

Smallholder Agricultural Landsape Understanding

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Why?

The Climate & Food Security Challenge

- The global food system is a primary driver of climate change.
- Smallholder farms (<2 ha) produce >50% of the world's food but exist in complex, intricate mosaics proving to be challenging for current ML models.
- Prior work only maps fields, ignoring vital features like trees (carbon) and water (irrigation) needed for sustainability.

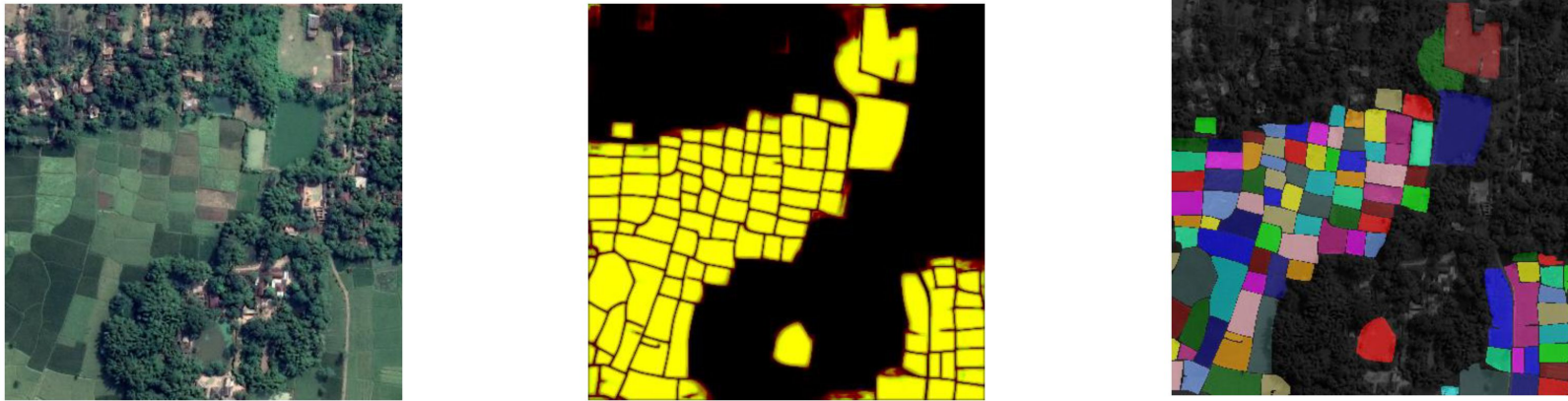


Figure 1: Our system segments satellite imagery (left) into semantic (center) and instance (right) maps for fields, trees, and water bodies.

Goal: A Holistic Landscape Map

- Developed and evaluated a national-scale system for granular agricultural mapping, focusing on smallholder farms.
- Moving beyond traditional field delineation, we use a multi-class approach to segment fields, trees and water bodies.
- We introduce novel post-processing heuristics to refine model outputs into final maps.
- We conduct rigorous, multi-faceted evaluation for real-world reliability, including benchmarking on public data, comparison with in-situ surveys, and on-ground validation with external partners.

API and Demo



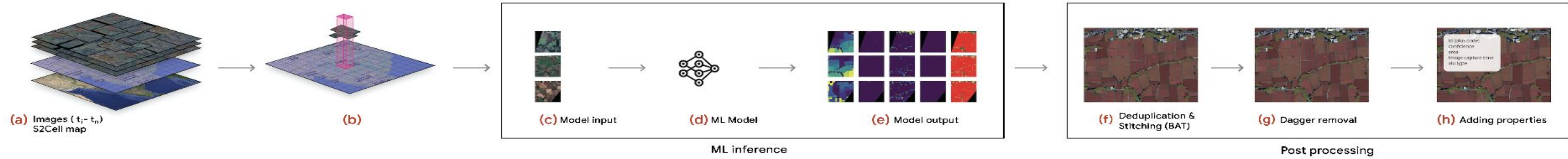
Video



Website and API

System Overview: ALU Pipeline

- Our ALU system processes multiple, time-varied satellite images through a panoptic segmentation model to identify agricultural features.
- The panoptic segmentation model is adapted from Gao et. al [1]
- A series of novel post-processing steps then vectorizes, stitches, de-duplicates, and refines these detections to create a single, consistent, large-scale map.



