High-resolution forest canopy height estimation in the African blue carbon ecosystem

Lagomasino, D. *et. al., Remote Sensing in Ecology and Conservation* (2015)

doi: 10.1002/rse2.3

Objectives:

- This study compared a high-resolution spaceborne imagery (HRSI) canopy height model using open-sourced routines with field measurements, derived ground measurements and updated shuttle radar topography mission (SRTM) canopy height measurements from the same region.
- The open-sourced routine used was NASA's Ames stereo pipeline (ASP), which was originally developed to provide high-quality digital surface elevation models (DSMs) and quick processing of HRSI stereo pairs from remotely-sensed planetary imagery.
- The first main objective of this study was to compare HRSI canopy height estimates with field surveys and with coarse-resolution (i.e. SRTM) remote sensing in mangrove forests in southern Mozambique.
- A second objective was to evaluate the adaptability of the ASP to accurately estimate bare ground and forest canopy surfaces.
- A third objective was to discuss the possibility for using HRSI canopy height maps as a technique to validate other spaceborne imagery products.
- The flat and low topography of mangrove forests allow for a presumptuously homogeneous soil surface elevation within the mangrove zone that can easily be subtracted from DSMs to obtain forest canopy heights.
- Three study areas were chosen in the southeastern Maputo Province of Mozambique, two on Inhaca Island and one in the Maputo Elephant Reserve.
- Field studies were conducted in 2005 on Inhaca Island and in 2008 in the Maputo Elephant reserve, with a total of 51 plots on Inhaca Island and 10 in the Elephant reserve.
- Three sets of orthorectified pairs of HRSI from World-View1 were collected over southeastern Maputo Province in September 2012; the two images for each set of stereopairs were collected in the same orbit with optimal viewing angles for better image accuracy and corrections.
- The ASP algorithm was used with HRSI stereo data to estimate a DSM that included the field measurement plots on Inhaca Island, the Machangulo Peninsula and the Maputo Elephant Reserve.
- The absence of accurate ground control points (typical of mangrove forests) in the study area limited the accuracy of the DSM; a horizontal accuracy of 5.5 m or less as expected for each DSM without the use of ground control points.
- The HRSI DSM was compared to coarse radar altimetry data collected from the SRTM mission in 2000.
- Canopy heights over the study area were estimated from both the finer 30 m (SRTM30) resolution and coarse resolution SRTM data, using a height correction equation.

New Science:

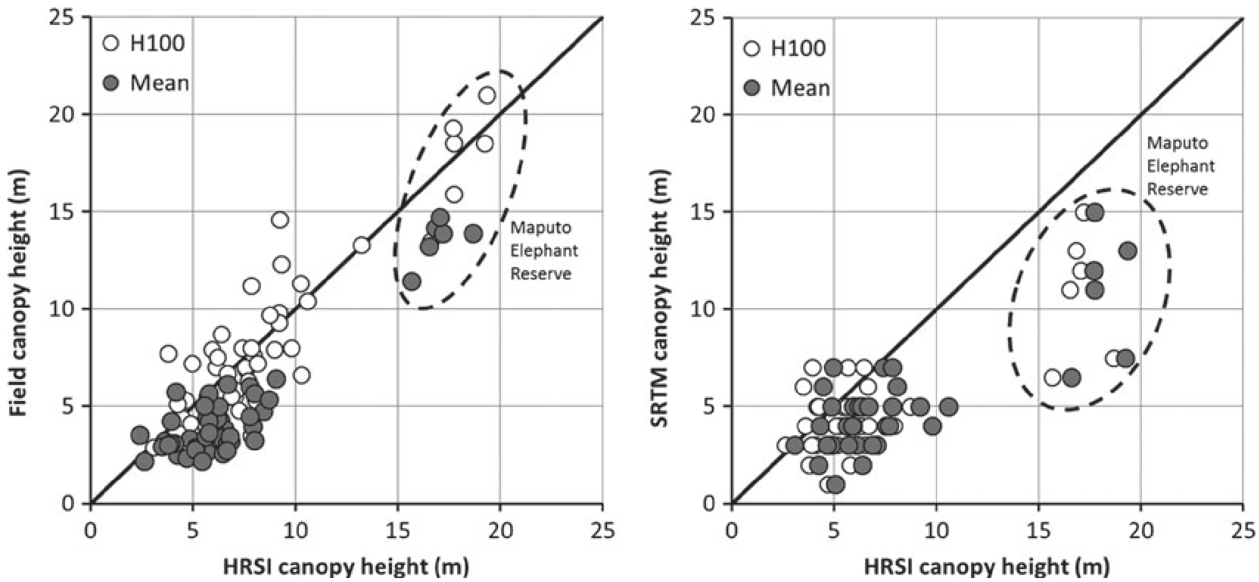
- This study demonstrated that HRSI is a useful and accurate tool for measuring canopy heights in Mangrove forests, allowing insights into regarding structure, function, and health of the ecosystems, as well as the aboveground carbon storage.
- The mean tree height and H100 (mean of 100 tallest trees) measured in both the field and with the digital canopy model provided the most accurate results with a vertical error of 1.18 – 1.84 m, respectively.
- Distinct patterns were identified in the HRSI canopy height map that could not be discerned from coarse shuttle radar topography mission canopy maps even though the mode and distribution of canopy heights were similar over the same area.
- The majority of mangroves taller than 10 m were located in the Maputo Elephant Reserve while shorter trees (less than 10 m height) were located on Inhaca Island and the Machangulo Peninsula.
- Despite the length of time separating the field measurement datasets (2005, 2008) and the SRTM data acquired in 2000, canopy height estimates using the ASP and HRSI from WorldView1 (collected in 2012) resulted in strong correlation between the mean and H100 canopy heights.
- The comparison between HRSI and SRTM height models reveals that the taller trees (>10m) tend to be underestimated using SRTM data.
- The low offset determined from the linear regression of field and HRSI canopy suggest that there was a near negligible vertical bias in canopy height using the ASP routines.

