Nile Basin Initiative
Eastern Nile Technical Regional Office (ENTRO)

Nile Cooperation for Results (NCORE)

Climate Risk Assessment Study

Consultancy Service

By
Elfatih A B Eltahir

Report on
Strategy for Climate Smart Investment Planning

December 2014

Table of Contents

Summary

Here, we describe a strategy for climate-smart development incorporating climate adaptation measures as part of project investment planning. Based on the risks identified in the planning exercise described in an earlier report of this study, a specific set of adaptation measures are proposed here as potential elements of a climate smart development strategy. These measures include: (1) Incorporation of climate change considerations in the investment planning process; (2) Management strategies that aim to enhance performance of the system performance indicators considered, including operating roles and procedures in the countries of the Eastern Nile basin and proactive coping institutional strategies that reduce the impact of climate change on the performance indicators; and (3) Institutional strengthening, including training and capacity building strategies, monitoring systems upgrades, and regional coordination to mainstream CRA. Here, we propose that the investment planning process in the future should follow a methodology different than traditional approaches, in order to recognize and address the uncertainty about future climate change. The planning methodology should be modified such that we optimize the "expected" benefits, to be derived from the proposed investment. Expected value is defined here in a statistical sense that recognizes uncertainty about future hydrologic conditions. In carrying this climate risk assessment study, we consider two options, Renaissance dam: (640 masl), and (620 masl). These two options are compared in terms of flexibility and reliability under two scenarios of future climate conditions (wet, and dry). The main risk from climate change stems from the possibility of over-design of a dam project or an irrigation project by overestimating the availability of water in the future. Under such condition, the cost of investment may not be economically justifiable given the actual returns on investment. The other risk associated with climate change stems from the possibility of under-design of such project by underestimating the availability of water in the future. Under such condition, an opportunity is lost for optimally designing the project to fully utilize the added water resource due to climate change. We emphasize that the inherent uncertainty in any future climate scenario should necessarily favor investment plans where the options for investment are spread over future time. In this report, we propose 4 regional institutions that should be established, affiliated with ENTRO, to enhance the capacity of the region to adapt to climate change: (i) Eastern Nile Irrigation management Information System (ENIIS); (ii) Eastern Nile watershed Observatory for Climate change Detection (ENOCD); (iii) Eastern Nile Center for Regional Climate Prediction (ENCRCP); and (iv) Eastern Nile Carbon Trade Center (ENCTC).

1. Introduction & Background

The overall objective of the study is to develop and operationalize an analytical framework for integrating climate risks into the process of investment planning and management of the EN water resources. Such analytical framework for Climate Risk Assessment (CRA) could be used to guide water related investment in the EN and form the basis for climate screening for investment project and provide guidance to the development of climate smart strategies.

The specific objectives of the consultancy are:

(i) Customize the proposed Climate Risk Assessment (CRA) Methodology for the EN, with a set of Adaptation and Mitigation measures integrated as part of the show case to illustrate the effectiveness of the proposed methodology in promoting climate smart planning and climate resilient growth.

(ii) Address challenges facing the operationalization of the proposed framework, identify and prioritize future strategic directions for designing climate smart measures in the EN.

(iii) Strengthen the capacities of the EN national & regional institutions and their abilities to use the proposed analytical framework for climate risk assessment, as means for integrating adaptation and mitigation measures as part of the planning process.

(iv) Develop climate smart development strategies incorporating, interventions, impacts on indicators and prioritized options. This will be undertaken through assessment of current situation (information, institutions, infrastructure), identification of system sensitivity to historic conditions, establishing planning framework and carrying out capacity building and regional consultations at key stages of the study.

Here, in this report we describe a strategy for climate smart development mainstreaming climate risk adaptation and mitigation measures as part of project investment planning.

