GC11L-1028

Climate Resilience across Topographic Gradients in the Highlands of Ethiopia

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The Blue Nile Highlands

- Tropical highland region with steep elevation gradients.
- Densely populated, dominated by **smallholder agriculture**.
- Coupled processes of **land degradation and low investment capacity** act to increase climate vulnerability.

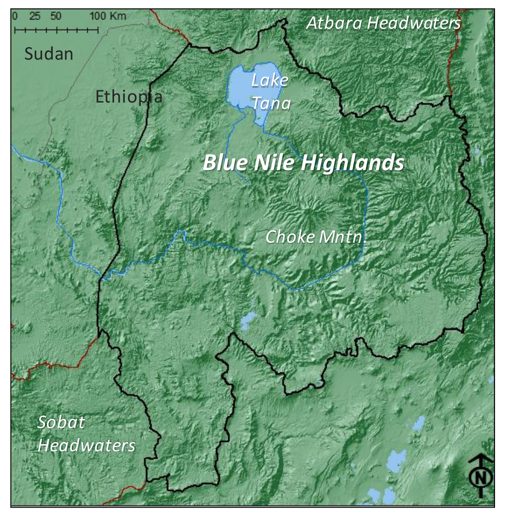

Figure 1: The Blue Nile Highlands

Climate risks and opportunities differ across topography.

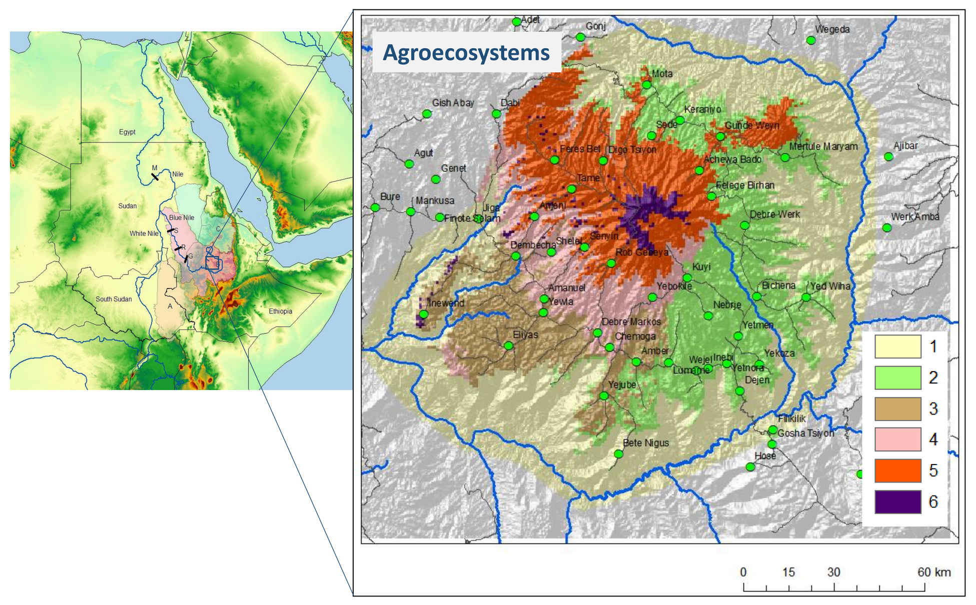

Figure 2: AES, defined on the basis of climate, soils, and farming systems, for Choke Mountain, in the middle of the Blue Nile Highlands (Simane et al., 2013)

Agroecosystems: a lens for climate risk and resilience

- Agroecosystems (AES) can define regions of **coherent climate resilience strategies.**
- A similar approach is used by the Ethiopian government to define **Climate Adaptation Zones** nationally.

Resilience strategies defined at the scale of the AES can be both locally appropriate and scalable.

Climate variability and change

- The BNH are predominantly humid to sub-humid.
- Most rain falls in June-September.
- Interannual **rainfall variability is large.**
- Local **climate contrasts are significant.**
- Temperatures are rising, and will continue to rise.
- Future **rainfall trends are uncertain**, but many models predict increases in rainfall totals and intensity.

