Irrigation in Zambia Eastern Province

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The Quadracci Sustainable Engineering Lab team conducted a survey in 2024 in the Eastern Province of Zambia to understand where farmers are irrigating, resulting in 30 clusters of irrigation sites for which data were collected. Survey results showed that these irrigated croplands exploit the topography's natural ability to allow water to accumulate in areas called dambos. Several studies provide an assessment of dambo hydrology in Southern Africa and estimate the density of dambos in Zambia to be 15-20% of the total land area.[1 2]

The riverine areas (dambos) can be identified by looking at Digital Elevation Models (DEM). By examining satellite imagery from the dry season, we can spot irrigated croplands because they remain greener than surrounding vegetation. However, this greenness alone does not distinguish irrigated croplands from riparian vegetation. Some key observations of looking at forests are that a threshold on the monthly Sentinel 2 EVI time series of the year can differentiate forests that have higher EVI values from cropland . In some cases, the EVI patterns of certain forests are very similar to those of croplands, making those areas difficult to distinguish using EVI alone. Therefore, we employed a random forest classifier (a machine learning model) to identify likely irrigated areas. After classification, we used high-resolution (sub-meter) imagery to confirm the locations of irrigation sites, which often exhibit a characteristic perimeter around the fields designed to retain water. This methodology is described in Figure 1.

We applied the methodology to a 20 km by 10 km area near Lusinde in Eastern Province to estimate the extent of irrigation in that region. Within this 192 sq km study area, the model predicted significantly more irrigation than what was actually observed:

- 28 sq km (~15% of the total area) was predicted to be irrigated by the classifier
- 2.5 sq km (9% of classifier predicted irrigation) was actually irrigated by visual inspection of high-resolution imagery

Figure 2 shows the method of estimating the actual irrigated area within the classifier-predicted irrigation using high-resolution satellite imagery. This process can be automated using computer vision algorithms or deep learning with convolutional neural networks. These clusters of sites can be translated into energy demand associated with irrigation, allowing for the study of how to connect to a nearby grid or set up a mini-grid for energy access.

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[1] Andrew Bullock, "Dambo Hydrology in Southern Africa—Review and Reassessment," *Journal of Hydrology* 134, no. 1–4 (June 1992): 373–96, https://doi.org/10.1016/0022-1694(92)90043-U.
[2] R. Boast, "Dambos: A Review," *Progress in Physical Geography: Earth and Environment* 14, no. 2 (June 1990): 153–77, https://doi.org/10.1177/030913339001400201.

