Limits to Population Growth and Water Resource Adequacy in the Nile River Basin

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Background

The Nile River is a critical source of water for Ethiopia, Egypt, and Sudan. Ethiopia, the region's most populous country and site of the largest water reserves, was left out of a 1959 agreement that divided the Nile between Egypt (75%) and Sudan (25%). Consequently, Ethiopia is currently barred from drawing any water from the Nile River for domestic use, even though 85% of the river's source originates in Ethiopia.

As agricultural production in Ethiopia expands to meet the demands of a growing population, it may eventually be forced to tap into its Nile reserves in a substantial way that impacts the water security of the two downstream countries of Sudan and Egypt.

In order for Ethiopia to sustain its growing population, it will inevitably require more water than its non-Nile sources can provide. This dynamic presents a serious potential for conflict in the region moving forward. Our study aims to identify when these potential conflicts are most likely to occur.

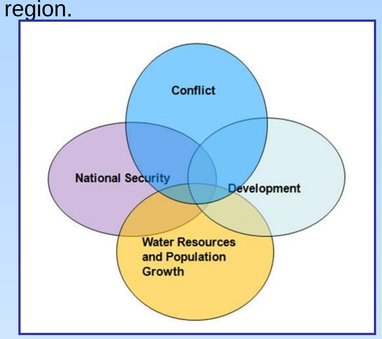
Problem Statement

The purpose of our study is to examine the potential limits to growth within Ethiopia, Egypt, and Sudan based on actual and projected estimates of population size and the adequacy of water resources between 1994 and 2100.

The Nile River flows from south to north along a 5548 km span. It consists of two channels: the White Nile and the Blue Nile. Because the Blue Nile accounts for roughly 85% of the total water flow, it is the primary focus of our model.

Literature Review

Our research has identified four primary spheres critical to an understanding of our problem statement: the relationship between population growth and water resource demand, the political and legal history of water usage in the Nile River Basin, economic development, and conflict and national security in the region, An understanding of the complex relationship between these four areas and the key stakeholders is essential to the development a robust and useful model for the region.



Methodology

Our model utilizes the Vensim software platform to create a system dynamics model that links population growth and Nile River flow.

The primary variables in our model are, for each country, the initial population, fractional birth and death rates, Nile flow data, and internal water resources independent from the Nile such as aquifers, lakes, and minor rivers.

Population statistics were gathered from the International Census Bureau databases from the year 1994 – 2012. The average birth and death rates during this period are used for each country, with minor adjustments made to factor in population changes due to factors not captured by birth and death rate.

Water data is drawn from the Food and Agriculture Organization of the United Nations and the Encyclopedia of Earth online database.

Population Growth Model

Population growth in each country is modeled using three causal loops (birth, death, and migration) tied together by the population stock. Comparing model population figures to actual data from 1994-2012 produces an R^2 correlation value of approximately 0.995 for each country.

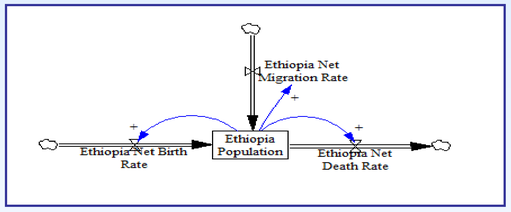


Figure: Ethiopia Population Model

Nile River Water Flow Model

The Nile River is modeled with a stock and flow system. Two source flows representing the Blue and White Niles represent the amount of water annually available from each source. These flows combine to form the stock Nile in Sudan, which in turn flows in to the stock for the Nile in Egypt and eventually empties in to the Mediterranean.

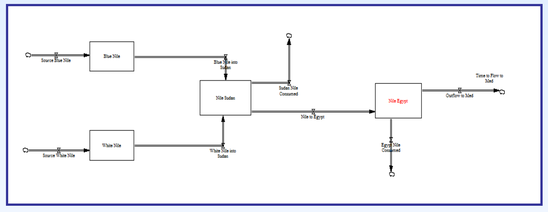


Figure: Nile Flow Model

Nile River Vensim Simulation

The population growth and Nile River flow models are integrated into a holistic simulation model of the basin.

