Optimizing Ethiopia's Crop Storage Infrastructure: A Geospatial and Network Science Approach

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Extended Abstract

Motivation. Ethiopia, Africa's largest cereal producer as of 2022 [10], faces a paradox of agricultural abundance and persistent food insecurity: cereals provide 70 percent of caloric intake [2], yet 15.8 million people required emergency food assistance in 2024 [12]. Postharvest losses alone consume 10 percent of Ethiopia's annual agricultural budget, enough food to feed 23 million people, driven largely by inadequate storage and unreliable transport [4, 5]. This study asks: (1) Where should storage facilities be located to minimize aggregate transport costs? (2) How does incorporating road infrastructure and production weighting shift optimal placements? (3) What cost penalty does restricting sites to FAO-recommended locations impose?

Approach and Methodology. This study integrates geospatial data and network science to formulate and systematically extend a mixed-integer programming (MIP) optimization model. Three datasets provide the empirical foundation: the Spatial Production Allocation Model (SPAM) at 10×10 km resolution for farm-level cereal production [6]; the FAO Crop Storage Final Location dataset specifying 853 recommended storage grid cells, collapsed to 25 regional clusters [3]; and the Global Roads Inventory Project (GRIP) at 8×8 km resolution for road network data [7]. Farm and storage nodes are structured as a bipartite network [1] (Figure 1), with edges representing farm-to-storage assignments. Focusing initially on maize, the most-produced crop by tonnage in Ethiopia, the objective function is progressively extended: from a baseline Euclidean distance model, to a production-weighted variant, to a travel-time formulation using road-network shortest paths, and finally to load-balanced variants penalizing uneven production distribution across facilities. Gurobi is used as the primary solver for the large-scale MIP problems. GenAI assisted in code development throughout the implementation.

Results. Each model variant excels in the metric it explicitly optimizes, with no single model dominating all dimensions. Restricting sites to FAO-recommended locations imposes a 267 percent cost penalty (443M vs. 121M meters) relative to the unconstrained gridcell baseline. Switching to production-weighted travel time reduces total system travel time by 1,361 hours, and load-balancing constraints eliminate the unrealistic concentration of nearly 2 million tons at a single facility seen in unconstrained variants.

Conclusions and Outlook. Strategic, data-driven facility placement substantially reduces transport costs and improves supply chain efficiency. The primary limitation is that farm nodes are defined at the coarse 10×10 km SPAM grid-cell level rather than actual field boundaries, blurring both production estimates and spatial assignments. Published in April 2026, Robinson et al. [9] presents the first global agricultural field boundary map at 10 m resolution (3.17 billion

Sentinel-2-derived polygons across 241 countries), making polygon-level farm nodes feasible at the scale of this study. The authors flag Ethiopian smallholder regions as underrepresented in training, making field boundary quality in East Africa an open priority that directly motivates this extension. Resilience formalization [11, 8] and multi-commodity extensions are parallel future directions.

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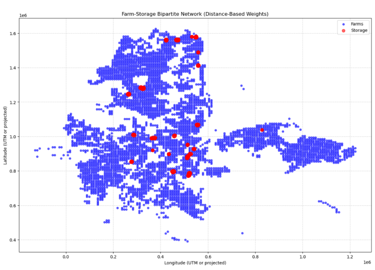

Figure 1: **Farm–storage bipartite network.** Blue: 4,316 farm nodes (SPAM); red: 853 FAO storage nodes. [6, 3].

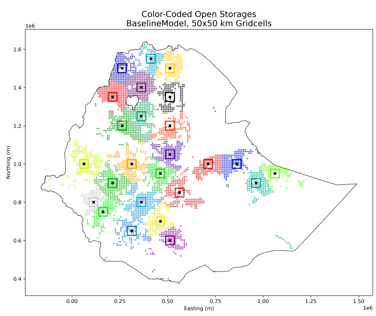

Figure 2: **Gridcell baseline.** 25 facilities from unconstrained 50×50 km grid; color = catchment area.

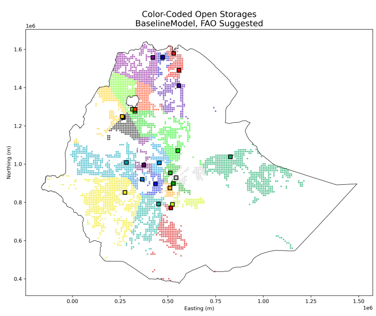

Figure 3: **FAO-restricted baseline.** Same formulation; sites restricted to FAO-recommended locations (267% cost increase).