2.0 Planning Ahead: Climate Smart Development Strategy:

Based on the risks identified in the previous planning exercise, a specific set of adaptation measures will be proposed here as potential elements of a climate smart development strategy. These measures include:

(1) Incorporation of climate change considerations in the investment planning process. Modifications in the configurations of the investment will be discussed which may represent a feedback loop into the planning process to mitigate any negative impacts of climate change;

(2) Management strategies that aim to enhance performance of the system performance indicators considered, including operating roles and procedures in the countries of the Eastern Nile basin and proactive coping institutional strategies that reduce the impact of climate change on the performance indicators and

(3) Institutional strengthening, including training and capacity building strategies, monitoring systems upgrades, and regional coordination to mainstream CRA.

Indicators	**High GERD (135 meters)**		**Low GERD (115 meters)**	
	Dry	**Wet**	**Dry**	**Wet**
(A) Power from GERD	**High**	**Low**	**Medium**	**Low**
(B) Power from Rosairies	**Medium**	**Low**	**Medium**	**Low**
(C) Irrigation in Sudan	**Low**	**Low**	**Low**	**Low**
(D) Flow of Water to Egypt	**High**	**Medium**	**High**	**Medium**

Table I: Summary of the Results of the Analysis on the Impact of Two Climate Change Scenarios, under two Infrastructure Investment Scenarios.

High, Medium and Low refer to the level of sensitivity to Climate Change.

3.0 Incorporation of climate change considerations in the investment planning process:

In a traditional water resources planning exercise, different configurations of investment options (dams for hydropower, irrigation projects, etc) are screened and evaluated to determine which options, and at what sizes, to be recommended. This decision is constrained based on social and technical viability, and optimized for economic feasibility. In order to carry such exercise, we need to assume that certain climatic conditions and their associated hydrologic conditions would prevail in the future. For most water resources projects planned and executed up to now, planners made the assumption that observed past climate and hydrologic conditions at the site of development is the best predictor of the future conditions. The underlying assumption here is that the climate system is stationary, with no long-term change. In evaluating this system the economic benefit, B, from the investment option considered is related to the assumed future hydrologic conditions, H_1 ,

$$B = G\,(H_1) \qquad (1)$$

Where G is a unique deterministic function. H_1 is usually assumed equivalent to past hydrologic conditions, H_2. These benefits from the proposed investment is then compared to the anticipated cost, C. The return from investment measured in terms of (B – C), or B/C, is maximized using standard optimization techniques.

Recently, the realization of the serious potential for significant changes in the climate system at regional and local scales raised significant questions about the assumption, $H_1 = H_2$. Instead, it would be more rational to assume that H_1 should be based on climate model predictions of future hydrologic conditions, H_3, i.e. assuming $H_1 = H_3$. This assumption would indeed be quite justified if models predictions were sufficiently accurate to give enough credibility to the projected hydrologic conditions. Unfortunately, model projections will always be of limited accuracy and will exhibit significant uncertainty even when using the same model to make such projections. This uncertainty is amplified further by the fact that different climate models would not agree on the exact nature of the future hydrologic conditions.

Here, I propose that the investment planning process in the future should follow a different methodology that recognizes the uncertainty about future climate change. The planning methodology should be modified such that we optimized the “expected” benefits, E (B), from the proposed investment. Expected value is defined here in the statistical sense that recognizes uncertainty about future hydrologic conditions. The expected value is defined here to acknowledge the uncertainty about the benefits from the investment introduced as a result of the uncertainty in future hydrologic condition. In mathematical terms,

$$E(B) = \int G(H_1) \, . \, f_{H1}(h_1) \, . \, d\,h_1 \qquad (2)$$

Where $f_{H1}(h_1)$ is the probability density function that the random vector H_1, describing future hydrologic conditions, takes the specific scenario described by h_1. This probabilistic approach is the formal way to address the uncertainty in future climate scenarios. It requires quantification of the uncertainty about future climate conditions that assign different probabilities to different scenarios depending on our best estimate of how likely that scenario will be realized in the future. E (B) can then be easily compared to the cost C, or differenced (B-C), in order to screen and select the optimal investment option.