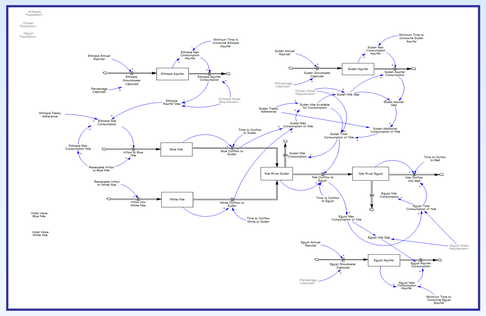


Figure: Integrated River-Population Model

Scenario Development

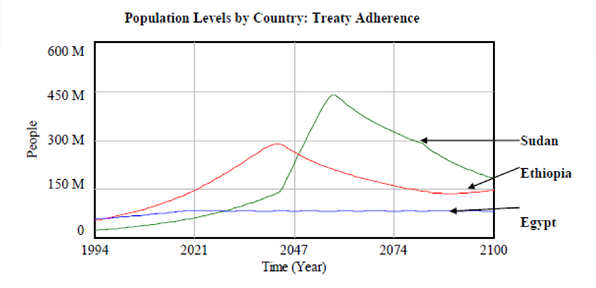
We examine regional limits to growth using three primary scenarios: strict adherence to the 1959 treaty limitations, relaxation of the treaty limitations, and an examination of desalinization as a potential source for conflict reduction.

Modeling Assumptions

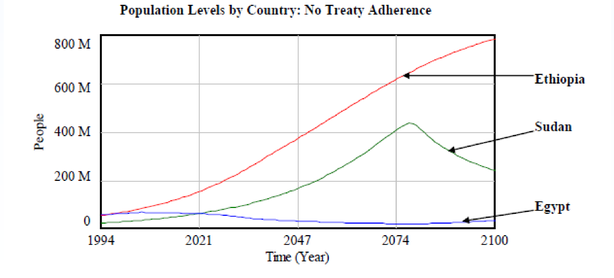
- Fertility and mortality rates remain constant
- Per capita water consumption levels remain constant
- Rechargeable internal water resources consist of 50% of the total annual rainfall across each landmass.
- Industrialization, agricultural development, and ecological factors such as pollution and river flow are held at constant levels.

Base Simulation Results

If the countries operate strictly under the treaty allocations, Ethiopia outgrows its internal water resources by mid-century, resulting in a dramatic reduction in its population. Clearly this result is untenable from Ethiopia's perspective.



By relaxing treaty restrictions, Ethiopia's population grows unabated to approximately 800 million by 2100, while Egypt's population is reduced by half from 2030-2100. Large internal water reserves sustain Sudan until the latter part of the century.



Desalinization

- Desalination, to meet Egyptian demand for water, must be able to scale with demand from .17 to 3.79 km^3 (one trillion gallons) per year through the latter half of the century.
- The world's largest current plant can produce 0.34 km^3 per year at a cost of $1.64 billion.
- To meet estimated demand, Egypt would require close to 14 plants of this capacity, at a minimum construction cost of $20 billion and a lead time of approximately 3 years per plant.
- Externalizing this cost through regional and international aid would ease the economic burden on Egypt and decrease the likelihood of conflict.

Conclusions

- A water crisis in the Nile River Basin is inevitable.
- Enforcement of 1959 treaty provisions is not feasible.
- The impact of this crisis can be attenuated only by reducing birth rates, reducing per capita water consumption, or increasing water supply.
- Desalination does not appear to be the "magic bullet" solution touted by some experts at present.
- Regional and international influence will be essential to keeping peace in the region. If past levels of basin wide cooperation are a reliable indicator, conflict is highly likely when regional actors are left to resolve the crisis on their own.