2011) annual irrigation development projection is lower than that seen in variant 1 because the rapid increase of irrigation in many upper riparian countries (Ethiopia, South Sudan, Tanzania and Uganda) occurred after the projection was made. This shows high uncertainty in the projection of growth of irrigation development in the Nile Basin. However, it also gives us an opportunity to understand the low end of irrigation growth without any targeted policy intervention. Hence, it is included as part of this study. The recently compiled and 2018 updated current irrigation areas (Technical Report I; NBI 2020a) are used as a baseline to project irrigation expansion to 2030 and 2050 (see Section 4.1, Table 7).

Figure 2. Projections of the rate of growth (%) of irrigation development based on FAO-Nile historical trend in the NB countries.



	Burundi	DRC	Egypt	Ethiopia	Kenya	Rwanda	Sudan	Tanzania	Uganda
2018-2030	1.93		0.69	1.02	1.85	1.9	0.36	1.56	0.97
2030-2050	1.76		0.35	0.92	1.11	1.61	0.62	1.45	0.98

4.5 Planned Development Projection Scenario (PLANScen)

As discussed in Section 2, most of the NB countries have developed irrigation master plans or conducted integrated water resources management studies or developed some form of a strategic development agenda[5]. The master plan documents propose irrigation development plans, the details of which are shown in Table 11. As each country conducted its own study, had its own planning horizon and used its own methodology, each of the plans is different; so it is a challenging task to harmonize them to one projection period (2030 and 2050). For instance, the planning horizon of Uganda is 2035 (PEMConsult 2011), while Kenya has a plan until 2030 (JICA2013). Ethiopia currently follows a five-year planning cycle, and its Growth and Transformation Plan II runs to 2020 (NPC 2016). Furthermore, it was noted during the review period that different reports provide different planned irrigation areas (Table 11). In addition, it was not clear whether the planned areas verified and supplied to NBI by each country had a planning period at all. As a result, the planned areas stated by Burundi, Rwanda and Uganda are significantly lower than what is available. In this study, country-validated data on planned irrigation area supplied by NBI have been considered for consistency. It is also assumed that the NBI-verified area accords to a planning horizon of 2050.

[5] The master plan references and strategic documents are included as reference.

This scenario is different from the BaUScen in that it is based on a country's inventory of resources and is a reflection of that country's national policy ambition, including food security. This development scenario assumes that NB countries are determined to achieve Goal 2 of the SDGs, which requires them to meet national food security targets and reduce hunger by 2030. Accordingly, two variants of irrigation development projections have been considered to reflect the different emphasis on irrigation development depending on the urgency of food production in the region. The two variants of planned irrigation development scenarios are: (I) Partial Implementation (variant I); and (II) Full Implementation (variant II).

Table 11. Planned (target) irrigation development harmonized to 2030 and 2050.

Country	Planned (validated by NBI[a,b])	Planned (compiled by this study[c])	Planned[d]	Planned[e]
Burundi*	6,276		18,160	80,000
DRC	-		-	-
Egypt	529,400		502,196	-
Ethiopia	1,420,061		1,430,461	1,216,130
Kenya	66,682	277,764[f]	259,699	282,119
Rwanda*	4,447		50,000	589,712.7[g]
South Sudan	214,330		125,000	415,128
Sudan	1,117,800		1,130,400	-
Tanzania	50,677	27,460	45,140	-
Uganda*	4,048		233,177	582,928[h]

Notes:

*The NBI-verified areas for Burundi, Rwanda and Uganda are small compared to the master plan data.

[a] Excel data collected from NBI office.

[b] For Rwanda, Kenya, Tanzania and Kenya, the area is indicated as planned and for the rest of the countries, the planned area is indicated as cropped and equipped, and the equipped area is used in this table as planned.

[c] This study compiled planned irrigation area from master plans, IWMI and other previous studies.

[d] Awulachew et al. 2012 - medium term.

[e] Awulachew et al. 2012 - long term.

[f] Planned development until 2030 in JICA 2013.

[g] Maimbo et al. 2010.

[h] PEMConsult 2011.

