Water, Food and Energy security in Shared River Systems

Case study Eastern Nile Basin

Lars Ribbe

8th Conference on Sustainable Development of Energy, Water and Environment Systems

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Dubrovnik
Lars Ribbe

Research and Education in the area of „Integrated Land and Water Resources Management“
Outline

1. Sustainable Development and the NEXUS
2. Challenges in the Eastern Nile Basin
3. Outlook and Potential Solutions
1. NEXUS
The Future We Want: Outcome document adopted at Rio+20

Secretary-General Ban Ki-moon shares the future he wants

What kind of future do you want?
Challenge: „Understanding the Nexus“

Water, Energy and Food Security: Three pillars of sustainable development + social and political stability

*Today* 2012: 7 bn
No access to…
safe water: 0.9 bn, electricity: 1.5 bn, sufficient food: 1 bn

*Tomorrow* 2030: 8.5 bn?
Compensate for current deficit + account for additional demand:

→ Supply of around 40% water, energy, food additionally!
Overlap: impact (tradeoffs, synergies)

Increasing security in one sector may reduce security in another!
Water demand of food production

Reservoir construction and (irrigation) operation

Hydropower development

Water demands of energy production

Energy demands of water distribution and treatment

Energy demand of food production and processing

Biofuels
Required:
- Intersectoral Approaches
- Interdisciplinarity
- International Cooperation
- ...more research
Which system level/scale is appropriate?
River basin level

Boundary for a local water system within which

• ...water can only be used once for food production or other consumptive uses

• ...hydropower production impacts downstream users

• ...“natural boundary“...often basis for political boundaries, traffic grids, energy grids...
The basin as system boundary to analyze the NEXUS
Multiple users...adding complexity
(in particular if political boundary crosses basin!)
Scope and relevance of shared Basins

- Worldwide: 263 transboundary watersheds
- They represent
  - 40% of world population,
  - 50% of land area and
  - 60% of runoff

Why the Nile Basin?

• Large: 3 Mio km²
• Contested (scarce) resources
• Transboundary (11 riparians)
• Interesting: lower riparian „strongest“ country (vs Mekong, Euphrates...)
2. NILE BASIN
New “Treaty”: Cooperative Framework Agreement (CFA) 2010:

• “Disputed Nile agreement signed. Four African countries have signed a new treaty on the equitable sharing of the Nile waters despite strong opposition from Egypt and Sudan who have the major share of the river waters”  
  (Al Jazeera, May 15, 2010)

• “Egypt’s share of the Nile’s water is a historic right that Egypt has defended throughout its history”

• "Egypt reserves the right to take whatever course it sees suitable to safeguard its share"  
  (Mohammed Allam, Minister of Water Resources and Irrigation, Egypt April 18, 2010)
Egypt's dependency on the Nile water

Nile assures water, energy and food security:

- National food production through irrigation
- Significant hydropower production (Aswan): 14 out of 121 billion KWh
- Supply of whole population and industry with water
Does only Egypt depend on the Nile?
Production of Electricity from different energy sources in 2011

Egypt
- 89%
- 10%
- 1%

Ethiopia
- 99%
- 1%

Sudan
- 6%
- 47%
- 47%

1959:

Treaty between Egypt and Sudan after Sudan’s independence (1956) and Aswan Dam planning (1952): 55.5 BCM/year for Egypt, 18 BCM/year for Sudan, 10 BCM/year for seepage and evaporation.
The Enduring Tension

Just Egypt and Sudan!!
What about us ????
Nile Basin: A closer look

Basic Facts:

- 11 riparian countries,
- 160 (370) million people,
- 3.1 million km² (10% of Africa),
- Past of poverty and conflicts, recent strong economic development

Two main sub-basins:

- **White Nile**, Equatorial Lake (15%) and,
- **Eastern Nile**, Egypt, Sudan, Ethiopia

  - > 80% of area, 70% of population, 60% of cropland...80% of GDP

(Map: ITT 2013)
Nile Basin ...  
Topographic Zones:

1. **Lake Plateau**: Peaks 4,300 (m), slope gently
2. **Ethiopian Plateau**: Peaks 3,500 (m)
3. **North Sudan and Egypt**: Plain area < 400 (m)
Eastern Nile Basin

Issues on the ENB:

**Ethiopia**

- Generates 85% water reaching Egypt’s Aswan Dam
- Ethiopia only holds a limited “right” of exploration of the water resource
- Most populated riparian state
- New hydropower dams

(Map: ITT 2013)
Eastern Nile Basin

Issues on the ENB:

Sudan

- 97% of its water resource used in Agriculture sector
- 60% of Land Mass in Basin
- Sudd Swamp – Evap loss of >50% of all Water in White Nile
- South Sudan
Eastern Nile Basin

Issues on the ENB:

Egypt

- 96% of population live in Nile Delta/Basin
- Entirely dependent on Nile waters (Only 4% from underground reserves)
- Water stressed Country (700 m³/cap/y)
What will the future bring?
Water Demand

- Increasing water need for domestic use.
- Growing number of “water stressed” countries in the basin.

