Implementation of customized hydropower model for enhancing the hydropower generation in Tanzania

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Presented by Alberto Troccoli

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1. Introduction

- Tanzania, situated on the eastern coast of Africa, is bordered by Kenya and Uganda to the north, Rwanda, Burundi, and the Democratic Republic of the Congo to the west, and Zambia, Malawi, and Mozambique to the south.

- Its strategic location provides access to various rivers and water bodies, making it an ideal location for hydropower generation.

- Tanzania is blessed with numerous rivers, lakes, and water bodies, which contribute to its vast potential for hydropower generation.

- Tanzania is one of the few countries in Africa that has many transboundary water resources (14 in total).
Those transboundary water resources are part of the 9 Lake/River basins. Those 9 lake/river basins are

1. Pangani Basin
2. Wami/Ruvu Basin
3. Rufiji Basin
4. Ruvuma Basin
5. Lake Nyasa Basin
6. Internal drainage Basin
7. Lake Rukwa Basin
8. Lake Tanganyika Basin
9. Lake Victoria Basin

Among the 9 Lake/River basins 7 of them are transboundary while only 2 (Rufiji and Wami/ruvu) are not transboundary.

Rufiji is the largest Basin and most of the hydropower plants are located there.
Several studies have indicated that Tanzania is the country that has many areas where the small hydropower plants can be established.

Some of those studies include:

Ombeni J Mdee et al 2018 (as shown in the map)

Baraka Klchonge, 2018 (Indicated 75 small hydropower plant sites)
Despite of having many water resources with various promising area for establishing new hydropower plants but still the dependence of hydropower generation in Tanzania decreased from 96% in 2003 to 34% in 2015.

Initiatives in enhancing hydropower generation in Tanzania
As part of its initiative to enhance hydropower production, Tanzania is currently undertaking the Julius Nyerere Hydropower Project, which is expected to generate an impressive capacity of 2,115 MW. This project reflects Tanzania's commitment to expanding clean and renewable energy sources for sustainable development.
Despite of initiative taken in Tanzania; Tanzania’s hydropower sector is vulnerable to climate variability and change, highlighting the need for strategies that consider climate factors to ensure sustainability and resilience.

The Case study 6 under the FOCUS-Africa Project aims to develop a cutting-edge hydropower model that will incorporate climate parameter and hence better planning of the hydropower generation in Tanzania.

The hydropower model will focus on six main hydropower plants (Shown on the map with rectangle shape) with a data spanning from 2008 to 2022.
Hydro Power plants considered

<table>
<thead>
<tr>
<th>Hydropower plant</th>
<th>Installed capacity (MW)</th>
<th>Plant factor/ performance (%)</th>
<th>Annual generation (GWh)</th>
<th>Generation type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kidatu</td>
<td>204</td>
<td>31</td>
<td>558.34</td>
<td>Reservoir</td>
</tr>
<tr>
<td>Kihansi</td>
<td>180</td>
<td>50</td>
<td>793.49</td>
<td>Run-of-river</td>
</tr>
<tr>
<td>Mtera</td>
<td>80</td>
<td>24</td>
<td>166.68</td>
<td>Reservoir</td>
</tr>
<tr>
<td>Hale</td>
<td>21</td>
<td>20</td>
<td>36.11</td>
<td>Run-of-river</td>
</tr>
<tr>
<td>New Pangani</td>
<td>68</td>
<td>23</td>
<td>137.2</td>
<td>Reservoir</td>
</tr>
<tr>
<td>Nyumba ya mungu</td>
<td>8</td>
<td>31</td>
<td>21.53</td>
<td>Reservoir</td>
</tr>
</tbody>
</table>
The meteorological stations situated in the hydropower plant catchment area together with their rainfall and temperature annual cycle.
## Methodology

**SIMULATION OF HYDROPOWER GENERATION**

- **Hydropower generation data**
- **TANESCO discharge data**
- **Spatial aggregated precipitation (CHIRPS) and temperature (ERA5 Land)**
- **GIOFAS data**

**Input data for the hydropower model**

**Simulation of hydropower generation (Script)**

**Extracted data to the nearest grid point**

### Leave 1 out approach

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<tbody>
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<td>Training period</td>
<td>Predict 2008</td>
<td></td>
<td>Training period</td>
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<td>Training period</td>
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<td>Training period</td>
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<td>2011</td>
<td>Training period</td>
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<td>Predict 2011</td>
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<td>2012</td>
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<td>Predict 2012</td>
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</tbody>
</table>
Importance variable assessment
### Result and Discussion