4.5.1 Partial Implementation (Variant I)

Variant I of the planned development scenario assumes that NB countries are determined to achieve Goal 2 of the SDGs. However, due to financial and human resources limitations, some countries in the basin are working toward improving land productivity and expansion of rainfed agriculture rather than making heavy investments in planned irrigation development. Furthermore, studies indicate that utilizing the forgotten potential of rainfed agriculture with supplemental irrigation can contribute up to 75% of food production by 2025 (Siderius et al. 2016). Coupled with the lower investment requirement and recent worldwide assessments stressing intensification of existing irrigation areas rather than expansion to new areas, it is reasonable to assume that countries would likely focus more on investment to enhance rainfed agriculture than expand irrigation (e.g., Foley et al. 2011). The cost of rainfed agriculture intensification involves interventions such as high-yielding seeds, adequate supply of fertilizer, agriculture management, etc. This is a less costly option and more manageable in order to achieve food security by the target year of 2030. This does not imply that irrigation expansion will completely cease; it will continue at a slower pace than envisaged in the target development plan. It is probable that irrigation expansion will focus on drier and lowland fertile areas for both food security and economic growth. The NB countries' desire and implementation capacity cannot be objectively verified to assess how much planned irrigation can be developed until 2050. Nevertheless, it is reasonable to assume, under this variant I of PLANScen), that half of the planned irrigation area can be developed at the end of the planning period (Table 11). If we assume that half of the planned area is to be developed by 2030 and the remaining half by 2050, the annual rate of irrigation development will be 8.3% until 2030 and 5% beyond 2030 for the partial planned area.

4.5.2. Full Implementation Scenario (Variant II)

Variant II of PLANScen assumes that the NB countries are determined to achieve Goal 2 of the SDGs within the specified period. Apart from the drive to achieve Goal 2 (improving food security and reducing hunger), rapid population growth, climate change and dietary changes in the countries necessitate the need for expansion of irrigation development in the basin even beyond the planned irrigation development. Under this sub-variant of the scenario, it is assumed that countries will fully develop all irrigation areas planned by each country (Table 11).

5. SCENARIO ANALYSIS RESULTS, DISCUSSION AND RECOMMENDATIONS

5.1 Scenario Projection Results and Discussion

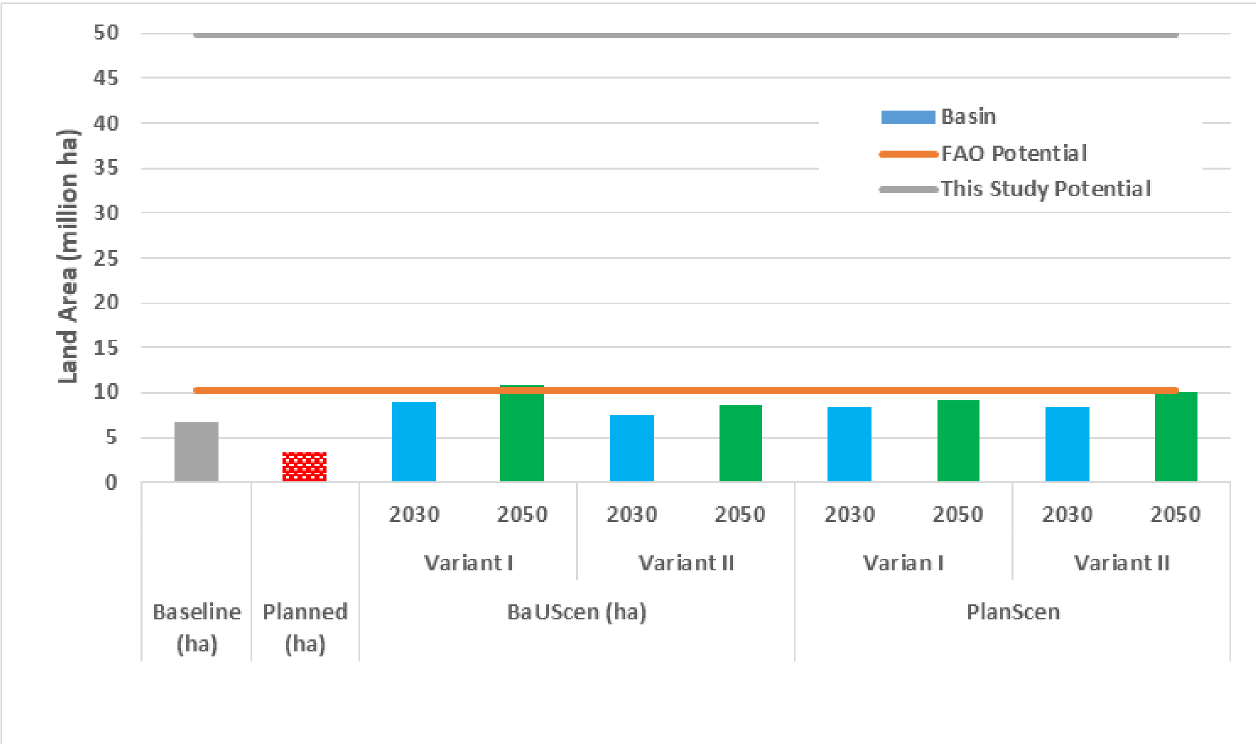
The results of the study to make future irrigation projections until 2050 are discussed on the basis of the two future scenarios: The Business as Usual Scenario (BaUScen) and the Planned Implementation Scenario (PLANScen). As described in Section 4.3, each Scenario carries two possible variants that have been developed based on a realistic understanding of regional studies. The results are discussed from a regional as well as national perspective and compared with the available potential land for irrigation. Figure 3 and Table 12 summarize the projected irrigation area as of 2030 and 2050. The individual projection scenario values are given in Tables 13 to 16.