Water resources availability per capita (m³)

- Stress Level
- Scarcity Level

[Map of Freshwater Stress and Scarcity in Africa by 2025]

[Graph showing water resources availability per capita (m³) from 1990 to 2050 for Ethiopia and Egypt]

(FAO 2011)
Population 1980-2010 / UNDESA 2030 population prospects

- Egypt
- Sudan
- Ethiopia
Sudan

Total population with Unimproved Water (x1000)

World Bank, World Development Indicators, 2013
Ethiopia

Total population with Unimproved Water (x1000)

World Bank, World Development Indicators, 2013
Economic Development

Eastern Nile Countries

Economic Development
## Power Demand

### Demand Forecasts for 2005 through 2020

<table>
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<tr>
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<td>420</td>
<td>562</td>
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<td>18.8</td>
<td>6,417</td>
<td>9,550</td>
<td>14,212</td>
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<td>14.2</td>
<td>5,709</td>
<td>7,384</td>
<td>9,442</td>
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<td>14.3</td>
<td>3,003</td>
<td>4,134</td>
<td>5,559</td>
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<td>Total</td>
<td>105,607</td>
<td></td>
<td>135,750</td>
<td>181,603</td>
<td>241,057</td>
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(World Bank, 2004)
<table>
<thead>
<tr>
<th>Country</th>
<th>Dam</th>
<th>River</th>
<th>Year of Const.</th>
<th>Storage Capacity (BMC)</th>
<th>Purpose</th>
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<td>Commis.</td>
<td>Current</td>
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<td>Aswan High Dam</td>
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<td>162</td>
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<td>Sennar Dam</td>
<td>Blue Nile</td>
<td>1925</td>
<td>0.48</td>
<td>0.29</td>
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<td>White Nile</td>
<td>1937</td>
<td>3.50</td>
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<td>Khashm Elgirba Dam</td>
<td>Atbara</td>
<td>1964</td>
<td>0.617</td>
<td>0.37 (60%)</td>
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<td></td>
<td>Roseires Dam</td>
<td>Blue Nile</td>
<td>1966</td>
<td>2.12</td>
<td>1.59 (75%)</td>
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<td></td>
<td>Merowe Dam</td>
<td>Main Nile</td>
<td>2009</td>
<td>8.3</td>
<td></td>
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<tr>
<td>Ethiopia</td>
<td>Tekeze</td>
<td>Upper Atbara</td>
<td>2008</td>
<td>9.3</td>
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<td>Uganda</td>
<td>Owen Falls</td>
<td>Lake Victoria</td>
<td>1954</td>
<td>-</td>
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(Map: ITT 2013)
## Basic figures of Grand Renaissance (Millennium) Dam

<table>
<thead>
<tr>
<th>Description</th>
<th>Value (Units)</th>
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<tbody>
<tr>
<td>Total catchment area at dam axis (km²)</td>
<td>172,250</td>
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<tr>
<td>Reservoir surface area at full supply level (km²)</td>
<td>1,680</td>
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<tr>
<td>Storage capacity of the reservoir, Billion cubic Meter</td>
<td>63</td>
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<tr>
<td>Areal average rainfall of the catchment (mm/year)</td>
<td>1,230</td>
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<tr>
<td>Rainfall @ dam site (mm/year)</td>
<td>850</td>
</tr>
<tr>
<td>Net evaporation loss from Reservoir (mm/year)</td>
<td>1080</td>
</tr>
<tr>
<td>(After deducting rainfall on the reservoir)</td>
<td></td>
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<tr>
<td>Total Evaporation Losses (full supply); (km³)</td>
<td>1.84</td>
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<tr>
<td>Mean inflow to the reservoir from 1911-2003 (m³/sec)</td>
<td>1,547</td>
</tr>
<tr>
<td>Max. Hydropower capacity (MW) / net generation (GWh)</td>
<td>6,000 / 15,000</td>
</tr>
<tr>
<td>Starting date</td>
<td>April 2011</td>
</tr>
<tr>
<td>Completion date</td>
<td>July 2017</td>
</tr>
</tbody>
</table>

**Sources:**

1. Personal communication with personnel working on the dam project
3. Value adopted from calculated areal rainfall of upper Blue Nile
4. Adopted from near by meteorological station (Ethiopian Meteorological Agency)
5. [http://www.tigrainline.com/articles/article121230.html](http://www.tigrainline.com/articles/article121230.html)
Impacts vs benefits?