I would like to also propose that the inherent uncertainty in any future climate scenario should necessarily favor investment plans where the options for investment are spread over future time. For example, a series of two dams that are phased in such that one dam is built now and the other to be built in 10 years, is more favorable to one big dam to be built now in order to generate the same amount of energy as the two dams. The reason lies in the fact that the two dams cascade offers the opportunity to revaluate the feasibility of the investment in the light of the additional information that would be become available from the data collected in those 10 years, or so.

In general the main risk from climate change stems from the possibility of over-design of a dam project or an irrigation project by overestimating the availability of water in the future. Under such condition, the cost of investment may not be economically justifiable given the actual returns on investment. There is very little that can be done to remedy or to adapt to such situation. The other risk associated with climate change stems from the possibility of under-design of a dam project or an irrigation project by underestimating the availability of water in the future. Under such condition, an opportunity is lost for optimally designing the project to fully utilize the added water resource due to climate change. However, this situation can be remedied through further adaptation to climate change by introducing another dam as part of a cascade master plan, or by expanding the irrigation project.

3.1 Example: Renaissance Dam and Investment Planning Process in the Eastern Nile Basin:

In this study, the investment of Renaissance dam and hydropower project is deemed to be a reasonable candidate for analysis compared to any other option. This is the most significant development project in the Nile basin since construction of the High Aswan Dam in the 1960s. Hence for this study to remain relevant to current developments in the basin, this project is an obvious choice. The system performance indicators considered included:

(1) Hydropower generation in Renaissance,
(2) Irrigation agriculture in Sudan,
(3) Hydropower generation in Rosaries, and
(4) Contribution of the flow in Khartoum to the water supplied to Egypt.

In carrying a climate risk assessment study we considered two options: (i) Renaissance dam (640 masl); and (ii) Border dam (620 masl). The latter was the option considered before the announcement of the decision to choose the Renaissance dam option.

Energy Generated	Renaissance 640 Dam Energy Historical	Renaissance 640 Dam Energy Wet	Renaissance 640 Dam Energy Dry
Average over the 35 years (GWH/year)	15,880.00	18,790.00	12,650.00
Median or 50 % reliable energy (GWH/year)	15,585.00	15,585.00	12,570.00

Revenue from Energy Generated	Renaissance 640 Dam Energy Historical			Renaissance 640 Dam Energy Wet			Renaissance 640 Dam Energy Dry		
Rates Assumed	Low	Medium	High	Low	Medium	High	Low	Medium	High
Using Average Energy generated (Million $/year)	476	794	1,111	563	940	1,315	380	632	885
Using Median or 50 % reliable energy (Million $/year)	467	779	1,090	467	779	1,090	377	629	880

Energy Generated	Renaissance 620 Dam Energy Historical	Renaissance 620 Dam Energy Wet	Renaissance 620 Dam Energy Dry
Average over the 35 years (GWH/year)	13,000.00	15,500.00	10,550.00
Median or 50 % reliable energy (GWH/year)	13,260.00	13,260.00	12,830.00

Revenue from Energy Generated	Renaissance 620 Dam Energy Historical			Renaissance 620 Dam Energy Wet			Renaissance 620 Dam Energy Dry		
Rates Assumed	Low	Medium	High	Low	Medium	High	Low	Medium	High
Using Average Energy generated (Million $/year)	390	650	910	465	775	1,085	317	527	739
Using Median or 50 % reliable energy (Million $/year)	397	663	928	398	663	928	385	641	898

Table II : Performance of the two investment options GERD 620 and 640, under three climate scenarios (Wet, Historical, and Dry) conditions. Low, Medium, and High refer to the electricity rates assumed of 3c per KWh, 5c per KWh, and 7c per KWh respectively.