Novel Post-Processing

Challenge: Inconsistent Detections in Satellite Imagery Stacks

1. Trained ML model inference is run on a vast satellite imagery archive
2. A single physical object (e.g., a field) may be detected with inconsistent shapes across different images or not get detected at all in some images

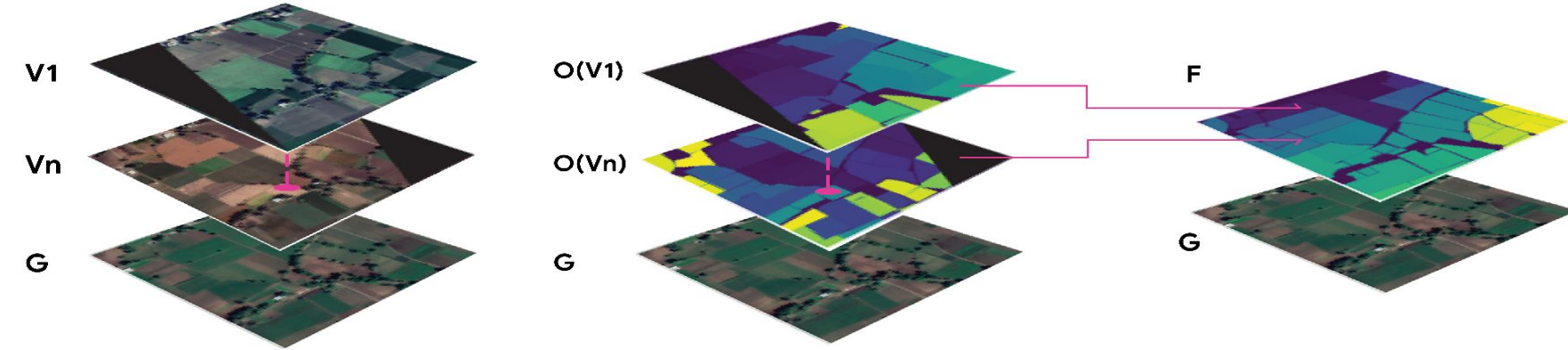


Figure 3: BAT [Best Autogen Tracker] Workflow

Best Autogen Tracker: Stitching and Deduplication:

1. BAT workflow first stitches fragmented boundary detections by clustering objects falling on tile boundaries.
2. Deduplicates objects by building a chronological validation score for each candidate and applies heuristics (quality vs freshness) to determine best detection

