Climate Resilience across Topographic Gradients in the Highlands of Ethiopia

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Abstract

The highlands of Ethiopia are a densely populated, agriculturally active region characterized by strong topographic contrasts. These contrasts have significant implications for agricultural productivity and for vulnerability to climate variability and change. These differing vulnerabilities are evident in analyses of economic and health outcomes over time, and they were on stark display during the major El Niño drought of 2015. To provide meaningful analysis of climate vulnerability in this region and, ultimately, to support climate resilience strategies, it is necessary to account for this topographic diversity. Recognizing this, the Government of Ethiopia has applied an "adaptation zone" approach to climate change planning, in which adaptation zones are defined in large part by agroecology. Here, we present results of studies we have performed in the Ethiopian Highlands over the past decade in which agroecosystems were applied as a lens for analyzing hydrology, land management and change, agricultural production, and nutrition under climate variability. This approach has informed a number of active development initiatives in the region, including protection of high elevation zones, farmer-led initiatives on soil and water management, and introduction of new cropping strategies. Looking forward, climate projections at the scale of the agroecosystem point to emerging risks and opportunities for resilient agricultural development in the region.

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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.

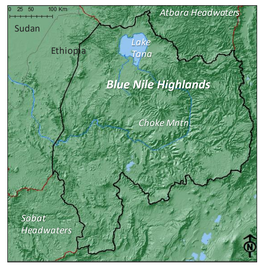


Figure 1: The Blue Nile Highlands

Climate risks and opportunities differ across topography.

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}.

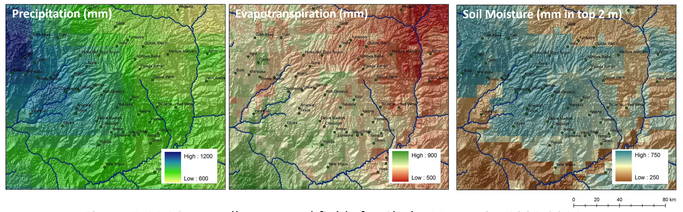


Figure 5: LDAS annually averaged fields for Choke Mountain, 1981-2014

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.

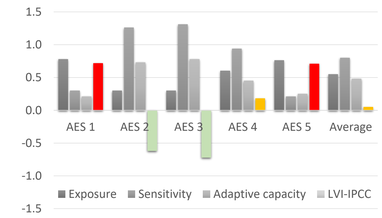


Figure 8: LVI-IPCC and its components, by AES (Simane et al., 2016)

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

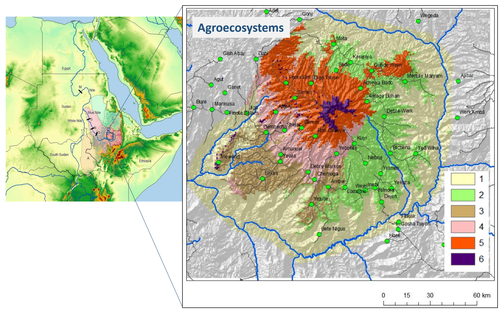


Figure 2: AES, defined on the basis of climate, soils, and farming systems, for Choke Mountain, in the middle of the Blue Nile Highlands (Simane et al., 2013)

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.

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.

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.

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.

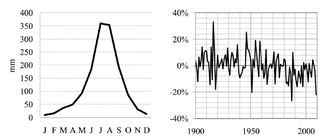


Figure 3: BNH rainfall seasonality and variability

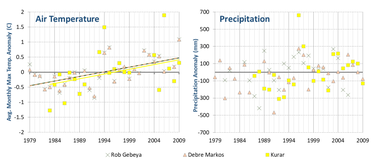


Figure 4: Observed T_{air} and precipitation trends at stations in AES1 (Kurar), AES4 (Debre Markos), and AES 5 (Rob Gebeya), from Simane et al. (2016)

Resilience strategies must address current variability and acknowledge future uncertainty.

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.

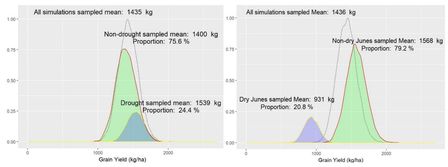


Figure 6: AES 1 sorghum yield distribution for (left) normal vs. drought years based on total rainfall, (right) years with low June rainfall vs. normal June rainfall

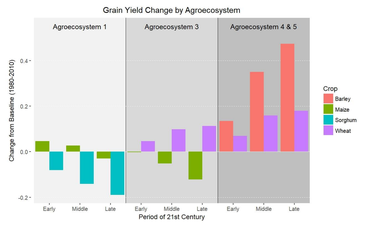
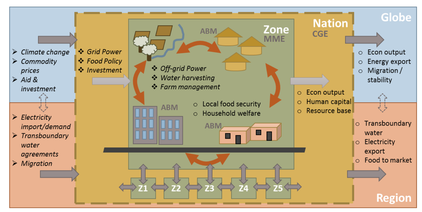


Figure 7: Projected change in yield by crop and AES, for a high emissions scenario

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

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**!)



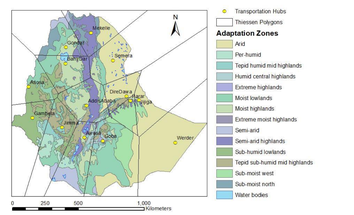


Figure 9: (top) framework for multiscale FEW analysis; (bottom) model structure for Ethiopia

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

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