Regarding hydrologic conditions in the Nile basin, the future is quite uncertain. Both modeling exercises sponsored by the IPCC (CMIP3, and CMIP5) suggest that models do not agree even on the sign of the predicted changes in rainfall and river flow. Half of the models point to an increase while the other half point to a decrease in rainfall and river flow. Hence, in this study we took the approach of constructing two scenarios based on observed hydrologic conditions. We selected a dry (wet) decade and repeated its sequence to construct a dry (wet) scenario (See Planning Report).

If we apply the methodology discussed above in section 3 and equation 2 to the example of the Renaissance dam considered in this study, we consider only two options for the dam (620, and 640), and two scenarios for the climate. We assign a probability of 0.5 to the dry scenario and a probability of 0.5 for the wet scenario. We use the medium electricity rate of 5c per KWh. The annual benefits from the 620 and 640 options under historical flow, which would be the traditional way of carrying the analysis, are (650$M and 794$M). According to equation 2 the corresponding benefits for 640 and 620 options would be (0.5 x 775 = 0.5 x 527 = 651$M; and 0.5x940 + 0.5x 632 = 786$M). This analysis only slightly favors the 620 option, however the differences are too small to be practically significant. However the simple example illustrates how the climate risk analysis methodology can be applied. In a more comprehensive analysis, more scenarios can be considered, for example based on projections from a select group of credible Global Climate Models (GCMs). Such estimates of benefits B can then be compared to the cost C in order to decide on the optimal investment option.

The other consideration in comparing the two investment options is reliability as shown in table 2. Although the 640 option preserves its significant advantage in reliability, under wet climate scenario, as measured by the median energy generated. This advantage evaporates under the dry climate scenario. In fact the median energy generated under the dry climate scenario from the 620 option even exceeds slightly that generated from the 640 option, which may be due to enhanced losses due to evaporation. This difference in the level of reliability if the climate gets drier highlights the potential risk from over-design if the climate turns drier. On the other hand, the analysis on average energy generated suggests that the 640 option is suited to fully utilize any additional water that may be gained from a wet climate change.

Finally, I would like to emphasize the general conclusion discussed above regarding the climate-smart advantage of a master plan that includes the options for a cascade more than one medium to small dams, in comparison to one big dam. This advantage is inherent in the fact that we will indeed learn more precise knowledge about climate change as nations live into the 21st century; by collecting more observed data and building better models. Hence, a planning process that has discrete options that can be exercised in the future regarding expansion (or not) of hydropower generation facilities (or also irrigation schemes) is inherently more optimal in dealing with a problem such as climate change.

4.0 Climate Smart Management Strategies:

One major risk of climate change is the reduction in water flow to Egypt as a result of climate change. Due to its location downstream from the other Nile countries, Egypt is particularly vulnerable to climate change. This conclusion is particularly evident in the dry scenario of climate change. In both investment options of Border and Renaissance, the flow that would be exceeded 67% under the historical flow scenario, will now be exceeded only 50% of the time under the dry scenario. Under such conditions, the flow to Egypt will be reduced significantly. This impact of climate change could have significant impacts on hydropower generation as well as agriculture in Egypt.

In contrast to water flow to Egypt, hydropower generation in Rosaries and irrigation in Sudan are not as sensitive to climate change (See Table I). This difference in sensitivity is primarily due to the location, downstream from the GERD but upstream from the main users of the Nile water in Egypt.

Since electricity generated from hydropower is linearly proportional to flow, the only feasible adaptation of the energy sector to a reduced flow in the Nile is to develop other renewable energy sources such as hydropower and wind energy.

Renaissance (640)

	Percent Exceedance	
Climate Scenarios	4812 MCM/Month (Threshold Value)	5695 MCM/Month (Threshold Value)
Historical	66.6 (2/3)	33.3 (1/3)
Wet	66	35
Dry	49	19

Border (620)

	Percent Exceedance	
Climate Scenarios	4,700 MCM/Month (Threshold Value)	5,700 MCM/Month (Threshold Value)
Historical	66.6 (2/3)	33.3 (1/3)
Wet	70	38
Dry	49	17

Table II: Flow of Water to Egypt under Two climate Scenarios and Two Investment Options.