Notably, variant I of the BaUScen is the rapid irrigation growth scenario relative to the other scenarios. It is intended to represent the recent ambitious irrigation expansion plans in the upper riparian countries. It would expand the current basin irrigation area from 6.6 Mha to 8.9 Mha by 2030 and to 10.8 Mha by 2050 (Table 12). This projection is within the limit of the potential suitable land for irrigation produced as part of this study (Technical Report 2b; NBI 2020b) but slightly exceeds the potential irrigable land projection of FAO (1997) by 2050 as shown in Table 12. Variant II of BaUScen and variant I of PLANScen have lower projections by 2030 and 2050 and are within the limit of potential suitable land produced as part of this study (Technical Report 2b; NBI 2020a), and that of FAO (1997). The full implementation of variant II of PLANScen would give the second highest possible expansion of irrigation area. Under this scenario, the current 6.3 Mha of irrigated area can be extended to 8.3 Mha by 2030 and 10.0 Mha by 2050, which is within the limits of both potential irrigation area boundaries. Figure 3 shows the projected area under the different scenarios and the potential area boundaries at the basin scale.

Except Egypt, no country's potential expansion scenario surpasses the potential irrigable area identified as part of this study (Technical Report 2b; NBI 2020b). The expansion scenarios of many countries exceed the FAO-identified potential irrigable area for 2050.

As a note of caution, the planned irrigation area for Burundi, Rwanda and Uganda, as reflected in the data supplied by them to NBI, is small in relation to potential. It is also significantly lower than the planned area in their respective master plans (see Section 4.5, Table 11). Future scenario studies need to include additional areas as planned in the master plan.

Figure 3. Total Nile Basin irrigation development projection and estimated potential (in million hectares).



5.2. Evaluation of Irrigation Projection Scenarios on Water Availability

The results of this projection study need to support the evaluation of the impact of irrigation expansion on water demand. The results need to be evaluated using NBI-integrated basin-wide modeling systematically with and without considering the proposed water saving scenario (see Technical Report3: Water Saving). Based on the final assessment, strategic policy recommendations will be developed and presented to the stakeholders. The following evaluation and analysis procedure will be pursued.

- First, the results of the four variants of the two projection scenarios are evaluated without considering the proposed water saving scenario. The unmet demands (water deficit) is assessed at the country level and on a regional scale. This helps to understand both the national- and regional-scale unmet demands.
- Next, each variant of the projected areas is run under different proposed water saving and efficiency improvement scenarios.
- Limited sensitivity analysis may be conducted to understand the spatial effectiveness of the proposed saving and efficiency improvement scenarios.
- Based on the final assessment and synthesis, strategic policy recommendations that will serve the NB countries will be developed and presented to the stakeholders.

