East Africa Scenario

RESULTS

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Towards Innovative Solutions through Integrative Water Futures Analysis

WFaS Workshop, Entebbe, 4-6 Dec 2018
What can models tell us?

- The extended Lake Victoria Basin
- Biophysical drivers of hydrology
- Human water demand
- Socio-ecological water system characteristics
- Costs
The extended Lake Victoria Basin (eLVB)
The extended Lake Victoria Basin (eLVB)

The 61 sub-basins of the eLVB and their aggregation to 8 major basin regions
The extended Lake Victoria Basin (eLVB)

River network

61 sub-basins

Sub-basin connection
The extended Lake Victoria Basin (eLVB)

The 61 sub-basins of the eLVB and their aggregation to 8 major basin regions

Schematic sub-basin connection map

Major Basin Regions in the eLVB

- White Nile
- Semliki
- Victoria Nile
- LVB West
- LVB Simiyu
- LVB Mere
- LVB Kasera
- LVB Lake Victoria

- South Sudan
- DR Congo
- Uganda
- Kenya
- Rwanda
- Burundi
- UR Tanzania

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BIOPHYSICAL DRIVERS OF HYDROLOGY
Biophysical drivers of hydrology

- Elevation
- River network
- Climate
- Runoff
- River discharge

[Map showing various factors influencing hydrology]
Climate change

1st Story (of 2)

Climate Change and rainfall, runoff, river discharge
Precipitation change till 2050

Precipitation change based on:
- RCP 6.0
- Two Global Circulation Models:
  - HadGEM2-ES
  - MIROC5
- Hydro model: CWatM
- Periods of 10 years
  - 2006-2015 -> 2010
  - 2046-2055 -> 2050
Precipitation change till 2050

In general (but regionally different):
- Wetter rainy seasons
- Dryer dry season
In general (but regionally different):
- Wetter rainy seasons
- Dryer dry season
- Shift of the rainy seasons
In general (but regionally different):
- Slightly more runoff in April
Discharge change

Much higher in 2050 than in 2010! Why?
Discharge change

RCP 6.0: CWATM - Laropi station

Average discharge over 10 years
Climate change

1st Story (of 2)

Climate Change and rainfall, runoff, river discharge

- Important to look at monthly time scale
- Wetter rainy seasons
- Dryer dry season
- Shift of the rainy seasons
- Higher rainfall can nevertheless lead to lower runoff (due higher evapotranspiration)
- Less runoff but higher river discharge (storage of water in the lakes)
- High inter- and intra-annual variability
Land use – water use change

2nd Story (of 2)

Land use and water use change and river discharge
Discharge – land use & climate change

Climate change: RCP 6.0 – average of two GCM – dynamic
Land use: kept constant at year 2010
Water use: non

Vs. scenario 2

Land use: dynamic change from 2010-2050 - EA-RVS scenario

River discharge total eLVB at Laropi

Change in % from scenario 1 to 2
Discharge – land use & climate change

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Water use: non

Vs.

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Water use: dynamic change from 2010-2050 - EA-RVS scenario

River discharge total eLVB at Laropi
Land use – water use change

2nd Story (of 2)

Land use and water use change and river discharge

- Change in land use can lead to more discharge (due to less forest, more sealed area)
- Change in water use can lead to less discharge (more water consumption)
- Looking at land use and water use change at the same time: Land use change may counteract water use change
HUMAN WATER DEMAND
Human water withdrawal in eLVB 2010 to 2050

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
Distribution of human water withdrawal by sector

- **REF**: High water demand for domestic to cover high population growth
- **EA-RVS**: Higher share for agriculture to cover higher irrigation ambitions
- **Industrial water demand remains quite low with declining share**

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
Monthly irrigation water withdrawal for selected major sub-basins in 2050

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
Wastewater: discharge and treated

Source: IIASA WFaS East Africa (CWAT-ECHO model system)

- **REF**: More wastewater with less treated (only 50% by 2050)
- **EA-RVS**: Less wastewater with more treated (75% by 2050)
Water scarcity:
Water shortage based on WCI index

Water crowding index (WCI), Falkenmark index

Source: IIASA WFaS East Africa (CWAT-ECHO model system)

<table>
<thead>
<tr>
<th>Category</th>
<th>m³ per capita per year</th>
<th>People per 1 million m³</th>
</tr>
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<tbody>
<tr>
<td>no stress</td>
<td>&gt; 1700</td>
<td>&gt; ~ 600 (588)</td>
</tr>
<tr>
<td>Stress</td>
<td>&gt; 1000-1700</td>
<td>&gt; 1000 - ~600 (588)</td>
</tr>
<tr>
<td>Scarcity</td>
<td>&gt; 500 - 1000</td>
<td>&gt; 2000 - 1000</td>
</tr>
<tr>
<td>absolute scarcity</td>
<td>&lt;= 500</td>
<td>&lt;= 2000</td>
</tr>
</tbody>
</table>
Water scarcity: Water stress based on WEI index

Water exploitation index (WEI)
Water scarcity indicators in comparison

Water crowding Index (Falkenmark)
- Based on globally unified “water demand entitlements” (m³/person/year)
- High water scarcity signal for the eLVB basin as a whole and for many sub-basins

Water Exploitation Index
- In situ situation of potential water demand / water availability
- Rather low signal of water scarcity for eLVB and some sub-basins with severe scarcity

Expression for “economic water scarcity”?
- Simulated potential water demands remain below global averages of per capita consumption
- Much of the available water may not be accessed: actual water demand may be considerably lower than potential water demand by 2050
Potential further analysis

Where does irrigation development matter most?

IRRIGATION is the largest water user in the EA-RVS scenario.