• Reduce water availability during filling
• Evaporation losses: 1.8 km³
• Relocation of 5,000-20,000 people
• Increased life span of downstream dams (sediment trap)
• Flow regulation upstream instead of Aswan lake
Nile Basin...

Land Use:

(ESRI Global map 2008)
Land use dynamics
Beles sub basin land cover changes

- Cultivation
- Grassland
- Forest
- Woodland
- Savanah
- Water

Woldesenbet, 2013
Hydro-meteorological Variability!
Long term climate change???

Annual river flow at Border

Data source: Ethiopian Ministry of Water Resources
3. Outlook and Potential Solutions
Hydropower Potential

Ethiopia's potential: 45 GW

(World Bank, 2004)
Potential Energy

• Develop Renewable Resources!
  – hydropower...considering the impacts - developing „sustainable hydropower“
  – Solar Energy, Wind energy?!

• ...realizing that energy efficiency is most potential energy source of the future
Food

• Crop production: far below optimum efficiency (more crop per drop!)
• Import staple food from those countries which produce it efficiently (import of virtual water),
• produce high value crops for export
Low crop productivity in Gezira Scheme is possibly due to mismanagement of irrigation water at the field level.

Water use efficiency for main crops in Gezira Scheme, Sudan (1970-2007)

Source: Sabry et al., 2013
Water use efficiency in nine irrigated wheat systems

Wheat yield from 1961 to 2011

Source: FAOSTAT 2013
Projection of harvested areas of the Nile basin (Ha)

Source: FAO 2011
<table>
<thead>
<tr>
<th>Dam Name</th>
<th>Country</th>
<th>Reservoir Capacity (km³)</th>
<th>Power Generation (MW)</th>
<th>Expected Opening Date</th>
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<tbody>
<tr>
<td>Baro multi-purpose dam</td>
<td>Ethiopia</td>
<td>NA</td>
<td>896</td>
<td>NA</td>
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<tr>
<td>Grand Renaissance Dam</td>
<td>Ethiopia</td>
<td>63</td>
<td>6000</td>
<td>2018</td>
</tr>
<tr>
<td>Karadobi</td>
<td>Ethiopia</td>
<td>32.5</td>
<td>1600</td>
<td>NA</td>
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<td>Mabil</td>
<td>Ethiopia</td>
<td>13.6</td>
<td>1200</td>
<td>2025</td>
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<td>Mendaia</td>
<td>Ethiopia</td>
<td>15.9</td>
<td>2400-2800</td>
<td>2030</td>
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<tr>
<td>Fifth Cataract – Shereyk Dam</td>
<td>Sudan</td>
<td>NA</td>
<td>350</td>
<td>NA</td>
</tr>
<tr>
<td>Second Cataract- Dal Dam</td>
<td>Sudan</td>
<td>NA</td>
<td>340-780</td>
<td>NA</td>
</tr>
<tr>
<td>Third Cataract – Kajbar Dam</td>
<td>Sudan</td>
<td>3</td>
<td>360</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Nile basin actual and natural water balance by river basin**

**Nile basin actual and natural water balance by country**
Potential: rainwater

• How much water falls on the basin?
  – ca $1800 \times 10^9$ m³

• How much water flows into Egypt?
  – ca $55 \times 10^9$ m³

• ...rainwater harvesting!

• Storing more rainwater - under ground, - in smaller reservoirs, - in soil ?!!
„smart storage“

Without any measures, urban flood

With increase infiltration, no flood and use water for dry season

Fig-1: Paul Pavelic, IWMI
**General Concept:**

Share the benefits resulting from the development of the water resources in order to satisfy the needs of the concerned populations.

**Transboundary Benefit Sharing:**

- A common management of water resources generates net benefits compared to the unilateral development of the water resources.

- The concept is about the cooperation of riparian states for the use, protection, or joint development of shared water bodies (transboundary rivers, lakes and aquifers), whereby the riparian states focus on the benefits from water cooperation and the win-win options instead of a potentially conflicting water sharing.

