Integrating multi-temporal Landsat and hyperspectral imagery to monitor expansion of tropical tree plantations

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Background

An efficient means to map and monitor tree plantations is needed to detect tropical land use change and evaluate reforestation projects (1,2). Government payments for environment services (PES) have subsidized extensive tree planting in the San Juan-La Selva corridor region in northeastern Costa Rica, but tree plantation species differ in their ability to provide valuable timber, habitat, and forest connectivity for wildlife. To analyze tree plantation expansion and conversion to other land-usess in this region, we examined the potential of combining moderate-resolution hyperspectral imagery (HyMap) with multi-temporal multispectral (Landsat) data to accurately classify tree plantation species.

Landsat metrics improved hyperspectral accuracy

Figure 2: Accuracy for the two RF models (Producer's and user's*), by summary land-use class (mean +/- 95% CI).

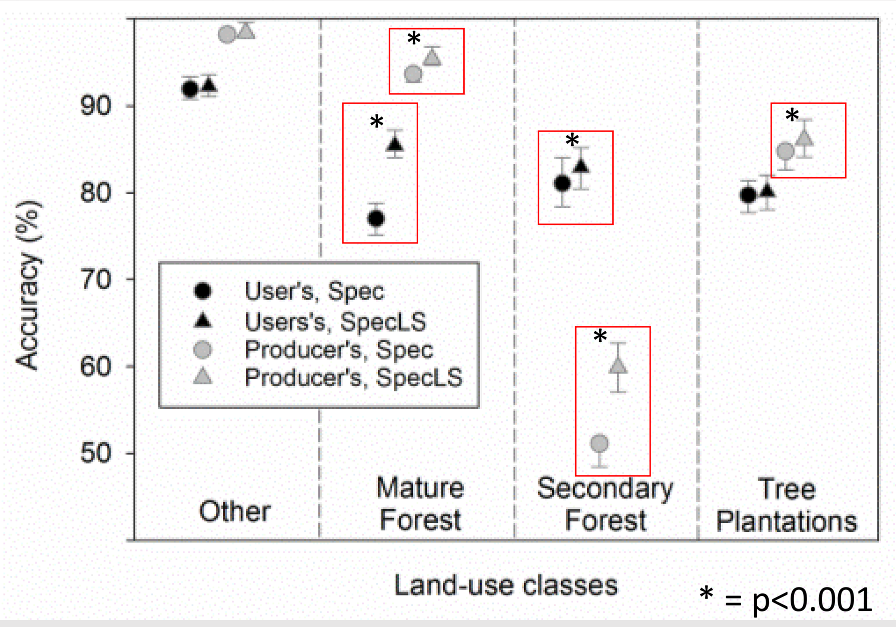
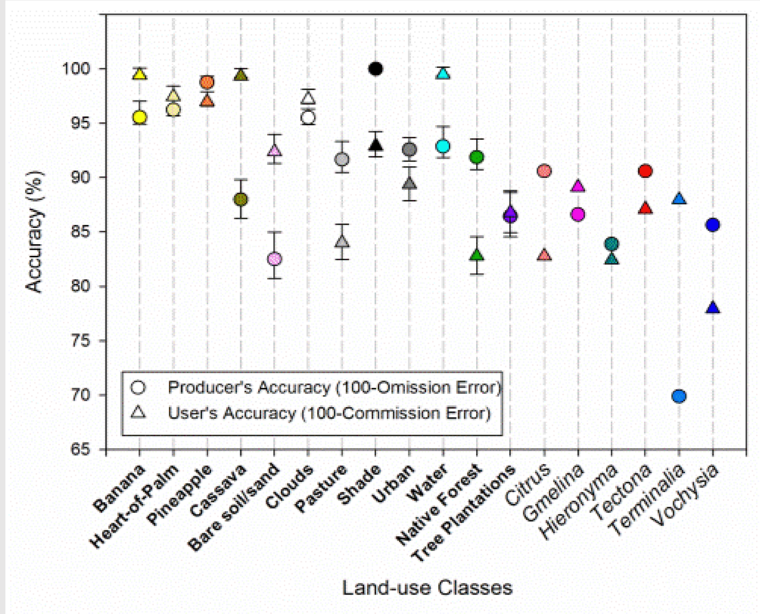
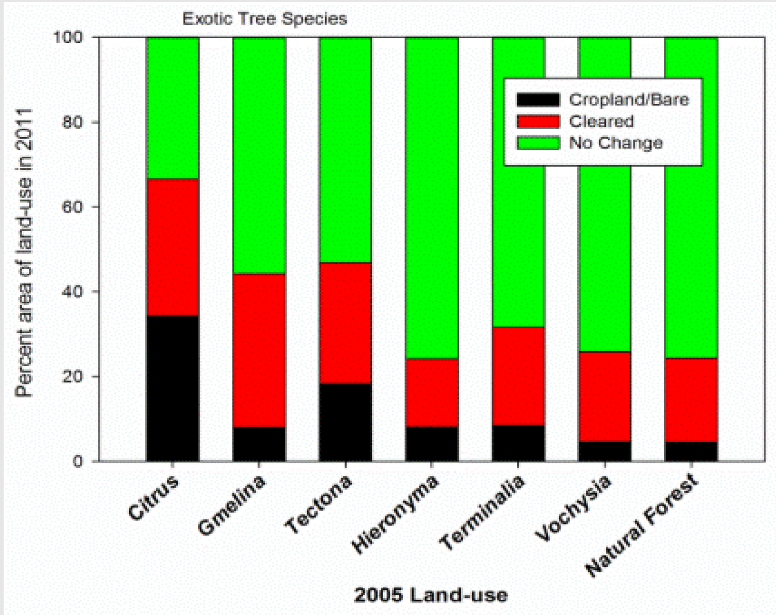