#### Simulation using Precipitation and temperature

<table>
<thead>
<tr>
<th>Hydropower plant</th>
<th>simulation</th>
<th>Correlation</th>
<th>Root Mean Square Error (normalized)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kihansi (KHI) – RoR</strong></td>
<td>Round 1</td>
<td>0.8113</td>
<td>0.2074</td>
</tr>
<tr>
<td></td>
<td>Round 2</td>
<td>0.7646</td>
<td>0.2297</td>
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<tr>
<td><strong>Pangani (NPF) – RES</strong></td>
<td>Round 1</td>
<td>0.3582</td>
<td>0.5324</td>
</tr>
<tr>
<td></td>
<td>Round 2</td>
<td>0.35121</td>
<td>0.5473</td>
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<tr>
<td><strong>Kidatu (KDT) – RES</strong></td>
<td>Round 1</td>
<td>0.3505</td>
<td>0.28590</td>
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<tr>
<td></td>
<td>Round 2</td>
<td>0.3180</td>
<td>0.2944</td>
</tr>
<tr>
<td><strong>Mtera (MTR) – RES</strong></td>
<td>Round 1</td>
<td>0.3599</td>
<td>0.3468</td>
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<tr>
<td></td>
<td>Round 2</td>
<td>0.3704</td>
<td>0.3541</td>
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</tbody>
</table>

#### Simulation using all predictors listed in previous slide

<table>
<thead>
<tr>
<th>Hydropower plant</th>
<th>simulation</th>
<th>Correlation</th>
<th>Root Mean Square Error (normalized)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kihansi (KHI) – RoR</strong></td>
<td>Round 1</td>
<td>0.9942</td>
<td>0.0384</td>
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<td></td>
<td>Round 2</td>
<td><strong>0.9953</strong></td>
<td><strong>0.0346</strong></td>
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<tr>
<td><strong>Pangani (NPF) – RES</strong></td>
<td>Round 1</td>
<td>0.99095</td>
<td>0.0765</td>
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<tr>
<td></td>
<td>Round 2</td>
<td><strong>0.9911</strong></td>
<td><strong>0.0749</strong></td>
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<tr>
<td><strong>Kidatu (KDT) – RES</strong></td>
<td>Round 1</td>
<td>0.9945</td>
<td>0.0307</td>
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<tr>
<td></td>
<td>Round 2</td>
<td><strong>0.9953</strong></td>
<td><strong>0.0282</strong></td>
</tr>
<tr>
<td><strong>Mtera (MTR) – RES</strong></td>
<td>Round 1</td>
<td>0.9756</td>
<td>0.0865</td>
</tr>
<tr>
<td></td>
<td>Round 2</td>
<td><strong>0.9759</strong></td>
<td><strong>0.0847</strong></td>
</tr>
</tbody>
</table>
Hydro Power modelling results

KDT SIMULATED (ALL PREDICTORS) AND OBSERVED HYDROPOWER GENERATION

KHI SIMULATED (ALL PREDICTORS) AND OBSERVED HYDROPOWER GENERATION
Hydro Power modelling results

MTR SIMULATED (ALL PREDICTORS) AND OBSERVED HYDROPOWER GENERATION

NPF SIMULATED (ALL PREDICTORS) AND OBSERVED HYDROPOWER GENERATION

Hydropower generation (kwt)
Challenges and Limitations

• The performance of reservoir-based hydropower plants, such as Kidatu, Mtera, and Pangani, has exhibited shortcomings in simulating hydropower generation using precipitation and temperature data. It is plausible that these limitations arise from human operation.

• Nevertheless, the integration of river discharge data has yielded a remarkable enhancement in the simulation of hydropower generation.
• The presented hydropower generation simulation using the random forest model covered the period from 2008 to 2022.

• The next step is to produce seasonal forecast for hydropower generation:
  
  o This involves bias adjustment of weather forecast models using CDFt based on reference data from CHIRPS for precipitation and ERA 5 land for temperature.

  o This adjustment will improve the accuracy of hydropower generation forecasting and support informed decision-making in the renewable energy sector.
References


Thank you