Here, we propose a new strategy for managing agriculture in the Eastern Nile basin, and especially in Egypt. We propose significant investment in improving agricultural productivity. The later is defined as

$$\eta_a = \eta_w \times \eta_c \qquad (3)$$

Where

η_a : Agricultural Efficiency, mass of crop produced per unit volume of water used.

η_w : Water Use Efficiency , volume of water transpired per unit volume of water used.

η_c : Crop Productivity, mass of crop produced per unit volume of water transpired.

Improvements in agricultural productivity can result in maintaining the same levels of crop production despite reduction in the volume of water available for agriculture. In my view the best win-win strategy to improve the capacity for adapting to climate change in the Nile basin is to invest heavily in improving agricultural productivity.

As illustrated in equation 3 above, there are two elements for any management strategy that seeks to improve agricultural productivity:

(i) Improvements in water use efficiency, which can be achieved by reducing water losses due to conveyance in channels, and application in the field;

(ii) Improvements in productivity, which can be achieved by increasing and optimizing the rate of application of fertilizers, better seeds, and use of pesticides.

As stated above improvements in agricultural productivity should have broad impacts creating desirable win-win situations. In particular

- Accelerate economic development, achieve food security despite of rapid population growth;
- Resolve emerging conflicts on water between different countries;
- Enhance capacity of African societies to deal with challenges of climate change.

5.0 Climate-Smart Institutions for Addressing Climate Change in the Eastern Nile:

In this section, we propose 4 regional institutions that should be established, affiliated with ENTRO, to enhance the capacity of the region to adapt to climate change.

5.1 Eastern Nile Irrigation management Information System (ENIIS)

The goal of ENIIS is enhancement of regional capacity for adaptation to climate change in the Nile basin through improvement of crop productivity, minimization of irrigation water losses and improvement in water use efficiency. Achieving this goal should help to alleviate water shortages in the event of decreased flow.

The proposed system consists of two components:

1. A network of monitoring stations (of order 10) distributed over the basin to monitor rainfall and other variables that can be used to estimate potential evaporation. The exact number and location of stations will have to be decided after careful analysis of the current and planned irrigation schemes in the region; and
2. A web-based information system that links together the stations and makes their data available in real time to potential users.

The proposed system should (1) be accessible to irrigation engineers in the basin countries to assist in their efforts to improve water use efficiency in irrigation schemes; (2) recommend methodologies on how to estimate irrigation requirements based on the observed local climate and crop type; (3) recommend optimal rates of application of fertilizers, and the mix of different types to suit different locations and different crops..

ENIIS is not meant to be the only effort by Eastern Nile countries to reduce irrigation water losses. Efforts by national institutions to reduce other losses due to aging infrastructure, water management practices should be enhanced, in addition to the ENIIS initiative.

ENIIS is modeled after California Irrigation Management Information System (CIMIS), please refer to CIMIS web site.

5.2 Eastern Nile watershed Observatory for Climate change Detection (ENOCD)

The goal of ENOCD is to establish and coordinate a monitoring network of flow, sediment flux, rainfall, temperature, and vegetation cover to enable documentation of the impact of climate change on the Eastern Nile watershed. The new observatory will consist of (i) enhancement and maintenance of existing networks of standard surface observations of rainfall, river flow, sediment loading, and surface temperature, (ii) incorporation and integration of new satellite data sets on rainfall and vegetation cover, and (iii) a web-based information system for data management and dissemination.

A similar observatory system, was introduced in other region of Africa, the Observatory for Environment and Sustainable Development of Senegal River Basin. Though the scale and general design of both observatories may not be very different, their goals and hence their specific designs are likely to be quite different. Unlike the Senegal observatory, ENOCD is proposed to enhance the capability for detection of climate change impact on the Nile basin.