Table 12. Summary of the results of scenario-generated projection of irrigated land (ha) by 2030 and 2050.

Country	Baseline or existing	NBI validated (2016/18)*	Business as Usual Scenario (BaUScen)				Planned Development Scenario (PLANScen)				Potential (FAO 1997)	Potential (This study, 2019)
			Variant I		Variant II		Variant I		Variant II			
			2030	2050	2030	2050	2030	2050	2030	2050		
Burundi	8,802	6,276	27,815	43,659	10,841	14,657	10,371	13,509	11,940	15,078	80,000	162,909
DRC											10,000	487,817
Egypt	3,823,736	529,400	4,190,815	4,496,714	4,140,342	4,430,166	3,956,086	4,220,786	4,088,436	4,353,136	4,420,000	3,377,971
Ethiopia	547,387	1,420,061	1,729,744	2,715,041	614,388	727,435	902,403	1,612,433	1,257,418	1,967,448	2,220,000	7,969,455
Kenya	61,257	66,682	193,572	303,835	74,856	91,474	77,928	111,269	94,598	127,939	180,000	1,927,607
Rwanda	8,868	4,447	28,023	43,982	10,890	14,396	9,980	12,203	11,092	13,315	150,000	464,665
South Sudan	111,355	214,330	351,881	552,320	116,165	130,570	164,937	272,102	218,520	325,685	150,000	3,580,578
Sudan	2,023,837	1,117,800	2,218,126	2,380,033	2,402,700	3,099,483	2,303,287	2,862,187	2,582,737	3,141,637	2,750,000	20,086,802
Tanzania	33,407	50,677	105,566	165,699	37,296	44,606	46,076	71,415	58,746	84,084	30,000	4,273,263
Uganda	21,190	4,048	66,960	105,102	22,817	24,780	22,202	24,226	23,214	25,238	202,000	7,308,534
Nile Basin	**6,639,840**	**3,413,721**	**8,912,503**	**10,806,385**	**7,430,294**	**8,577,566**	**7,493,271**	**9,200,131**	**8,346,701**	**10,053,562**	**10,192,000**	**49,794,233**

Source: Author's calculation.

Note: *For DRC, planned irrigation development data verified and supplied to NBI are not available.

Table 13. Summary of irrigation development projections (ha) based on Business as Usual Scenario (BaUScen) Variant I.

Country	Baseline 2016/18*	Annual growth rate (%), 2018-2030	Annual growth rate (%), 2030-2050	2030 projection	2050 projection	% increase 2018-2030	% increase 2030-2050	Potential (FAO 1997)	Potential (this study, 2019)
Burundi	8,802	0.18	0.09	27,815	43,659	216	57.0	80,000	162,909
DRC	-	0.18	0.09					10,000	487,817
Egypt	3,823,736	0.008	0.004	4,190,815	4,496,714	10	7.0	4,420,000	3,377,971
Ethiopia	547,387	0.18	0.09	1,729,744	2,715,041	216	57.0	2,220,000	7,969,455
Kenya	61,257	0.18	0.09	193,572	303,835	216	57.0	180,000	1,927,607
Rwanda	8,868	0.18	0.09	28,023	43,982	216	57.0	150,000	464,665
South Sudan	111,355	0.18	0.09	351,881	552,320	216	57.0	150,000	3,580,578
Sudan	2,023,837	0.008	0.004	2,218,126	2,380,033	10	7.0	2,750,000	20,086,802
Tanzania	33,407	0.18	0.09	105,566	165,699	216	57.0	30,000	4,273,263
Uganda	21,190	0.18	0.09	66,960	105,102	216	57.0	202,000	7,308,534
Nile Basin	**6,639,840**			**8,912,503**	**10,806,385**	**34**	**21.0**	**10,192,000**	**49,794,233**

Source: Author's calculation.

Note: *For DRC, planned irrigation development data verified and supplied to NBI are not available.

Table 14. Summary of irrigation development projections (ha) based on Business as Usual Scenario (BaUScen) Variant II.