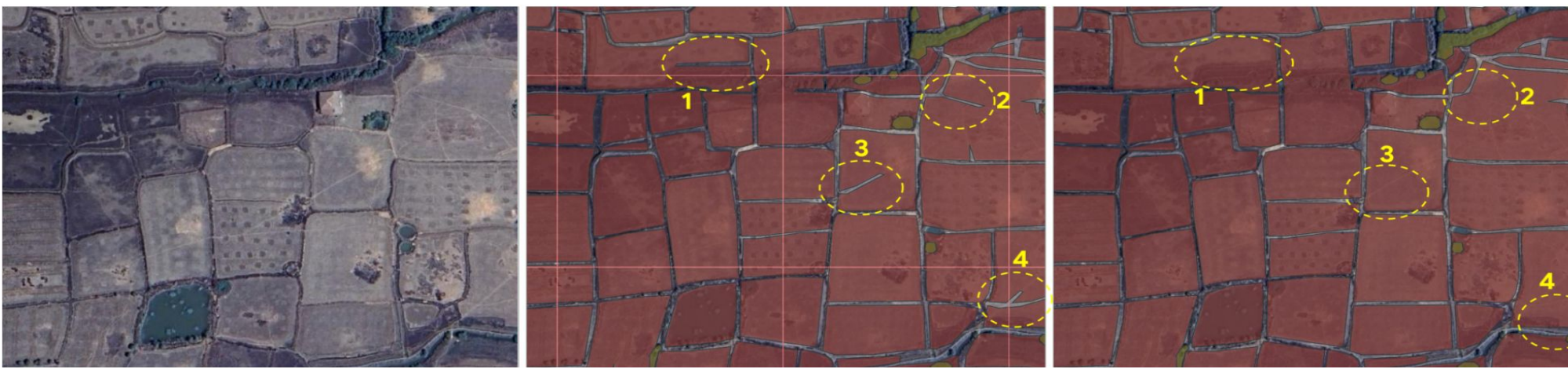


Figure 4: Left to right: Boundary Refinement:

Dagger Removal heuristic refines noisy polygons by identifying sharp, inward protrusions ('daggers') that lie within the polygon's convex hull.

External Benchmark Datasets

Data	Kenya [2]		India [3]		Vietnam and Cambodia [4]
	mIoU (Border)	mIoU (Extent)	medIoU	IoU50	Polis
Previous Best	0.58	0.53	0.85	0.89	20.3
ALU (our)	0.61	0.61	0.84	0.93	11.89

Agricultural Census Comparison

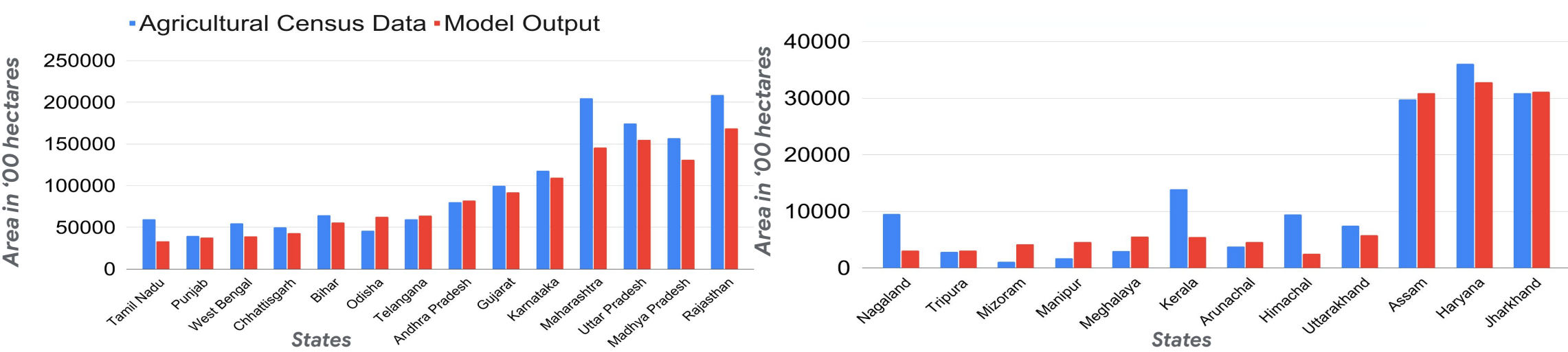


Figure 5: ALU-derived agricultural area (red) shows strong correlation with official census data (blue) across Indian states.

On-Ground Validation

- Validated with partners (Govt. of Telangana & TeamUp) by integrating the ALU API into their on-ground crop booking application.
- Achieved **82%** field-level accuracy in a 19-village pilot, identifying key areas for improvement like over-segmentation (**7.45%**) and boundary errors (**8.18%**).

Conclusions

- We developed a rigorously validated, end-to-end system for holistic agricultural landscape understanding
- First national-scale mapping of India's smallholder farms, a critical group comprising **86.2%** of the agricultural workforce and managing approximately half of the total cultivated area.