Figure 3: Final map accuracy for the seventeen final classes (means +/- 95% confidence interval, where possible).



Non-native species were rapidly cleared

Figure 5: Changes in land-use by tree plantation species. 2005-2011. These changes were calculated by comparing the HyMap-derived land-use map (2005) with the fate of forest regrowth areas in Landsat-derived 2005 and 2011 land cover maps (see 4). Areas cleared in 2011 transitioned to pasture or were harvested for timber, while some tree plantations were converted to a crop production land-use (cropland/bare). The three exotic (non-native) species are labeled on the left, while secondary forests (natural forests that were identified as regrowth in Landsat maps) are labeled on the right.



Hypotheses

1. **Hyperspectral + Landsat data will increase discrimination of secondary forests and tree plantations from mature forests, compared to hyperspectral imagery alone.**
2. **Hyperspectral + Landsat data will distinguish the principal species comprising tree plantations.**
3. **Cross-sensor integration will permit monitoring of the dynamics of secondary forests and tree plantations in northeastern Costa Rica.**

Results

- Hyperspectral data discriminated tree plantations (TP) from mature forests (MF) and secondary forests (SF), but MF and SF were poorly discriminated (Figure 2).
- Adding multi-temporal Landsat data significantly improved classification accuracy of SF and TP (overall accuracy: 92.7%). (Figure 2).
- We accurately classified all six TP spp. (Figure 3). Non-native tree species had higher classification accuracy.
- Non-native tree species made up the majority of tree plantations in 2005 (Figure 4), but they were more rapidly converted to cropland and pasture than native TP from 2005 to 2011 (Figure 5).