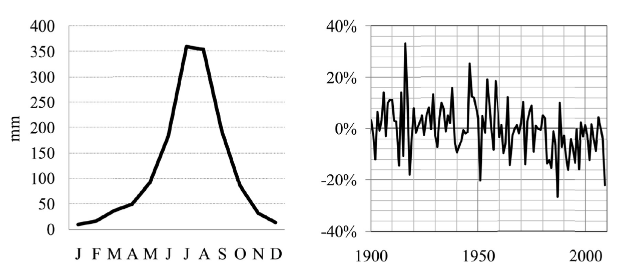
Figure 3: BNH rainfall seasonality and variability

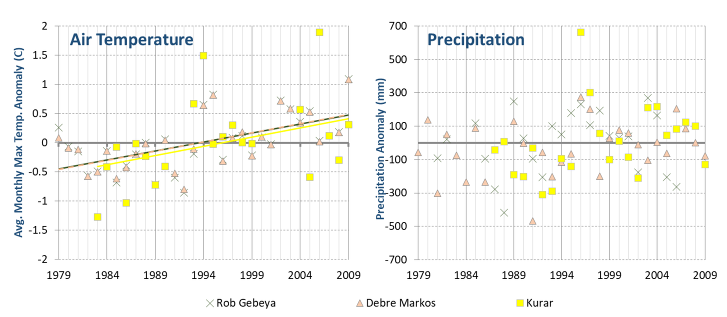

Figure 4: Observed T_{air} and precipitation trends at stations in AES1 (Kurar), AES4 (Debre Markos), and AES 5 (Rob Gebeya), from Simane et al. (2016)

Resilience strategies must address current variability and acknowledge future uncertainty.

Climate and Crops

Hydrology and climate analysis

- Retrospective analysis, 1981-2017, at 0.05° resolution with a **Land Data Assimilation System**.
- CHIRPS precipitation and topographically downscaled MERRA-2 meteorology
- Noah-MP Land Surface Model
- MODIS-derived vegetation and land cover parameters.
- Future precipitation and temperature downscaled from CMIP5 simulations.
- Future solar radiation (for crop models) estimated empirically as a function of daily T_{max} and T_{min}.

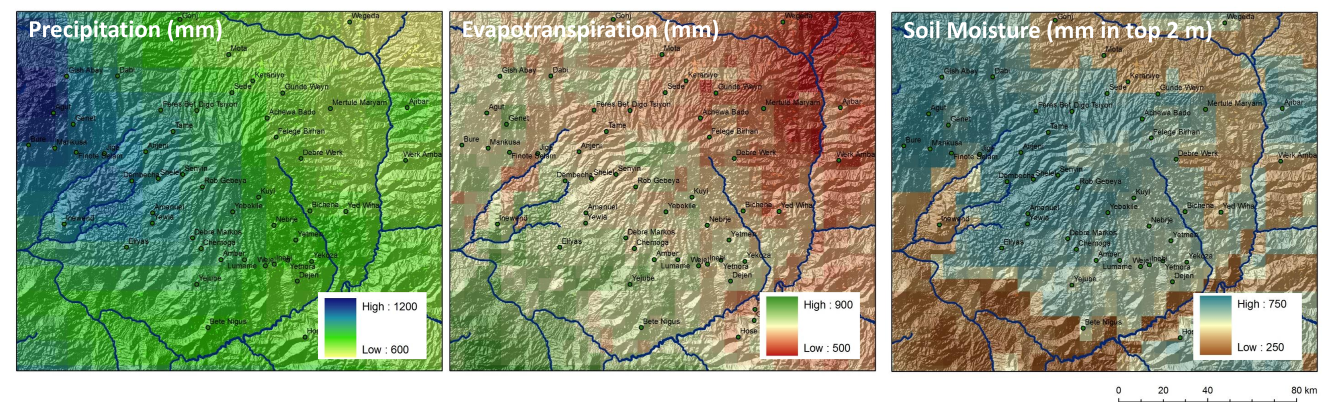

Figure 5: LDAS annually averaged fields for Choke Mountain, 1981-2014

DSSAT crop modeling

- Installed meteorological stations in each AES
- Collected detailed phenology, management, and yield data on-farm for 76 plots across AES 1-5.
- Barley, sorghum, bread wheat, and two maize cultivars were calibrated.

