Mapping small-scale irrigation for climate adaptation

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- Irrigation in sub-Saharan Africa can improve:
  - Yields, income, and food security
  - Resilience to drought and climate change
- A lack of data, especially on small-scale irrigation, constrains irrigation policy
- **Goal:** Map all small-scale irrigation across Zambia annually from 2016-2025 during the dry season (when most small-scale irrigation occurs)

Figure 1: Smallholder farmer irrigating his field in Zambia.

Driving Questions

Prevalence & change: How widespread is small-scale irrigation, and how fast is it expanding?

Spatial emergence: Where are irrigation hotspots forming, and how can that guide investment and water management?

Drivers & constraints: What climate, environmental, and economic factors shape adoption patterns?

Impact

- First multi-year, country-scale estimates distinguishing small- and industrial-scale irrigation in sub-Saharan Africa
- These maps will enable research, targeted investment, and water management.
- Outputs will be shared with local Universities, NGOs, research institutes and government agencies to embed results in policy and practice.

Figure 2: Small-scale irrigation annotated in Google Earth Pro images from randomly selected 1km x 1km tiles in the dry season from 2016-2025.

Dataset & Labeling

- 1 km x 1km tiles labeled with Earth Collect & Google Earth Pro.
- Focused on dry season images (June–October) from 2016-2025.
- Labels include irrigation type and extent.
- **936** Locations Labeled
- **2674** Images Labeled
- **¼** of images have some irrigation

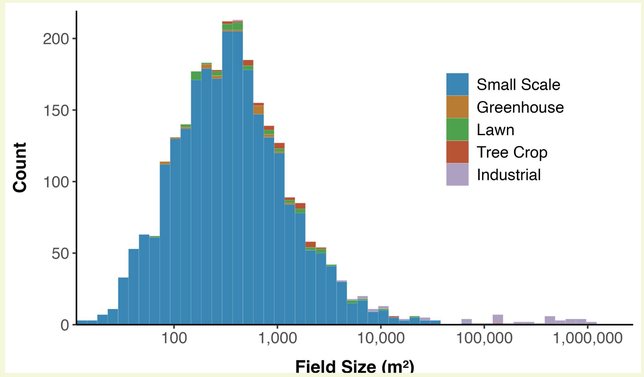

Figure 3: Distribution of irrigated field sizes (m^2) in hand labeled dataset. Fields are colored by the type of irrigation the labeler designated them as during labeling.

Small-scale irrigation makes up 95% of irrigated fields – adding up to ⅓ of all dry season irrigated land.

Features & Modeling

- Sentinel-2 optical bands and indices (e.g. NDVI) at a 10-day interval over the full year (37 time steps)
- The key signal is phenology (seasonal change): irrigated crops see a spike of greenness during the dry season while rainfed fields stay brown; wetlands remain persistently green.
- Spatial information may also help distinguish between irrigated areas and naturally green areas (wetlands)

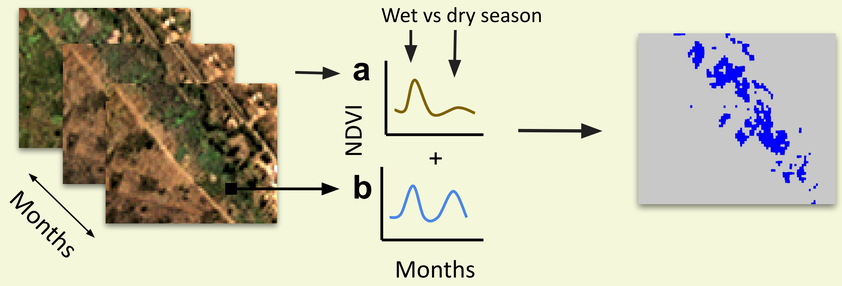

Figure 4: Seasonal vegetation patterns, as can be used to produce binary irrigation maps.

Baselines → Geospatial Foundation Models

Models:

- Benchmarks from tree-based baselines (Random Forest, Gradient Boosting on aggregated vegetation-index features)
- Lightweight transformers (e.g., PRESTO)
- Geospatial foundation models (e.g. TerraMind)
- Pre-computed embeddings (AlphaEarth)

Evaluation for research application:

- Irrigation presence (binary) at pixel and image (1 km) level – Precision, Recall, AUPRC, F1
- Irrigated area (continuous) at a 1km resolution – R2
- Test change detection via same-site year pairs and spatial hold-out regions for generalization.