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The Nile Water, Food and Energy Nexus – A System Dynamics Model

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EXTENDED ABSTRACT

Introduction

The Water, Food and Energy (WFE) are inextricably linked, and the WFE Nexus approach provides a transparent framework for investigating the trade-off and synergies among the WFE, without compromising the sustainability. It focuses on system efficiency rather than the productivity of the individual sectors. The Nexus is challenging in a transboundary river basin. As a result of the rapid population and economic growth in the riparian countries, each riparian country plans to utilise its own resources to meet the growing demand for WFE. This might lead to either more potential conflict or boost cooperation among the riparian countries [1]. That makes the Nexus is a relevant approach for addressing the WFE and the socio-economic dynamics in a transboundary river basin like the Nile River. The Nile basin is currently challenged by rapid population and economic growth that sparked new developments across the riparian countries to meet their growing WFE demands.

The Nile River, as shown in Figure 1, is one of the most complex rivers in the world because of its transboundary nature, i.e., its size, a variety of climates and topographies, and the high system evaporation losses. Several frameworks were used to evaluate the water resources developments and the management options in the basin, e.g. (Digna, et al.[2]; Guariso and Whittington [3]; and Wheeler et al. [4]), some of them could include the socio-economic drivers to the water system and provides an integrated framework to evaluate their impacts on the water system. However, these models could not address the socio-economic dynamics and the interlinkages among the water, food and energy. To date, a few numbers of studies stressed the WFE Nexus in the Nile basin, e.g. (Al-Riffai et al., [5]; Basheer et al.[6]; and Elgafy et al. [7]). However, the causal feedbacks, the interactions among the WFE, and the socio-economic dynamics were not considered in some of these studies, and the whole Nile River basin was not considered as well. An integrated approach is required to investigate the interactions among the WFE and the socio-economic dynamics in the basin. The modelling framework and the modelling approach used in the current study are explained below.

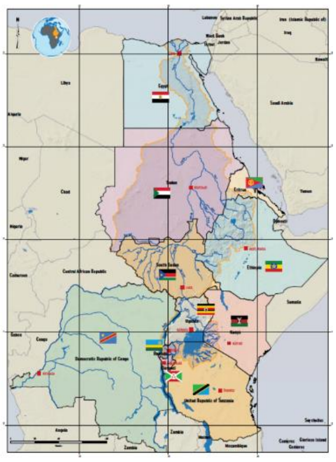

Figure 1. The Nile River

Methods and Materials

The modelling framework of the WFE and key socio-economic drivers are shown in Figure 2. A water balance for the entire Nile basin is integrated with the food production, through the agricultural land, and the energy through hydropower generation and energy use in water and food production (e.g. agriculture water, wastewater treatment). The Nexus components are linked with the socio-economic drivers to complete the framework and allow for investigating the socio-economic impacts on the WFE, and the synergies of the Nexus. System Dynamics Modelling (SDM) was chosen because of its ability to (a) address the broader interdependency and feedback among the Nexus components and the socio-economic dynamics, (b) provides a quantitative and qualitative platform to better understand the WFE Nexus interrelationships and the socio-economic dynamics without any additional packages. The model was built in Simile environment, which has a System Dynamics heart like other SDM software packages. The details of the water resources sub-model can be found here [8], while the complete WFE Nexus and socio-economic dynamics model developed for Egypt can be found here [9]. It was assumed that the input flows of the water resource sub-model for the period (1950-2014) are representative of the future Nile flows. 100 Synthetic flow series of the river inflows were generated using synthetic streamflow generator developed by Tsoukalas, I. et al. [10, 11]. The synthetic flow series are utilised to investigate the future of the WFE in the Nile basin

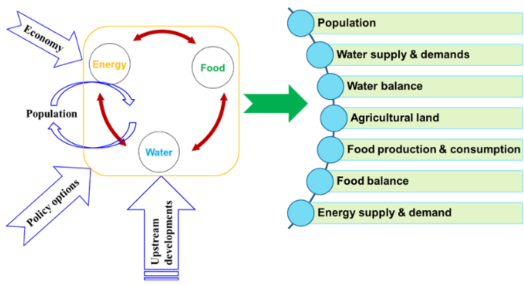

Figure 2. The modelling framework

and the planned developments in the riparian countries in the context of the WFE Nexus approach. The baseline scenario is developed first, in which the current status of the system has not changed in terms of water management, water demands and abstractions activities in the basin. For the complete WFE of Egypt, the demands were allowed to increase due to the population growth and agricultural land expansion. Future scenarios including new reservoirs and irrigation developments across the basin and their implications on the WFE in the Nile basin will be investigated. The results of the baseline scenario are presented here and shown below, and the extension of the current work is described in the next paragraphs.

Results and Discussion

The annual hydropower generation in the main regions for the base run scenario and the historical simulations are shown in Figure 3. While the average monthly supply to demand ratio of the irrigation in the main regions is shown in Table (1). It is noticeable that supply to demand ratio for Egypt under the baseline scenario will be reduced under the continuation of the current conditions, while the other regions showed a slight difference between the historical and the base run scenario.

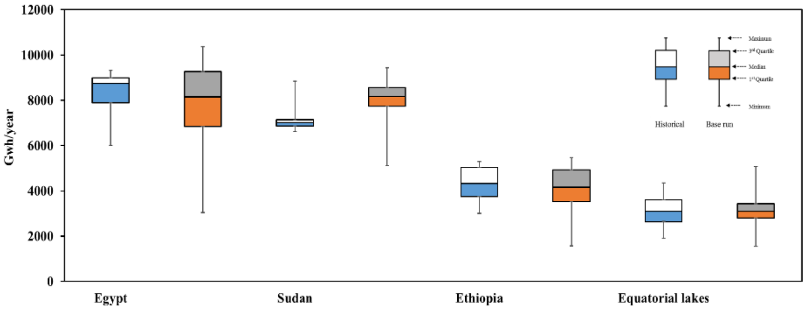

Figure 3. Annual hydropower generation

Table 1. Average monthly supply/demand ratio (%)

Region	Historical	Base run
Egypt	100	90
Sudan	98	99
Ethiopia	80	77
Equatorial lakes	95	94

Conclusions and Future Work

The developed model provides a framework that can be used to investigate the future of the WFE in the basin. The model showed a satisfactory performance and was able to capture the WFE, and the socio-economic dynamics [8, 9]. It will be used to investigate the planned developments in the riparian countries and their implication on the WFE in the basin. For example, it will be used to investigate different filling policies of the Grand Ethiopian Renaissance Dam (GERD) in Ethiopia (currently under construction) and the operation of the dam after filling the reservoir. The developed framework for the WFE and applied to Egypt showed a satisfactory performance and can be applied to the rest of the riparian countries in the same manner.

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