Subseasonal sensitivities and projected yields

- Even "drought tolerant" crops like sorghum are **vulnerable to subseasonal variability.**
- Projected changes in seasonal total precipitation may not offer adequate information on future crop risks.
- On average, **yields are expected to increase in high elevation AES and to decrease in lower, less humid AES.**
- In midland AES, direction of impact differs by crop.

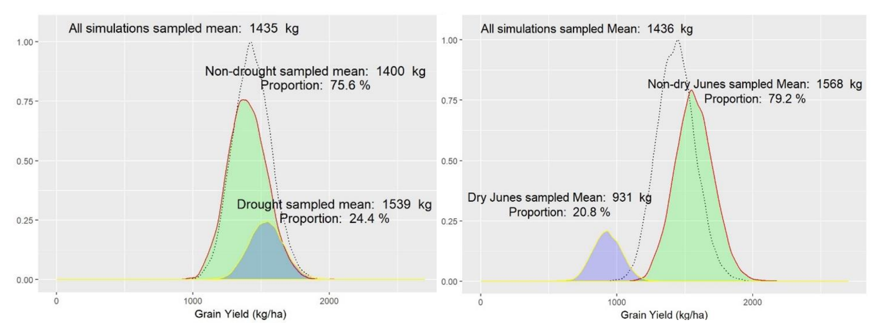

Figure 6: AES 1 sorghum yield distribution for (left) normal vs. drought years based on total rainfall, (right) years with low June rainfall vs. normal June rainfall

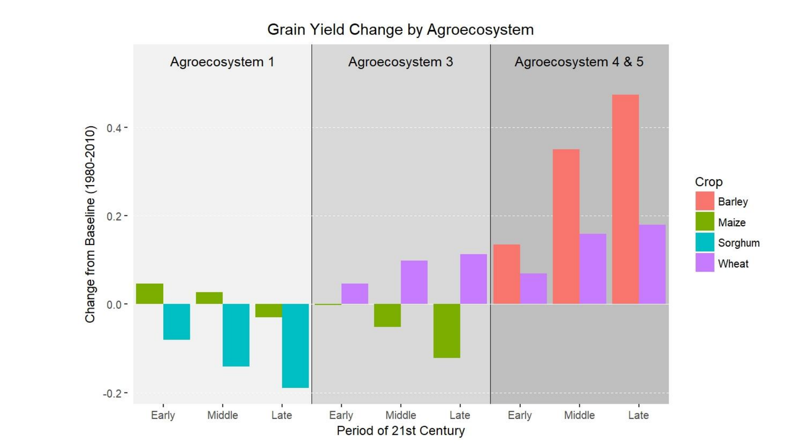

Figure 7: Projected change in yield by crop and AES, for a high emissions scenario

Yield projections must consider AES, crop choice, and subseasonal climate variability.

Vulnerability and Resilience

Livelihood Vulnerability Index (LVI)

- An IPCC LVI analysis was conducted across AES.
- **Vulnerability is greatest in the lowest and highest elevation AES.**
- High vulnerability in AES1 aligns with projected declining yields under climate change.

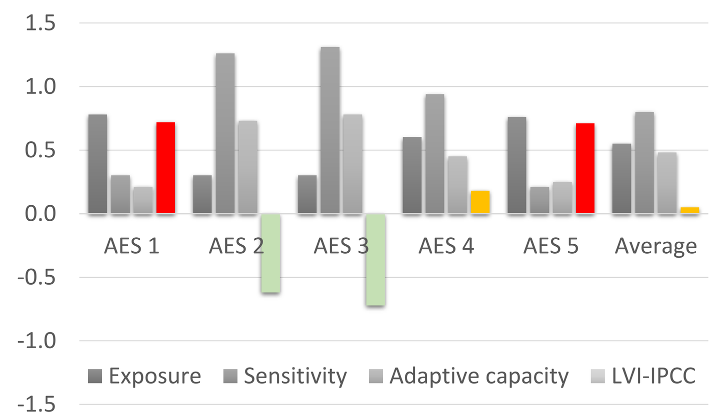

Figure 8: LVI-IPCC and its components, by AES (Simane et al., 2016)

Vulnerability and climate risk align in lower elevation AES. Midland AES have clearer adaptation options.