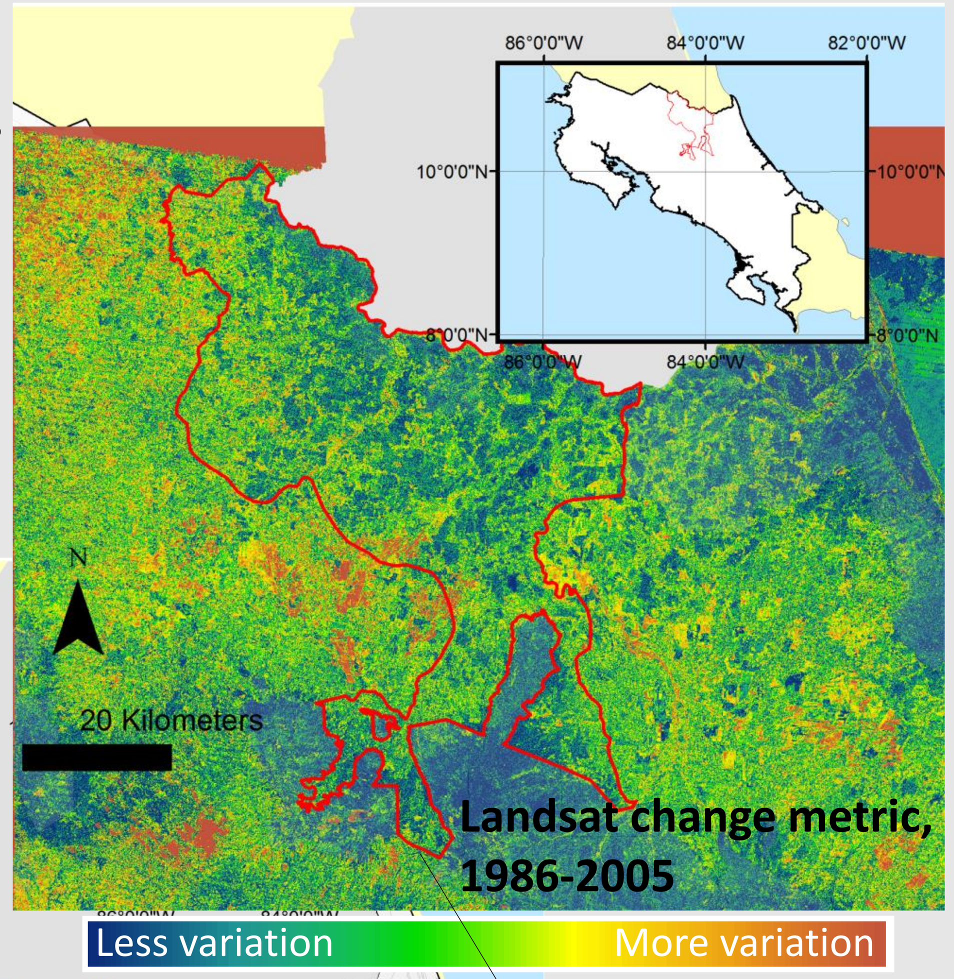
Conclusions

1. **Hyperspectral classification of secondary forests and tree plantations was improved by the addition of multi-temporal Landsat data; tree plantation species were accurately classified as well.**
2. **Increasing the persistence of regenerating forest cover requires PES to favor native species and secondary forest over exotic species.**
3. **The integration of hyperspectral and multitemporal data for enhanced land cover classifications can improve forest monitoring in reforesting tropical landscapes.**

Methods

- After LDA, we compared two Random Forest (RF; 3) models:
  - hyperspectral data alone (**Spec**; a HyMap 2005 mosaic)
  - hyperspectral and Landsat data (**SpecLS**).
- Landsat data: multitemporal metrics derived from a four-date Landsat image stack (1986-2005). Calculated two indices of temporal variability in Landsat band 5 (Figure 1).
- Model accuracy evaluated using a subsampling bootstrap of independent validation points (n=1637).

Figure 1: Images of the study area. The top image shows a metric derived from Landsat imagery: the mean of the Euclidean distance in Band 5 for all image pairs in a Landsat time series (1986-2005). The bottom image shows a HyMap mosaic.



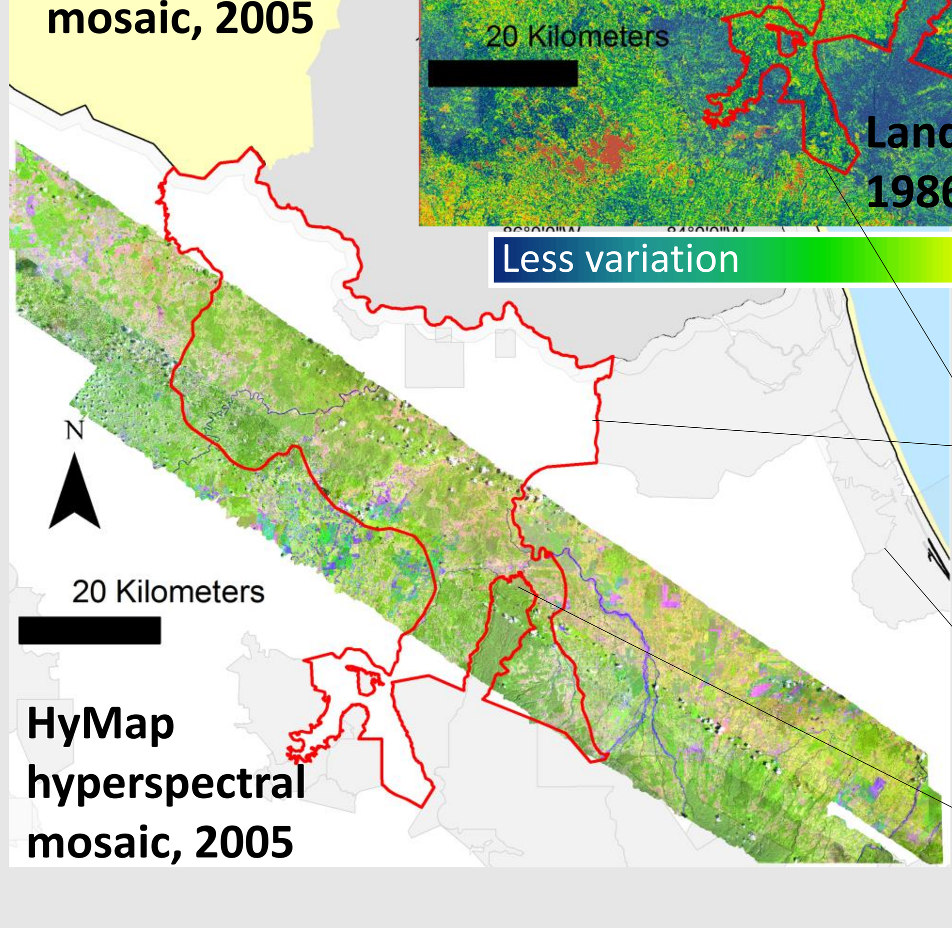


Figure 1 legend:

The San Juan-La Selva Biological Corridor (2466 km²)

Parks and wildlife refuges (shades of grey).