Country	2016/18 Baseline*	Annual growth rate (%), 2018-2030	Annual growth rate (%), 2030-2050	2030 projection (ha)	2050 projection (ha)	0% increase 2018-203	0% increase 2030-2050	Potential (FAO 1997)	Potential (this study ,2019)
Burundi	8,800	1.93	1.76	11,008	15,076	25.09	36.96	80,000	162,909
DRC								10,000	487,817
Egypt	3,447,200	0.69	0.35	3,756,414	4,032,510	8.97	7.35	4,420,000	3,377,971
Ethiopia	594,400	1.02	0.92	673,217	803,283	13.26	19.32	2,220,000	7,969,455
Kenya	47,800	1.85	1.11	59,296	73,118	24.05	23.31	180,000	1,927,607
Rwanda	7,700	1.9	1.61	9,602	12,848	24.7	33.81	150,000	464,665
South Sudan	111,300	0.36	0.62	116,509	131,678	4.68	13.02	150,000	3,580,578
Sudan	2,049,200	1.56	1.45	2,464,778	3,215,303	20.28	30.45	2,750,000	20,086,802
Tanzania	30,100	0.97	0.98	33,896	40,871	12.61	20.58	30,000	4,273,263
Uganda	16,500	0.64	0.43	17,873	19,487	8.32	9.03	202,000	7,308,534
Nile Basin	**6,313,000**	**1.2**	**1.0**	**7,142,592**	**8,344,175**	**13.1410108**	**16.82278**	**10,192,000**	**49,794,233**

Source: Author's calculation.

Note: *For DRC, planned irrigation development data verified and supplied to NBI are not available.

Table 15. Summary of irrigation development projections (ha) based on planned scenario PLANScen, Variant I.

Country	NBI-validated, 2016/18*	Partial implementation plan by 2050	Annual growth rate (%), 2018-2030	Annual growth rate (%), 2030-2050	2030 projected		2050 projected		Potential (FAO 1997)	Potential (this study, 2019)
					Partial projected	Total with existing	Partial projected	Total with existing		
Burundi	8,802	3,138	0.042	0.025	1,569	10,371	1,569	13,509	80,000	162,909
DRC*									10,000	487,817
Egypt	3,823,736	264,700	0.042	0.025	132,350	3,956,086	132,350	4,220,786	4,420,000	3,377,971
Ethiopia	547,387	710,031	0.042	0.025	355,015	902,403	355,015	1,612,433	2,220,000	7,969,455
Kenya	61,257	33,341	0.042	0.025	16,671	77,928	16,671	111,269	180,000	1,927,607
Rwanda	8,868	2,224	0.042	0.025	1,112	9,980	1,112	12,203	150,000	464,665
South Sudan	111,355	107,165	0.042	0.025	53,583	164,937	53,583	272,102	150,000	3,580,578
Sudan	2,023,837	558,900	0.042	0.025	279,450	2,303,287	279,450	2,862,187	2,750,000	20,086,802
Tanzania	33,407	25,339	0.042	0.025	12,669	46,076	12,669	71,415	30,000	4,273,263
Uganda	21,190	2,024	0.042	0.025	1,012	22,202	1,012	24,226	202,000	7,308,534
Nile Basin	**6,639,840**	**1,706,861**			**853,430**	**7,493,271**	**853,430**	**9,200,131**	**10,192,000**	**49,794,233**

Source: Author's calculation.

Note: *For DRC, planned irrigation development data verified and supplied to NBI are not available.

Table 16. Summary of irrigation development projections (ha) based on planned scenario PLANScen, Variant II.

