LARGE AREA MAPPING OF FOREST AND LAND COVER IN THE AMAZON BASIN: A COMPARATIVE ANALYSIS OF ALOS/PALSAR AND LANDSAT TM DATA SOURCES.

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1. INTRODUCTION

Information on the global distribution of tropical forests is critical to decision-making on a host of internationally significant issues ranging from climate stabilization and biodiversity conservation to poverty reduction and human health. The majority of tropical nations lack high-resolution, satellite-based maps of their forests, and in many cases, the barrier is persistent cloud cover[1-3]. Data availability is also a limitation that could be exacerbated by the projected near-term interruption in the 37-year Landsat satellite record[4]. These issues pose fundamental obstacles to countries that aspire to participate in a proposed United Nations climate change agreement that would reward tropical nations that succeed in reducing their rates of deforestation[5]. Robust forest monitoring tools, based on the broad range of available data sources, are needed if nations are to effectively track their successes in slowing forest loss. Here we show that modern spaceborne radar sensors can contribute significantly to the generation of high-resolution (< 25 meters) maps of tropical forest cover, unimpeded by clouds, haze, smoke, or darkness, with accuracies exceeding 90%. Through spatial and statistical comparisons with analogous Landsat-based maps, we demonstrate the potential of these data, which now provide global forest coverage annually, to advance the development of national forest monitoring systems while reducing current observational uncertainties.

Tropical forest clearing occurs at a rate of approximately 5.4 million ha/yr[6], accounting for about 12% of anthropogenic carbon emissions[7]. Current negotiations of the United Nations Framework

Convention on Climate Change (UNFCCC), set to culminate in December 2009 in Copenhagen, include a mechanism to compensate tropical nations for reducing greenhouse gas emissions from deforestation and forest degradation (REDD). A successful REDD mechanism will require operational forest monitoring, reporting, and verification systems that are reproducible, consistent, and accurate at national to pantropical scales, and satellite-based remote sensing supported by field observations is widely-accepted as the most objective and cost-effective approach[1, 2, 6, 8]. Passive optical imagery, like that provided by the venerable Landsat satellite series, has long been the principal source for areal estimates of deforestation at regional to continental scales[1, 2]; however, because clouds obscure the dense humid tropical forest approximately 72% of the time the use of this imagery is greatly constrained[1-3, 9].

2. STUDY AREA AND METHODS

Here we evaluate the ability of the ALOS/PALSAR to produce high-resolution, wall-to-wall maps of tropical forest cover across large geographic areas. For the purposes of our analysis, two image mosaics consisting of 116 ALOS/PALSAR scenes and 12 cloud-free Landsat 5 scenes (all scenes acquired June-August 2007) were generated for a 387,000-km2 region in the southeastern Brazilian Amazon encompassing the Xingu River headwaters [10]. The region, representative of many areas along the Amazon's agricultural frontier and currently the focus of a REDD pilot project, has more area in dense humid forest (~221,000 km2) than 93% of the world's 131 tropical nations[10]. Each mosaic was subjected to an empirical decision-tree algorithm used to classify land cover (a) at five different levels of class aggregation (15, 10, 7, 6, and 2 classes) and (b) using two different predictor-variable subsets. A collection of 896 field reference points spanning 15 land cover types was used to calibrate and cross-validate the 20 classification models developed as part of the analysis.

3. RESULTS

Overall accuracies for the PALSAR-based classifications ranged from 58-92% (Kappa=0.52-0.85) and were achieved using a combination of spectral and ancillary predictor variables (Fig 1). These results compare very well with analogous Landsat-based accuracies, which ranged from 64-95% (Kappa=0.59-0.90). Although the Landsat-based classifications exhibited consistently higher accuracies than those of PALSAR, performance differences between the two sensors became negligible as the number of classes decreased.

The ability of PALSAR to classify and map forest cover, i.e., to discriminate forest from non-forest – the most important objective for REDD monitoring, was examined in particular detail (Fig 1). The highest overall accuracies for the forest/nonforest classifications were achieved with an error of less than 2.4% separating the PALSAR (92.4 ± 1.8%) and Landsat (94.8 ± 1.5%) results (Fig 1b). A high-resolution (25-m), PALSAR-based forest/nonforest map of the Xingu region was subsequently produced and was spatially compared with an analogous Landsat-based map (Fig 1a). The locational similarity of the two maps was assessed using a two-way fuzzy comparison, an approach that closely mimics the process of human visual comparison[11]. Overall agreement between the PALSAR- and Landsat-based forest cover products varied from 89.7% to 93.8%, with minor boundary discrepancies (e.g., locations of forest/field edges) being the primary source of spatial dissimilarity between maps. Additionally, we compared both the PALSAR- and Landsat-derived maps to a 2007 estimate of forest cover derived from PRODES, the pioneering deforestation monitoring program operationalized by the Brazilian National Institute for Space Research (INPE). High levels of agreement, ranging from 97.4-97.9%, were observed.