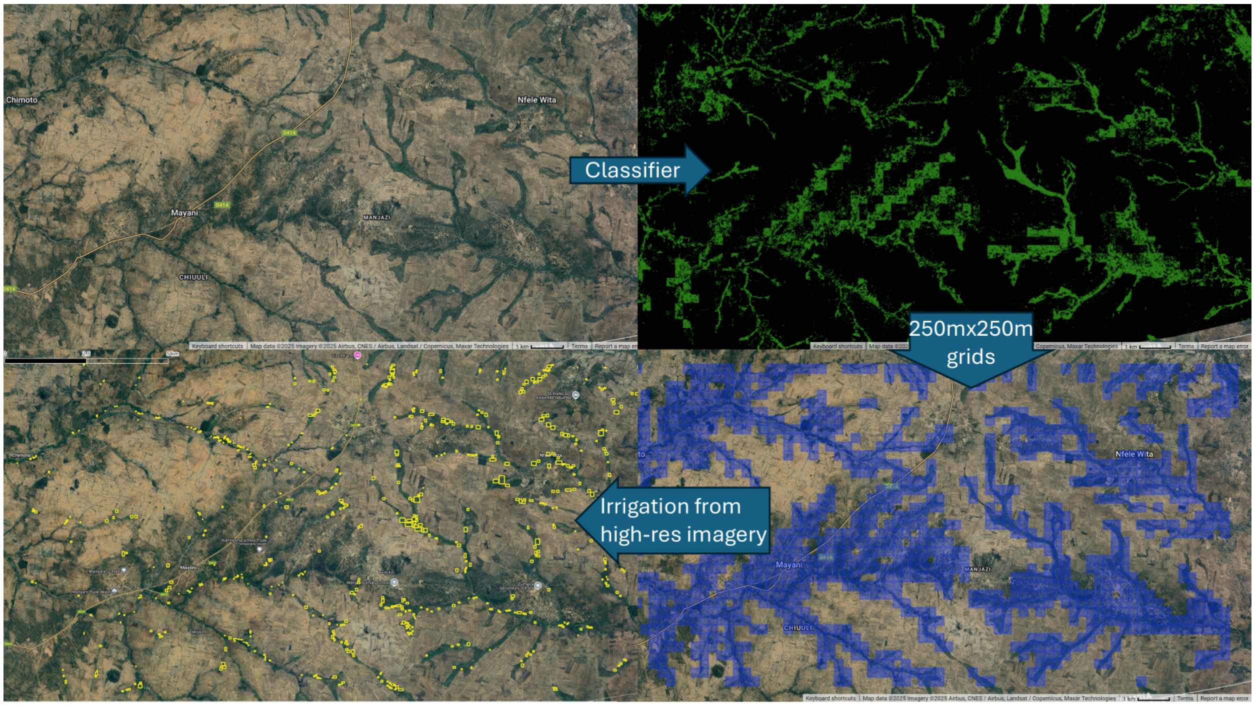

Figure 1: Irrigation detection methodology applied to a 20 km x 10 km area in Zambia Eastern Province. A random forest model classifies irrigation presence based on topology from Digital Elevation Maps and monthly mean time series of the Sentinel-2 Enhanced Vegetation Index (EVI) for the year. The classifications are gridded, and the area under each grid is examined using high-resolution imagery. Polygons (shown in blue against a yellow grid) are drawn where irrigation is found.

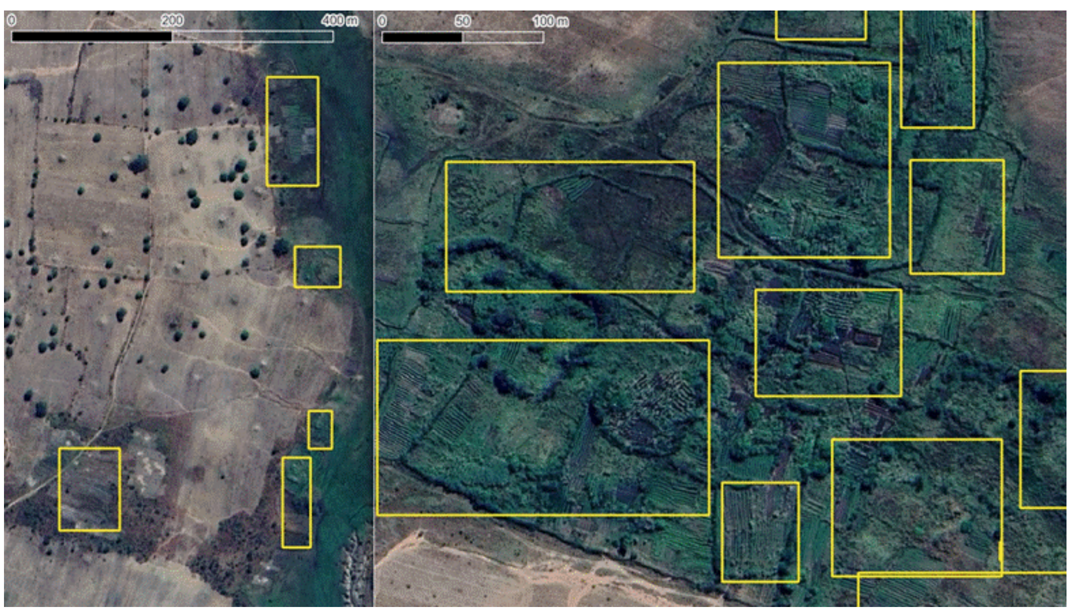

Figure 2: Estimating actual irrigated area from high-resolution imagery