5.3 Eastern Nile Center for Regional Climate Prediction (ENCRCP)

The goal of ENCRCP is reduction of uncertainty level about climate change predictions through local development and use of a new class of regional climate models; and through capacity building and education of young researchers from the Nile countries. The high level of uncertainty in predictions of future climate of Africa presents tremendous opportunity for young researchers looking to pursue a career in research related to the Nile water resources and climate change. There is an urgent need to motivate and inspire young minds to address this important and challenging issue.

5.4 Eastern Nile Carbon Trade Center (ENCTC)

The goals of ENCTC is (i) to develop the technical capacity needed in the three EN countries in order to engage the process of securing carbon credit for any new development activity in the region; and (ii) to recommend a specific methodology for water resources development projects in the Eastern Nile, on how to engage international institutions dealing with this topic. There is an urgent need for a focused effort from ENTRO to effectively address these two issues.

The Clean Development Mechanism (CDM) was established under the Kyoto Protocol. (Please see the reference list to learn more about CDM through their web site.) It allows approved projects in developing countries to earn Certified Emission Reductions (CERs) credits measured in tonnes of CO2. These CERs can then be sold to industrialized countries for use in accounting of their emission reduction targets. The CDM offers an opportunity for all the new hydropower projects on the Nile to obtain CERs. Nile basin countries should engage this process at the early stages in the planning of any new projects.

It is recommended that the role of ENTRO should focus on facilitation and capacity building at national and regional levels for:
(i) Using the existing CDM structure more efficiently;
(ii) Negotiation of better mechanism structure that enables better African participation in the future

	Broad Rational	Estimated Cost & Total period
(1) Eastern Nile Irrigation Management Information System (ENIIS)	Monitoring systems upgrade, win-win, regional coordination	Initial cost of $1M. operational cost of $300K /year for a period of 5 years: Total cost=$2.5M
(2) Eastern Nile watershed Observatory for Climate change Detection (ENOCD)	Monitoring systems upgrade; win-win,	Initial cost of $1M. operational cost of $300K /year for a period of 5 years: Total Cost=$2.5M
(3) Eastern Nile Center for Regional Climate Prediction (ENCRCP)	Training and capacity building, reduction of uncertainty in regional climate projections	Initial cost of $1M. operational cost of $1M /year for a period of 5 years: Total Cost=$6M
(4) Eastern Nile Carbon Trade Project (ENCTP)	Training and capacity building; regional coordination; improve access to climate opportunities	Initial cost of $200,000. operational cost of $500K /year for A period of 5 years: Total Cost= $2.7M

Table III: Proposed Regional Institutions, their Broad rational, and their Estimated Costs

Appendix: Data on the two options considered GERD 640 and 620

GERD 640:

Grand Ethiopian Renaissance Dam	
Country	**Ethiopia**
Location	**Benishangul-Gumuz Region**
Purpose	**Power**
Status	**Under construction**
Construction began	**April 2011**
Opening date	**July 2017**[1]
Construction cost	**$4.8 billion USD**
Owner(s)	**Ethiopian Electric Power Corp**
Dam and spillways	
Type of dam	**Gravity, Roller-compacted concrete**
Impounds	**Blue Nile River**
Height	**170 m (558 ft)**
Length	**1,800 m (5,906 ft)**
Reservoir	
Creates	**Millennium Reservoir**
Total capacity	**73×10^9 m^3**
Power station	
Commission date	**2018 (planned)**
Turbines	**16 x 375 MW Francis turbines**
Installed capacity	**6,000 MW(max. planned)**
Annual generation	**15,692 GWh Est**

Source EEPCO

Project cost is estimated to be 4.8 Billion USD.
About 3.4 Billion USD Civil work and 1.4 Billion USD H/E & M Equipment costs

GERD 620 (Same i*nstalled capacity)*:

Installed capacity is assumed to be the same as GERD 640 i.e 6000 MW
Storage 42.5 BCM
Source EN Power toolkit but values has been adjusted to account for the difference in installed capacity
Project cost is estimated to be 3.9 Billion USD.
About 2.6 Billion USD Civil work and 1.3 Billion USD H/E & M Equipment costs