Country	NBI-validated, 2016/18*	Full planned implementation by 2050	Annual growth rate (%), 2018-2030	Annual growth rate (%), 2030-2050	2030 projection		2050 projection		Potential (FAO 1997)	Potential (this study 2019)
					Partial projected	Total with existing	Partial projected	Total with existing		
Burundi	8,802	6,276	0.083	0.05	3,138	11,940	3,138	15,078	80,000	162,909
DRC	-								10,000	487,817
Egypt	3,823,736	529,400	0.083	0.05	264,700	4,088,436	264,700	4,353,136	4,420,000	3,377,971
Ethiopia	547,387	1,420,061	0.083	0.05	710,031	1,257,418	710,031	1,967,448	2,220,000	7,969,455
Kenya	61,257	66,682	0.083	0.05	33,341	94,598	33,341	127,939	180,000	1,927,607
Rwanda	8,868	4,447	0.083	0.05	2,224	11,092	2,224	13,315	150,000	464,665
South Sudan	111,355	214,330	0.083	0.05	107,165	218,520	107,165	325,685	150,000	3,580,578
Sudan	2,023,837	1,117,800	0.083	0.05	558,900	2,582,737	558,900	3,141,637	2,750,000	20,086,802
Tanzania	33,407	50,677	0.083	0.05	25,339	58,746	25,339	84,084	30,000	4,273,263
Uganda	21,190	4,048	0.083	0.05	2,024	23,214	2,024	25,238	202,000	7,308,534
Nile Basin	**6,639,840**	**3,413,721**			**1,706,861**	**8,346,701**	**1,706,861**	**10,053,562**	**10,192,000**	**49,794,233**

Source: Author's calculation.

Note: *For DRC, planned irrigation development data verified and supplied to NBI are not available.

6. CONCLUSIONS AND RECOMMENDATIONS

Agricultural expansion, including irrigated agriculture, will remain a phenomenon of developing countries in the twenty-first century. Almost all agricultural expansion in the world (irrigation and rainfed) will take place in the developing countries. The bulk of this projected expansion is expected to take place in sub-Saharan Africa and Latin America. It is anticipated that irrigation expansion will also remain a phenomenon of the Nile Basin countries. The NBI Irrigation Assessment Report and the Technical Report I of this project showed a rapid increase of irrigation area in the recent history of the basin.

Policy and strategy documents, master plans and programs indicate that almost all upper riparian countries are desirous of expansion of irrigation to enhance their food security and foster economic growth and transformation. However, Egypt's desire is focused more on improving productivity and water-use efficiency than expansion of irrigation land. Sudan, on the other hand, showed renewed interest in irrigation expansion due to the loss of oil revenue as a result of the secession of South Sudan in 2011, and recognizing the recent positive advances of liberalization and income generation activity. It should be noted that all countries, except Burundi and DRC, have submitted their future irrigation development plans to NBI. The planned irrigation schemes shown in the respective master plans and reviewed documents submitted by countries are mostly different from what was submitted to NBI and verified. The basis of the scenario development of this study is the NBI-validated planned area and the baseline irrigation data compiled under the Technical Report I of this project.

This study proposed two possible implementation-based irrigation development projection scenarios: Business as Usual Scenario (BaUScen) and Planned Development Scenario (PLANScen). The results show:

- The BaUScen of variant I extends the current basin irrigation area from 6.6 Mha to 8.9 Mha by 2030 and 10.8 Mha by 2050. The projected area is within the limit of the potential irrigation suitable land as presented in the Technical Report 2b of this project and slightly exceeds the FAO (1997) potential irrigable land by 2050.
- At the basin scale, BaUScen (variant II) and the two variants of the Planned Implementation Scenario (PLANScen) are nearly within the limits of both the potential irrigation areas of this study and that of FAO (1997).
- The full implementation of variant II of PLANScen would give the second highest possible expansion of irrigation area. Under this scenario the current 6.6Mha of irrigation would be extended to 8.3 Mha by 2030 and 10.0 Mha by 2050, which is within the limits of both potential irrigation area boundaries at the regional scale.

REFERENCES

Ahmed, A.A. 2006. ***Multipurpose development of the Eastern Nile: One system inventory report on water resource related data and information -- Sudan.*** Khartoum, Sudan: Eastern Nile Technical Regional Office (ENTRO).

Alexandratos, N.; Bruinsma, J. 2012. ***World agriculture towards 2030/2050: The 2012 revision.*** Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). (ESA Working Paper No. 12-03).

Awulachew, S.B; Demissie, S.S.; Hagos, F.; Erkossa, T.; Peden, D. 2012. Water management intervention analysis in the Nile Basin. In: ***The Nile River Basin: Water, agriculture, governance and livelihood***, (eds.) Awulachew, S.B.; Smakhtin, V.; Molden, D.; Peden, D. London, UK: Routledge. pp. 292–310.