4. CONCLUSIONS

Our results confirm the effectiveness of ALOS/PALSAR as an accurate source for map-based estimates of forest cover in the Xingu region, nearly equaling those produced by Landsat, the most widely used sensor, and PRODES, the most highly regarded system, used to monitor tropical deforestation. Further work is needed in other parts of the humid tropics, such as Central Africa, where anthropogenic forest disturbance typically occurs at a finer scale (≤ 1 hectare) than that observed across much of Amazonia. With state-of-the-art radar data becoming increasingly accessible to the forest monitoring community, additional research is also needed to explore potential synergies between radar and optical data sources, with an emphasis on forest change detection using satellite-based, time-series data.

Overall, the research presented here provides further recognition of the expanding ability of space-based remote sensing to support not only international REDD activities but the broad range of local- to regional-scale forest monitoring applications. The work presented here is now being expanded pan-tropically[12]. A wall-to-wall PALSAR-based map of forest cover spanning the entire pan-tropical belt will be made publicly available in late 2010.

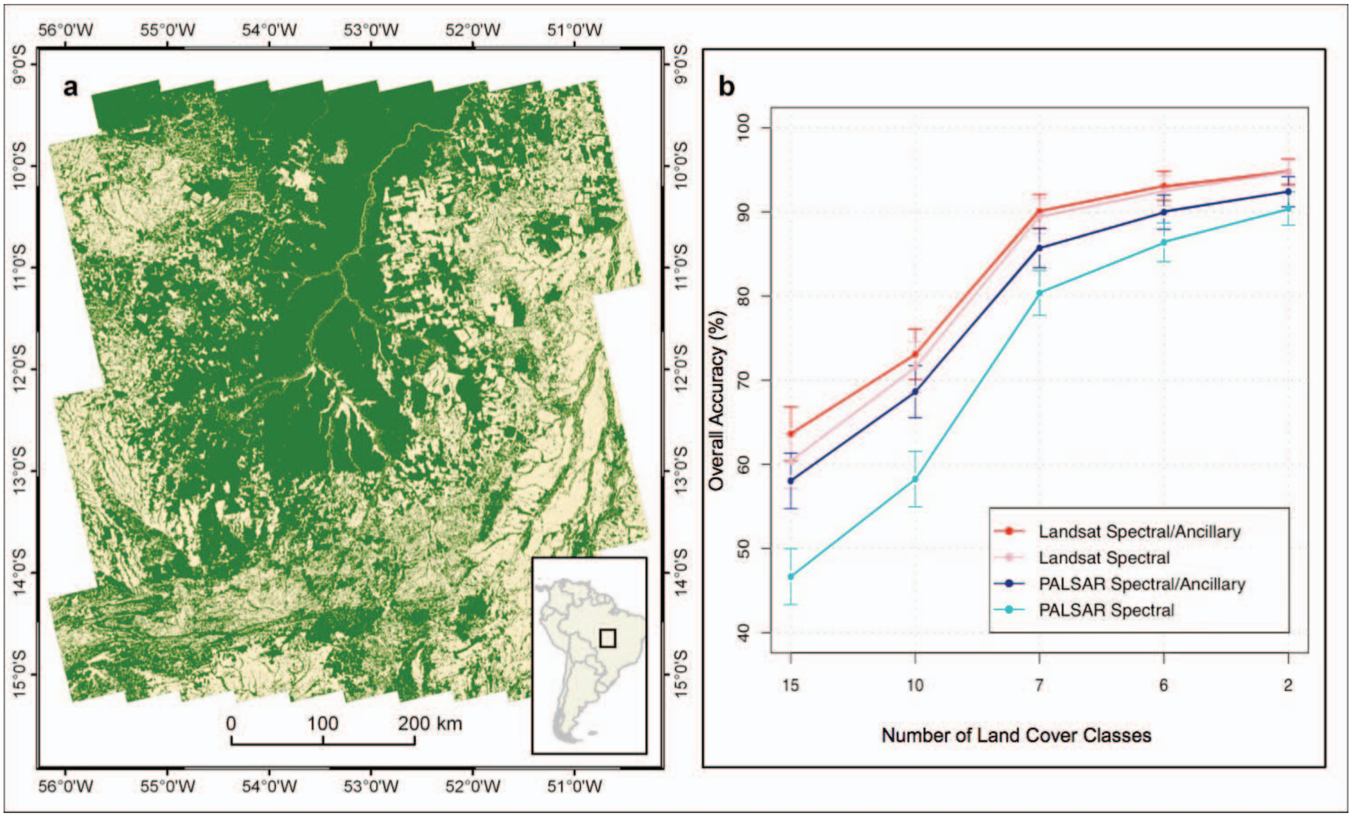

Figure 1. Land cover classification results. (a) Two-class PALSAR-based categorical map of the Xingu River headwaters region distinguishing forest (green) from nonforest (beige); overall classification accuracy = 92.4 ± 1.8%. (b) Overall accuracies associated with 20 separate PALSAR- and Landsat-derived land cover classifications. Numerical results and class-wise accuracies are included in Table 1 and Supplementary Appendices 1-20, respectively.

5. REFERENCES

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