Soft-linking climate-land-water-energy assessment and planning models for sustainable development in rural Africa: preliminary results from the LEAP-RE RE4AFAGRI project

Giacomo Falchetta\textsuperscript{1,2}, M. Awais\textsuperscript{1}, E. Byers\textsuperscript{1}, V. Giordano\textsuperscript{3}, G. Ireland\textsuperscript{4}, F. Semeria\textsuperscript{3}, M. Tuninetti\textsuperscript{3}, A. Vinca\textsuperscript{1}, and A. Zulu\textsuperscript{5}

1. IIASA - International Institute for Applied Systems Analysis, Laxenburg, Austria
2. CMCC, Venice, Italy
3. DIATI, Politecnico di Torino, Turin, Italy
4. University of Cape Town, Cape Town, South Africa
5. University of Zambia, Lusaka, Zambia
Background: rural SSA – WEFE Nexus challenges

Under baseline trends, most development gaps still open (or even larger) by 2030, together with a rapidly growing population (900+ million people by 2050, UN 2019 prospects)

- Rainfed agriculture and scarce electricity access
- Low productivity and raw crops to wholesale
- Poverty and inequality traps

Figures: Falchetta (2021)
Data: World Bank, FAO

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Study objectives

- Multi-sectoral **assessment and planning of technologies and policies** to promote integrated climate-water-renewable energy-agriculture sustainable development in rural areas
  - To inform **policymakers**
  - To support the creation of **robust business models** for private companies

- **Multi-scale focus**: local access to electricity and irrigation water; local system configuration and investment costs; up to macro consequences for financing energy and water supply technologies.

- Pilot implementation in **Zambia**, open modelling framework to **scale and replicate in other countries / basins**
The RE4AFAGRI modelling platform

Four models representing land-water-crop-food-energy requirements and dynamics (WaterCROP, M-LED, OnSSET and MESSAGE-NEST) are calibrated and soft-linked through the RE4AFAGRI platform.
## Scenarios and data

### Scenarios table

<table>
<thead>
<tr>
<th>Story/question</th>
<th>RCP</th>
<th>National goals</th>
<th>SSP</th>
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<tbody>
<tr>
<td>&quot;Baseline&quot;</td>
<td>RCP 7.0</td>
<td>Current policies&lt;br&gt;Agriculture: historical trend of production</td>
<td>SSP2</td>
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<tr>
<td>Improved access</td>
<td>RCP 7.0</td>
<td>Electricity access: halving the gap in 2030&lt;br&gt;Water access &amp; sanitation: halving the gap in 2030; Food security: increasing water supply to meet domestic food crops production demand in 2030 (given current diet, no extensification, fertilization, trade)</td>
<td>SSP2</td>
</tr>
<tr>
<td>Ambitious development, sustainable targets</td>
<td>RCP7.0 (SSP1, RCP2.6 on land)</td>
<td>Energy universal access, universal water access &amp; sanitation; nutrition security: improve yields to meet future food crop production demand to meet the EAT Lancet diet in 2030;&lt;br&gt;Renewable electricity share = 100% + climate constraints</td>
<td>SSP2</td>
</tr>
</tbody>
</table>

### Main input datasets
- ISIMIP3b climate data
- RCP-SSP: socio-economic development and climate projections
- MAPSpam 2017 SSA cropland extent
- IEA energy balances
- GRID3 population settlement extents
- OSM power grid geometry
- Global Solar & Wind Atlases (RES potential)
- MESSAGEiX database
- Additional data (see LEAP-RE deliverable 12.5)
Results – irrigation gap and needs

In Zambia, irrigation needs grow as a result of climate change (2020-2050 in baseline scenario), as well as due to increase of irrigated land (improved access scenario) and to close the irrigation gap (ambitious development scenario).

- Total water demand grows from 1,180 MCM/yr. in 2020 to 1,250 MCM/yr. in 2050
- Considerable within-country variability observed in sub-national river basin/administrative unit intersections, and shift in seasonality (intensification of peak demand).
Results – water pumping and crop processing energy

- Energy demand for water pumping is determined both by irrigation needs and by the local accessibility to groundwater/surface water resources.
- Currently, low demand as vast majority of cropland is rainfed...
- With irrigation expansion and climate change → growing demand

Seasonality of irrigation plays an important role in determining monthly variability in pumping energy demand.

- Crop processing energy demand is a function of crop yield and processed throughput
- Considerable energy demand growth driven by policies promoting energy access and local crop processing in the three scenarios
- Impact of crop yield change induced by climate change embedded.
Results – electricity demand (total)

- Electricity demand is currently concentrated in the capital city Lusaka and in the mining districts in the North-Western part of Zambia.

- Electricity demand will grow strongly and become less unequally distributed by 2050.

- Residential, commercial, and industrial demand will represent the bulk of the growth in electricity demand.

- Still, agricultural demand plays an important role in rural areas and in determining electrification needs and solutions (next slides).
Results – energy access, 2030

- The bulk of new connections require central grid extension, but a substantial number (>1/3) will come from mini-grids.

- Standalone solutions are mostly insufficient to provide energy for non-residential energy needs (e.g., crop processing) and thus only penetrate in few non-productive locations.

- Investment requirements and capacity additions mirror energy access gaps and cost-optimal set-ups

- Largest additions are found in highly populated and productive-activity dense Lusaka and Central region

- Overall, about 1.2 GW are required to achieve SDG 7.1 of universal electricity access by 2030

- This translates in 3.9 bn. USD in capacity, transmission, and distribution infrastructure investment requirements.
Final objective: integrated assessment and development goals

- Implementation of **bottom-up estimates** of local water needs, electricity demand, and optimal electricity access technologies presented here into a **WEF Nexus multi-node integrated assessment model**

- To estimate **investment portfolios** under different scenarios and policies

- For instance, **cost of water supply** and **synergies and trade-offs between development objectives**

- **National and sub-national basin-level** results to inform **stakeholders** at multiple levels

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Session HS5.5  
Thu, 27 Apr, 09:05–09:15

Vinca et al., *The benefits of rural electrification to improve water access and irrigation in Sub-Saharan Africa, a water-energy-land assessment framework applied to Zambia.*
Data:
The RE4AFAGRI Zenodo channel hosts both the data products generated as outputs of the modelling platform (visualised in the Dashboards) and the original input data to operate the modelling platform and replicate the analysis.

Code:
The RE4AFAGRI Github repository hosts the source code of the modelling platform, which, in combination with the data bundles, allows to run the analysis from scratch with customised assumptions and data, or adapt it to other geographies.

Documentation:
The RE4AFAGRI Wiki page hosts the official documentation of the modelling platform, to be used during the RE4AFAGRI capacity building activities, as well as by autonomous users willing to operate their own version of the platform.
Forthcoming trainings and events

RE4AGRI – WRI Workshops - 2023
Addis Ababa, 16-20th October 2023

- High-level course on tools, assessment and policy analysis of the water-energy-land nexus in SSA
- Technical course on WEL-nexus modelling tools
- WRI offices, UNDP complex
- Approx 30 participants, free to attend

Info and application: https://iiasa.ac.at/events/oct-2023/re4afagri-iiasa-and-world-resources-institute-wri-joint-workshops

LEAP-RE Stakeholder Forum
Kigali, 11-14th October 2023

A workshop to support African policy makers and private developers on topics relating to the water-energy-land nexus and rural development - focusing on making data-informed decisions with support of the RE4AFAGRI dashboards and business models.
Thank you!

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falchetta@iiasa.ac.at