Drone Imagery can count dwellings & estimate population in an informal settlement to within 14% of an independent census

INTEGRATING HIGH-RESOLUTION IMAGERY AND MACHINE LEARNING FOR SMALL AND INFORMAL-AREA POPULATION ESTIMATION IN MELUSI (ATTERIDGEVILLE, PRETORIA)

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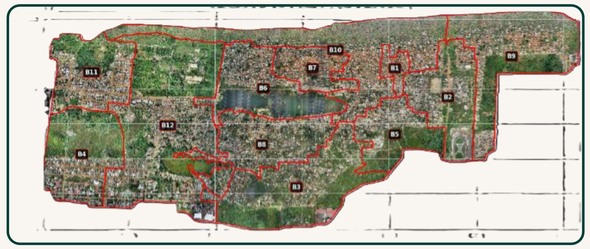
INTRO

- Informal settlements house millions across Sub-Saharan Africa yet are **undercounted**.
- Standard census methods fail where streets are **nameless boundaries** shift seasonally
- Melusi houses ~43,000 residents with **no reliable block-level population data**.
- We fill the gap with a **reproducible** ML pipeline that turns **drone imagery** into **population estimates**, anchored to an independent household survey



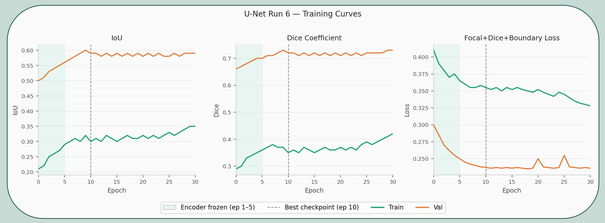
0.537 — TTA IoU — U-NET SEGMENTATION
0.829 — RECALL — DWELLING DETECTION RATE
13.7% — MAPE — BLOCK LEVEL ERROR
0.643 — DICE — U-NET SEGMENTATION
0.767 — BLOCK R^2 — RF REGRESSION FIT
41,329 — EST. POPULATION — VS 43,000 ANCHOR (~4% ERR)

METHODS

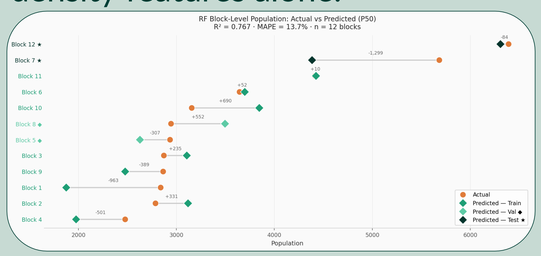
1. Blocks boundaries **adaptively** derived from OSM and centroids using **KNN**.
2. Drone orthophoto tiled to 512x512px.
3. **Adaptive** hybrid labels: GOB and SAM **union** ground truth filtered through LiDAR Z-height **discrimination** to suppress non-dwelling.
4. U-Net (ResNet34 encoder) with **TTA** inference across 2 test blocks
5. **ElasticNet baseline** on **log population-per-dwelling** and Random Forest residual regression, spatially cross-validated by block using **GroupKFold**
6. Settlement estimate **aggregated** from block-level predictions and validated against target

RESULTS

1. U-Net **recovers 80%** of dwellings for test blocks



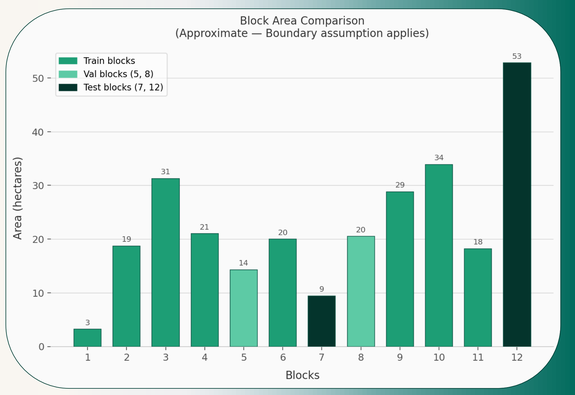
2. **Block-level regression explains 77%** of population variance using dwelling density features alone.

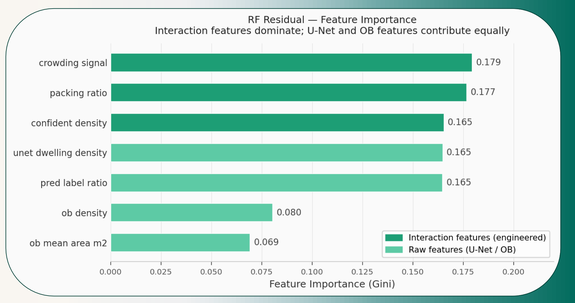


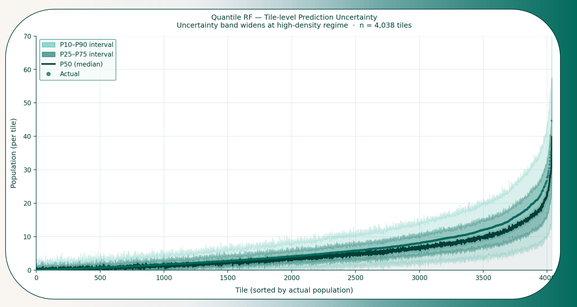
3. Settlement-level estimate: 41,329 residents, within **4%** of the 43,000

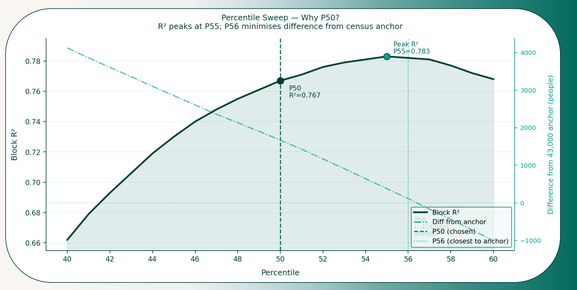
DISCUSSION

1. **High recall** over **precision** is correct, undercounting dwellings has worse service delivery consequences than overcounting
2. GOB and LiDAR labels introduce **partial circularity**; independent field-surveyed labels remain the key validation gap
3. Block 7 is the largest misfit, consistent with **high-density underfit at tile level**
4. **Fully reproducible** from raw drone data to population estimate, ready to rerun on any LiDAR-covered settlement









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