The map shows current irrigated areas.
What can models tell us?

• The extended Lake Victoria Basin
• Biophysical drivers of hydrology
• Human water demand
• Socio-ecological water system characteristics (combining biophysical, human and economics)
SOCIO-ECOLOGICAL WATER SYSTEM CHARACTERISTICS

Combining the biophysical, human and economic dimension
Cost-efficient water withdrawals, EA-RVS

Water withdrawal development in the eLVB, by use sector and source

Scenario EA-RVS

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
Cost-effective water withdrawal to meet people’s water needs

### Scenario EA-RVS

<table>
<thead>
<tr>
<th></th>
<th>AGR 2010</th>
<th>IND 2010</th>
<th>DOM 2010</th>
<th>AGR 2030</th>
<th>IND 2030</th>
<th>DOM 2030</th>
<th>AGR 2050</th>
<th>IND 2050</th>
<th>DOM 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water</td>
<td><img src="EA-RVS_Surface_water.png" alt="Graph" /></td>
<td><img src="EA-RVS_Groundwater.png" alt="Graph" /></td>
<td><img src="EA-RVS_Wastewater_recycling.png" alt="Graph" /></td>
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</table>

### Scenario REF

<table>
<thead>
<tr>
<th></th>
<th>AGR 2010</th>
<th>IND 2010</th>
<th>DOM 2010</th>
<th>AGR 2030</th>
<th>IND 2030</th>
<th>DOM 2030</th>
<th>AGR 2050</th>
<th>IND 2050</th>
<th>DOM 2050</th>
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Legend:
- AGR: Agriculture
- IND: Industry
- DOM: Domestic

Graphs show cubic kilometers of water withdrawal for each scenario and sector from 2010 to 2050.
Potential further analysis

Yellow areas show regions of high environmental value as designated in the World Database of Protected Areas (WDPA).
[download from Oct 2018]

How would water allocation change if more emphasis were given to environmental flows?
River streamflow when considering people’s water needs

Discharge in LAROPI, 2010 – 2050, Scenario EA-RVS

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
COSTS

How much will it cost to meet people’s water needs?
# Annual costs, Scenario EA-RVS

<table>
<thead>
<tr>
<th>million $ / year</th>
<th>2010</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY costs</td>
<td>27</td>
<td>74</td>
<td>126</td>
</tr>
<tr>
<td>OPERATIONAL &amp; MANAGEMENT costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water reservoirs</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Waste water treatment (Recycling)</td>
<td>3</td>
<td>30</td>
<td>82</td>
</tr>
<tr>
<td>Surface water withdrawal (diversion)</td>
<td>343</td>
<td>842</td>
<td>1469</td>
</tr>
<tr>
<td>Groundwater withdrawal (pumping)</td>
<td>60</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>Wastewater re-use</td>
<td>11</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>TOTAL</td>
<td>444</td>
<td>975</td>
<td>1721</td>
</tr>
</tbody>
</table>

*Source: IIASA WFas East Africa (CWAT-ECHO model system)*
Investment costs, Scenario EA-RVS

Investment costs over 10-year periods in the eLVB

<table>
<thead>
<tr>
<th>million $ / year</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic / Industry sector</td>
<td>0</td>
<td>86</td>
<td>82</td>
<td>78</td>
<td>234</td>
<td>481</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>0</td>
<td>28</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>33</td>
</tr>
<tr>
<td>Irrigation systems</td>
<td>30</td>
<td>98</td>
<td>165</td>
<td>182</td>
<td>231</td>
<td>706</td>
</tr>
<tr>
<td>Water supply</td>
<td>0</td>
<td>261</td>
<td>574</td>
<td>784</td>
<td>1054</td>
<td>2672</td>
</tr>
<tr>
<td>TOTAL</td>
<td>30</td>
<td>473</td>
<td>822</td>
<td>1044</td>
<td>1522</td>
<td>3892</td>
</tr>
</tbody>
</table>

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
Annual costs in EA-RVS and REF

Annual costs for management & operation including energy

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
**Investment Costs in EA-RVS and REF**

Cumulative investment costs 2010-2050

<table>
<thead>
<tr>
<th></th>
<th>EA-RVS</th>
<th>REF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>400 mio</td>
<td></td>
</tr>
<tr>
<td>2040</td>
<td>300 mio</td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td>1,000 mio</td>
<td>1,200 mio</td>
</tr>
</tbody>
</table>

**Scenario EA-RVS**

- Management DOM & IND
- Reservoirs
- Irrigation systems
- Water supply

**Scenario REF**

- Management DOM & IND
- Reservoirs
- Irrigation systems
- Water supply

Source: IIASA WFaS East Africa (CWAT-ECHO model system)
Potential further analysis

Where in the eLVB will the costs for the water sector be incurred, in which sub-basins, in which countries?
NEXUS

Analysis across sectors
Energy – Water Nexus

Large-scale hydro-power stations

Current stations:
Nalubaale (180 MW), Kiira (200 MW)
Bujagali (250 MW)

From 2020 onwards:
Isimba (183 MW), Rusumo (80 MW)
Karuma (600 MW), Ayago (600 MW)

<table>
<thead>
<tr>
<th>1000 MWh</th>
<th>2010</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity for water services</td>
<td>550</td>
<td>1,625</td>
<td>3,048</td>
</tr>
<tr>
<td>Hydro-electric power production</td>
<td>3,137</td>
<td>14,464</td>
<td>13,572</td>
</tr>
<tr>
<td>Percentage used for water sector</td>
<td>18 %</td>
<td>11 %</td>
<td>22 %</td>
</tr>
</tbody>
</table>

Source: IIASA WFaS East Africa (CWAT-ECHO model system)