Impact of Climate Change on the Ecohydrology of the Nile River Basin

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Presentation Outline

- Introduction
- Upstream Catchment degradation
- Climate Change in the Nile
- Modeling tools
- Impact of climate change
- Adaptation strategies
Major threats in the Nile Basin

- Deforestation, Soil erosion - land degradation
- Climate Change
Impact of soil erosion

- Land and water degradation are the major issues in the Upper Nile due to deforestation and soil erosion.

- Poor land use practices and improper management systems have played a significant role in causing high soil erosion rates, sediment transport and loss of agricultural nutrients.

- Studies indicated that Ethiopia loses about 1.3 billion metric tons of fertile soil every year and the degradation of land through soil erosion is increasing at a high rate, Hurni (1989)
River flow with high sediment concentration
Degradation in water bodies due to hydrological and environmental changes
Emboch

- the top 250 lake regions of Global Importance for Biodiversity

- the aquatic biodiversity at extreme risk due to invasion of Emboch – Aquatic weed (water hyacinth)
Modeling Tools

- Soil water Assessment Tool – SWAT
- Generalized Environmental Modeling System for Surface waters (GEMSS)
- GIS based - Multi criteria Evaluation
SWAT (Soil water Assessment Tool)

- SWAT is a river basin scale developed to predict the impact of land management practices on \textit{water, sediment and agricultural chemical yields}

- The SWAT system (ArcSWAT), embedded within geographic information system (GIS), can integrate various spatial environmental data
GEMSS - Generalized Environmental Modeling System for Surface waters

- GEMSS is an integrated system of 3-D hydrodynamic and transport modules embedded in GIS.

- The hydrodynamic and transport relationships used in GEMSS are developed from:
  - the horizontal momentum balance,
  - continuity,
  - constituent transport and
  - the equation of state.
MCE-GIS tool for Decision support system

- Multi-Criteria Evaluation (MCE) is a method for decision support
  - number of different criteria are combined to meet one or several objectives.

- The decision was made after combination of four criteria (factor maps): Slope, Landcover, Soil types and River
GIS input files needed:
- the digital elevation model (DEM),
- land cover,
- soil layers

DEM
- delineate boundaries, stream network
- calculate average slopes

Land use, Soil and Slope layers
- to create and define Hydrological Response Units (HRU’s).
SOIL PHYSICAL PROPERTIES

- Number of layers in the soil
- Soil hydrologic group (A, B, C, D)
- Maximum rooting depth of soil profile
- Texture of soil layer
- Depth from soil surface to bottom of layer
- Moist bulk density
- Available water capacity of the soil layer
- Saturated hydraulic conductivity
- Organic carbon content
- Clay content, Silt content, Sand content
Meteorological Data
- precipitation
- air temperature
- solar radiation
- wind speed and
- relative humidity
Hydrological Data
- River Discharge and
- Suspended sediment load

Land Management
- Data for management practices such as planting, harvest, tillage operations, and pesticide and fertilizer application.
Time series of measured and simulated flow, Gilgel Abay
Sediment Yield Modeling

- The annual average simulated sediment yield was 28.7

- Calibration period:
  NSE=0.81,
  PBIAS=28 %,
  RSR=0.23 &
  R²=0.85

- Validation period:
  NSE=0.79,
  PBIAS=30 %,
  RSR=0.29 &
  R²=0.80

Comparison between measured and simulated monthly sediment yield
Erosion vulnerable areas in Lake Tana Basin, Ethiopia

SWAT = 18.4%

MCE = 25%
Climate change is a significant change in the statistical distribution of weather patterns over periods. e.g. weather conditions or the distribution of extreme events.
Climate Change

- By 2040 the share of people in the Nile region facing water scarcity could reach 35%. That’s more than 80 million people, *Coffel and Mankin 2020*

- 250 million people rely on the Nile for water that may not exist by 2080, Zoë Schlanger 2019
A major effect of climate change is alterations in hydrologic cycles and changes in water availability. Increased evaporation & changes in rainfall, has the potential to affect runoff, floods and droughts.
Assessment of impact of climate change

- Assessing the impact of climate change involves
  - Projections of climatic variables (e.g. precipitation, temperature) at a global scale.
  - Downscaling of global-scale climatic variables to local-scale hydrologic variables
Projected seasonal changes in rainfall

(a) Dry Season

(b) Wet Season

Decreasing rainfall trend
Projected seasonal changes in temperature

(a) Dry Season

(b) Wet Season

Increasing Temperature (0.6 – 2.8 C)
Variation among GCM outputs for different SRES - Precipitation/Rainfall
Impact of Climate Change on Water Resources
Lake Tana basin comprises an area of 15096 km$^2$

- The lake is a natural type
  - Average area = 3300 km$^2$
  - Maximum depth = 14 m.
  - Inflow Rivers are GilgelAbay, Ribb, Gumera, Megech
Impact of Climate Change on Surface and Ground Water 2046-2065
Hydrodynamics of Lake Tana - using Combined SWAT and GEMSS model
The velocity vectors in cm/s at the water surface, Feb. 10, 2006.
Temperature contours and the velocity vectors, section S5, January 2, 2006), legend color in °C.
Contours of dye concentration (mg/l) at the water surface December 31, 2006.
Adaptation strategies - Measures

- Appropriate catchment treatment strategies should be implemented
  - Watershed management methods like afforestation and water conservation are recommended to reduce the impact on the Blue Nile basin.

- Create an equitable water allocation scheme upstream and downstream countries.
  - “historical rights” – Egypt’s long-held claims need to be revised so that the needs of upstream countries like South Sudan and Ethiopia, which require water to build their economies, should be highly considered.

- Any intervention and planning strategies should highly consider the short and long-term climate variability and change.
Thank You!