La Selva Biological Station is centrally located in the imagery (a 4509 km² mosaic).

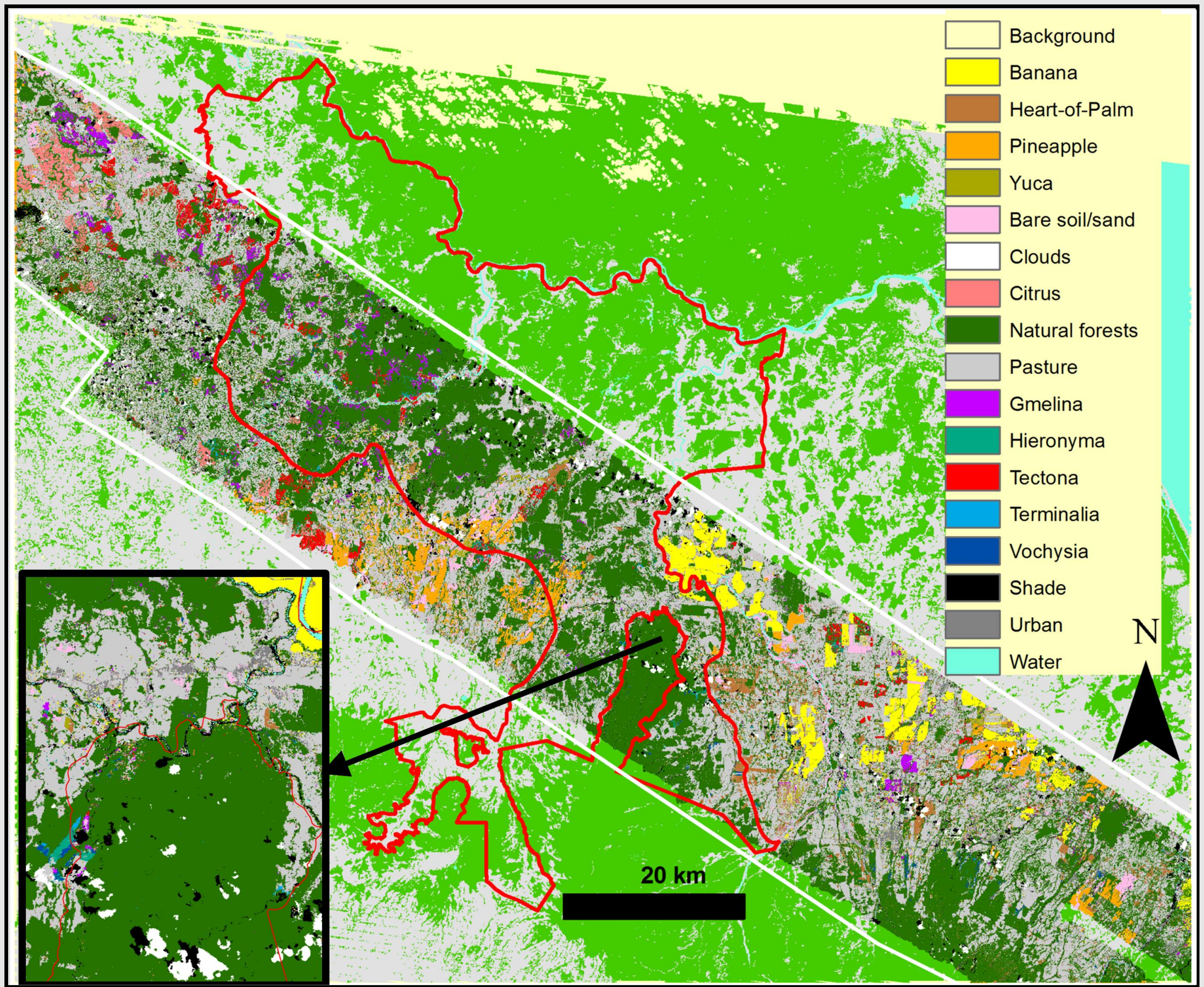


Figure 4: Final seventeen-class land cover map. The HyMap land-use classification is shown inside the white outline. The regional forest-nonforest map outside the white outline is derived from 2005 Landsat imagery (4); nonforest is shown in light gray and forest in light green.

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Literature Cited

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*Producer's accuracy is defined as 100 minus the error of omission for a given class, and user's accuracy is defined as 100 minus the error of commission for a given class.