Development applications

- The AES approach is applied to establish **Climate Smart Villages (CSV)** in the Blue Nile Highlands and across the country.
- In CSV, farmers engage to **select and implement climate resilience strategies** informed by expert analysis and AES-relevant experience.
- Progress on livelihoods and natural resource management is **tracked**.
- CSV are platforms for implementing sustainable **locally-owned businesses.**
- Please see poster **GC11L-1033**!

AES-based resilience strategies are being incorporated to national development plans.

Systems Perspective

- AES form the basis for ongoing **multiscale food-energy-water (FEW) nexus** analysis.
- We are developing a **participatory social-ecological systems model** for the BNH.
- In parallel, we have built a generalizable **multiplayer FEW model** (Bakker et al., 2018) set in the Ethiopian context (Please see **H13M-1931**!)

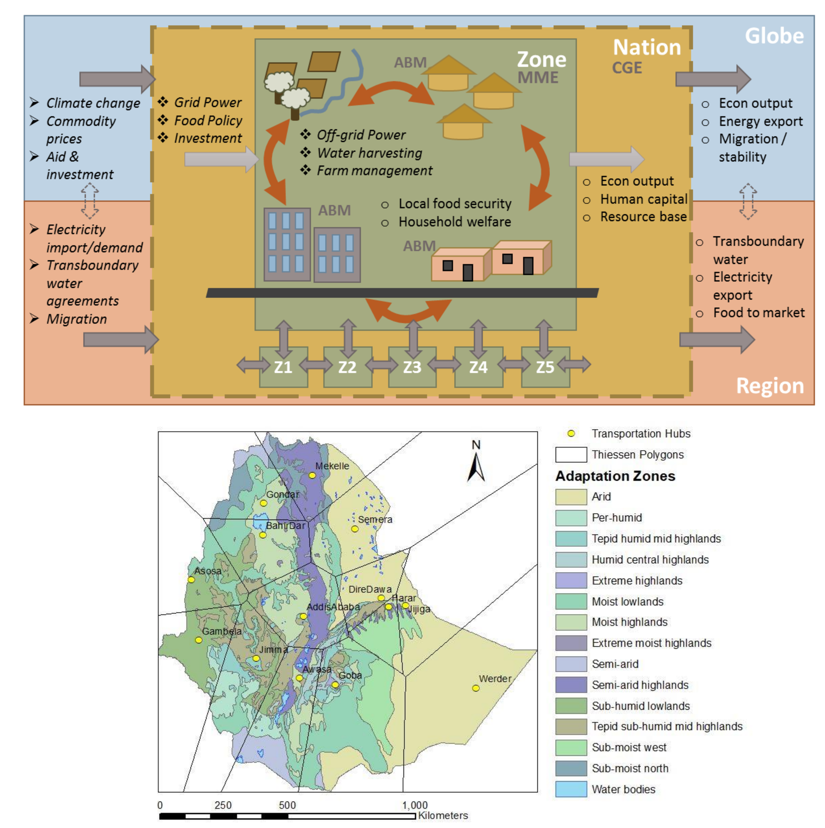

Figure 9: (top) framework for multiscale FEW analysis; (bottom) model structure for Ethiopia

Resilience is a multi-scale, multi-sector challenge.

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Simane, B., Zaitchik, B. F., & Foltz, J. D. (2016). Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region. *Mitigation and Adaptation Strategies for Global Change*, *21*(1), 39-65.
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Bakker, C., Zaitchik, B. F., Siddiqui, S., Hobbs, B. F., Broaddus, E., Neff, R. A., ... & Parker, C. L. (2018). Shocks, seasonality, and disaggregation: Modelling food security through the integration of agricultural, transportation, and economic systems. *Agricultural Systems*, *164*, 165-184.

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