Balaman, S.Y. 2019. Uncertainty issues in biomass-based production chains. In: ***Decision-making for biomass-based production chains: The basic concepts and methodologies***, (ed.) Balaman, S.Y. Cambridge, Massachusetts, United States: Academic Press. pp. 77–112.

Bekessy, S.A.; Selinske, M.J. 2017.Social-ecological analyses for better water resources decisions. In: ***Decision making in water resources policy and management: An Australian perspective***, (eds.) Hart, B.T.; Doolan, J. Cambridge, Massachusetts, United States: Academic Press Inc. pp. 151–164.

FAO (Food and Agriculture Organization of the United Nations). 1997. ***Irrigation potential in Africa: A basin approach.*** Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). (FAO Land and Water Bulletin 4).

FAO. 2011. ***The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk***. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); London, UK: Earthscan.

FAO. 2015a. ***Plan of action (2015-2019): Resilient livelihoods for sustainable agriculture, food security and nutrition.*** Country Programming Framework for Sudan. Khartoum, Sudan: Food and Agriculture Organization of the United Nations (FAO).

FAO. 2015b. ***National investment profile. Water for Agriculture and Energy:*** Sudan. Khartoum, Sudan, and Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

FAO. 2015c. ***Ethiopia: Irrigation market brief***. Country highlights prepared under the FAO/IFC Cooperation. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

FAO; NBI (Nile Basin Initiative). 2011. ***Information products for Nile Basin water resources management: Synthesis report.*** FAO-Nile Basin Project GCP/INT/945/ITA 2004-2009. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

Foley, J.A.; Ramankutty, N.; Brauman, K.A.; Cassidy, E.S.; Gerber, J.S.; Johnston, M.; Mueller, N.D.; O'Connell, C.; Ray, D.K.; West, P.C.; Balzer, C.; Bennett, E.M.; Carpenter, S.R.; Hill, J.; Monfreda, C.; Polasky, S.; Rockström, J.; Sheehan, J.; Siebert, S.; Tilman, D.; Zaks, D.P.M. 2011. Solutions for a cultivated planet. ***Nature*** 478(7369): 337–342. https://doi.org/10.1038/nature10452

Friis, C.; Reenberg, A. 2010. ***Land grab in Africa: Emerging land system drivers in a tele connected world***. Copenhagen, Denmark: The Global Land Project (GLP)-International Project Office (IPO). (GLP Report No. 1).

IMF (International Monetary Fund). 2013. ***Sudan: Interim poverty reduction strategy paper***. Washington, DC, USA: International Monetary Fund (IMF). (IMF Country Report No. 13/318). Available at https://www.imf.org/external/pubs/ft/scr/2013/cr13318.pdf (accessed on June 26, 2020).

IPCC (Intergovernmental Panel on Climate Change). 2000. ***Emissions scenarios: A special report of Working Group III of the Intergovernmental Panel on Climate Change***. Cambridge, United Kingdom: Cambridge University Press.

JICA (Japan International Cooperation Agency). 2013. ***The project on the development of the National Water Master Plan 2030: Final report—Volume I executive summary.*** Nairobi, Kenya: Ministry of Environment, Water and Natural Resources, and Water Management Authority.

JICA. 2015. ***Irrigation development master plan (IDMP): Water sector.*** Juba, South Sudan: Ministry of Electricity, Dams, Irrigation and Water Resources, Republic of South Sudan. (Final report).

JICA. 2018. The project on the revision of the national irrigation master plan in the United Republic of Tanzania: Final Report. Vol. I Main Report. Dodoma, Tanzania: National Irrigation Commission, Ministry of Water and Irrigation, United Republic of Tanzania.

Knox, J.W.; Haro-Monteagudo, D.; Hess, T.M.; Morris, J. 2018. Identifying trade-offs and reconciling competing demands for water: Integrating agriculture into a robust decision-making framework. ***Earth's Future*** 6(10): 1457–1470. https://doi.org/10.1002/2017EF000741

Maimbo, M.M.; Oduor, A.R.; Kipruto, C.; Nyolei, D.; Gachene, C.; Biamah, E.K.; O'Neil, M.; Miyuki, I.; Jephine, M. 2010. ***Rwanda irrigation master plan***. Nairobi, Kenya: World Agroforestry Centre (ICRAF) Water Management Unit; Ebony Enterprises Ltd (Israel); Ministry of Agriculture and Animal Resources, Government of Rwanda.