- Non-cooperation = economic losses
Future high voltage transmission lines?!
Opportunities

Hydropower

Protected Areas and Parks

Irrigation
Current Cooperation in the Nile Basin

• Established in 1999 to promote cooperation between all the Nile riparians (transitional)

• Goal: “Achieve sustainable socioeconomic development through the equitable utilisation of, and benefit from, the common Nile Basin water resources”

• *Modus operandi*: create enabling environment for the implementation of cooperative projects

• Strong support by international donors

• “NBI is a transitional arrangement until a permanent framework will be in place”
Towards Cooperation

- **Upstream**
  - Development

- **Downstream**
  - Equitable utilisation
  - Benefits-Sharing

Downstream

Upstream
The Water, Energy and Food Security Nexus

Research Focus of the Cologne University of Applied Sciences

The Nexus Research Focus aims at promoting scientific cooperation and developing joint projects and activities of participating institutes and faculties. The Nexus project is financed by the Cologne University.
Basin Case Studies developed together with partners of ITT
Learning from real life problems – Natural Labs

San Luis Potosí, MX
Closed Basin, Altiplano, floods and droughts, groundwater overuse

Limari, CL
Drought, basin vs field water use efficiency

Macacu, BR
Water Quality protection for urban drinking water supply

Gondar, ET
Rain-fed agriculture in Ethiopian highland

Gezira, SD
Optimisation of large scale irrigation

Azraq, IO
Closed Basin, groundwater RAMSAR wetland destruction

Baghmati, NP
Integrated river basin development

Vu Gia Thu Bon, VN
Coordinated Reservoir Management, Floods and Droughts

Semarang, ID
Coastal Zone and Urban Watershed Management

Wupper, DE
Information Systems for multi-purpose river basin management

Data ➔ Information ➔ Knowledge ➔ Action
Thank you for your attention!

Contact Information:
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Professor for Integrated Land and Water Resources Management,
Director of ITT, Cologne University of Applied Sciences
Additional Information
Research Overview of the Nile Basin Research group at ITT

- Scenarios on (future) water availability
- Water demand
- Basin water use / Base-line allocations
- Economic evaluation of water uses
- Alternative water allocation scenarios
- NBI - Institutional set-up for Cooperative development and benefit-sharing

- Downscaling of GCMs
- Remote Sensing
- Hydrological model
- Mike Basin
- SWAT, etc
- Agroclimatology / Agriculture (AquaCrop)
- Hydropower
- Households
- Industry

- Costs and benefits of development projects
- User value of water
- Intangible values of water
- Optimization models for transboundary water allocation

- Water rights issues and political interests
- National water policies vs regional integration
- Incentives for cooperation Partial vs. global coalitions

- Economic evaluation of water uses
- Alternative water allocation scenarios
- NBI - Institutional set-up for Cooperative development and benefit-sharing
References

1. UNEP 2000

2. World Health Organization


6. UNEP 1985

7. World Bank, 2004


Water Resources

(World Resources Institute, 2003)
# Existing Dams in the Eastern Nile Basin


<table>
<thead>
<tr>
<th>Dam name</th>
<th>Country</th>
<th>Crest Height (m)</th>
<th>Reservoir Capacity (km³)</th>
<th>Purpose</th>
<th>Power Generation (MW)</th>
<th>Operational Since</th>
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<td>16</td>
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<td>Irrigation/Flood control/Hydropower</td>
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<td>1970</td>
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<td>Egypt</td>
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<td>162</td>
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<td>1970</td>
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<td>Egypt</td>
<td>53</td>
<td>5</td>
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<td>592</td>
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<td>Tana Beles</td>
<td>Ethiopia</td>
<td>Run of river</td>
<td>-</td>
<td>Hydropower</td>
<td>460</td>
<td>2010</td>
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<td>Tekezze</td>
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<td>185</td>
<td>3</td>
<td>Hydropower</td>
<td>300</td>
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<td>48</td>
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## Irrigation and Food Security

### Farming areas in the Nile basin countries

<table>
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<tr>
<th>Country</th>
<th>Area (ha)</th>
<th>Area (% of total)</th>
<th>Population (1000)</th>
<th>Population density (inhab/km²)</th>
<th>Population (% of total)</th>
<th>Cropland (ha)</th>
<th>Cropland (% of total)</th>
<th>Cropland (% of area)</th>
<th>Cropland per inhabitant (ha/pers.)</th>
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<td>3 646</td>
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(WaterWatch, 2009)