MALR (Ministry of Agriculture and Land Reclamation). 2009. ***Sustainable agricultural development strategy towards 2030.*** Cairo, Egypt: Ministry of Agriculture and Land Reclamation (MALR).

MoIC (Ministry of Planning and International Cooperation). 2012. ***Strategic framework for economic and social development plan until year 2022.*** Cairo, Egypt: Ministry of Planning and International Cooperation (MoIC).

NBI (Nile Basin Initiative). 2012. ***Assessment of the irrigation potential in Burundi, Eastern DRC, Kenya, Rwanda, Southern Sudan, Tanzania and Uganda: Final report.*** Entebbe, Uganda: Nile Basin Initiative (NBI).

NBI. 2015a. ***Technical Notes II: Baseline on hydraulic infrastructure in the Nile Basin.*** Entebbe, Uganda: Nile Basin Initiative (NBI).

NBI. 2015b. ***Technical Notes IV: Future scenario definition and summary of results, including climate change.*** Entebbe, Uganda: Nile Basin Initiative (NBI).

NBI. 2020a. ***The baseline report: Benchmarking irrigation performance and projection of irrigation water demand in the Nile Basin.*** Addis Ababa, Ethiopia: Nile Basin Initiative. (Technical Report I).

NBI. 2020b. ***The land suitability report: Benchmarking irrigation performance and projection of irrigation water demand in the Nile Basin.*** Addis Ababa, Ethiopia: Nile Basin Initiative (NBI). (Technical Report 2b).

NPC (National Planning Commission). 2016. ***Growth and transformation plan II (GTP II) (2015/16-2019/20). Volume I: Main text.*** Addis Ababa: Federal Democratic Republic of Ethiopia.

Omiti, J.; Ommeh-Natu, H.; Ndirangu, L.; Laibuni, N.M.; Waiyaki, N. 2011. Exploration of food security situation in the Nile Basin region. ***Journal of Development and Agricultural Economic*** 3(7): 274–285.

PEMConsult. 2011. ***A national irrigation master plan for Uganda (2010-2035).*** Kampala, Uganda: Ministry of Water and Environment. (Final report).

Peterson, G.D.; Cumming, G.S.; Carpenter, S.R. 2003. Scenario planning: A tool for conservation in an uncertain world. ***Conservation Biology*** 17(2): 358–366. Available at https://training.fws.gov/courses/alc/alc3194/resources/publications/scenario-planning/Peterson_et_al_2003.pdf (accessed on June 26, 2020).

Siderius, C.; Van Walsum, P.E.V.; Roest, C.W.J.; Smit, A.A.M.F.R.; Hellegers, P.J.G.J.; Kabat, P.; Van Ierland, E.C. 2016.The role of rain-fed agriculture in securing food production in the Nile Basin. ***Environmental Science & Policy*** 61: 14–23. https://doi.org/10.1016/j.envsci.2016.03.007

Stewart, S.; Mahmoud, M.; Liu, Y.; Hartmann, H.; Wagener, T.; Gupta, H. 2007. Scenario development for water resources planning and management. In: ***Changes in water resources systems: Methodologies to maintain water security and ensure integrated management: Proceedings of symposium HS3006 at IUGG2007, Perugia, Italy, July 2007.*** IAHS-AISH Publication 315. pp. 192–198.

The Economist Intelligence Unit. 2018. ***Global Food Security Index 2018: Building resilience in the face of rising food-security risks***. London, UK: The Economist Intelligence Unit. Available at https://foodsecurityindex.eiu.com/Home/DownloadResource?fileName=EIU%20Global%20Food%20Security%20Index%20-%202018%20Findings%20%26%20Methodology.pdf

UNDESA (United Nations Department of Economic and Social Affairs). 2015. ***World population prospects: The 2015 revision, key findings and advance tables***. New York, USA: United Nations Department of Economic and Social Affairs (UN DESA). (Working Paper No. ESA/P/WP.241).

World Bank. 2020. Search and share development data. Data catalog. Available at https://datacatalog.worldbank.org/ (accessed on June 26, 2020).

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