Significance:

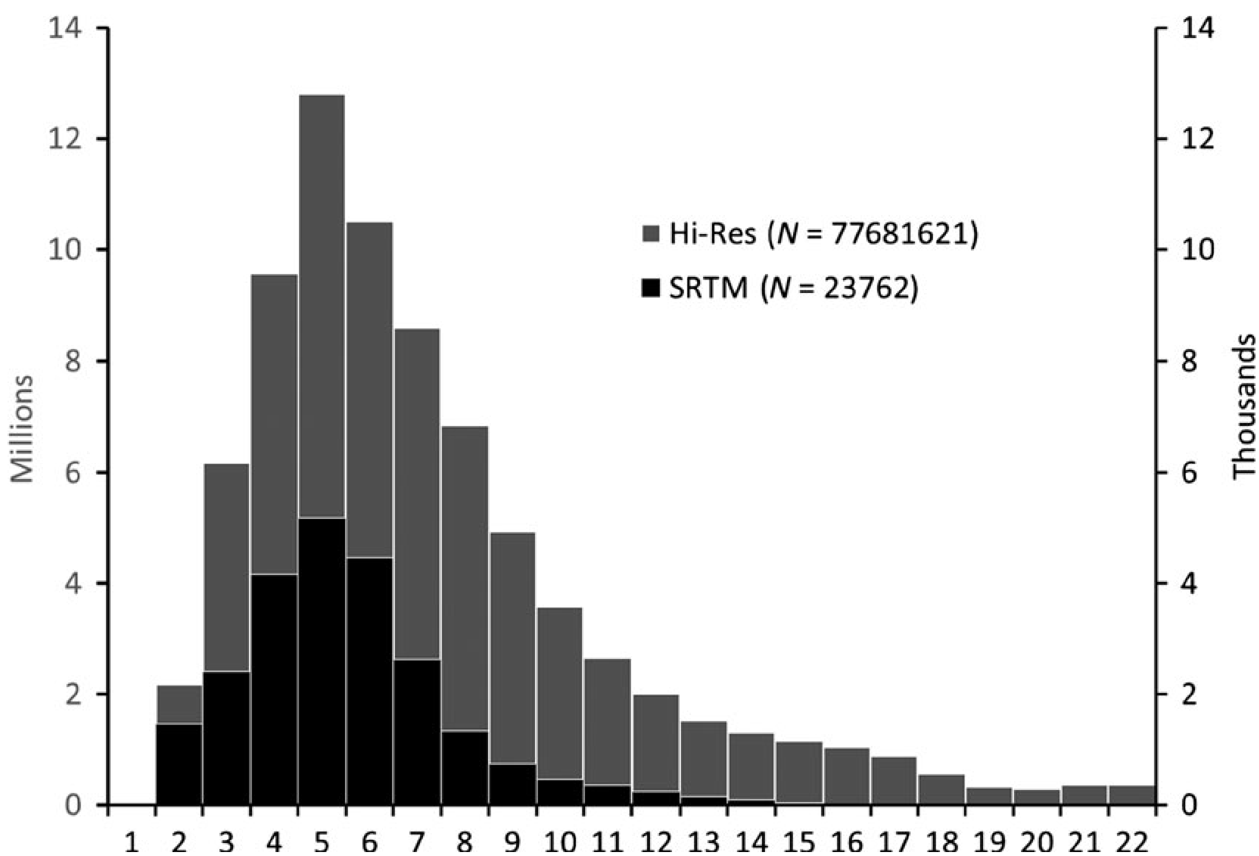
- Mangrove forests are some of the most productive blue carbon ecosystems and are of particular interest because of their large carbon storage pools and high rates of carbon sequestration that are two to four times higher than in mature tropical forests.
- Despite the surge in our scientific understanding of the carbon storage and sequestration dynamics in mangrove ecosystems, there is still uncertainty regarding the global above-ground carbon stocks and structures of mangroves.
- African mangrove forests have been largely absent from global carbon studies to date.
- Measuring above ground storage of carbon in mangrove forests is difficult, due to rapid mangrove forest degradation, limited accessibility, generalized global allometries, harsh field conditions and the difficult logistics of visiting and revisiting field sites.
- HRSI DSMs have the potential of providing a new type of three-dimensional dataset that could serve as a calibration/validation data for other DSMs generated from spaceborne datasets with much larger global coverage.
- HSRI DSMs could be used in lieu of Lidar acquisitions for canopy height and forest biomass estimation and be combined with passive optical data to improve land cover classifications.
- Adding HRSI to the repertoire of remote sensing of mangrove forest can provide researchers with more detail and create another layer of data integration to improve land cover, species and height classification maps and, ergo, develop more appropriate biomass and productivity models.
- The accuracy of HRSI DSMs in representing mangrove canopy height at the field scale could provide useful data for validating canopy height estimates from other

more globally available spaceborne imagery albeit with a scarcity of ground validation points.

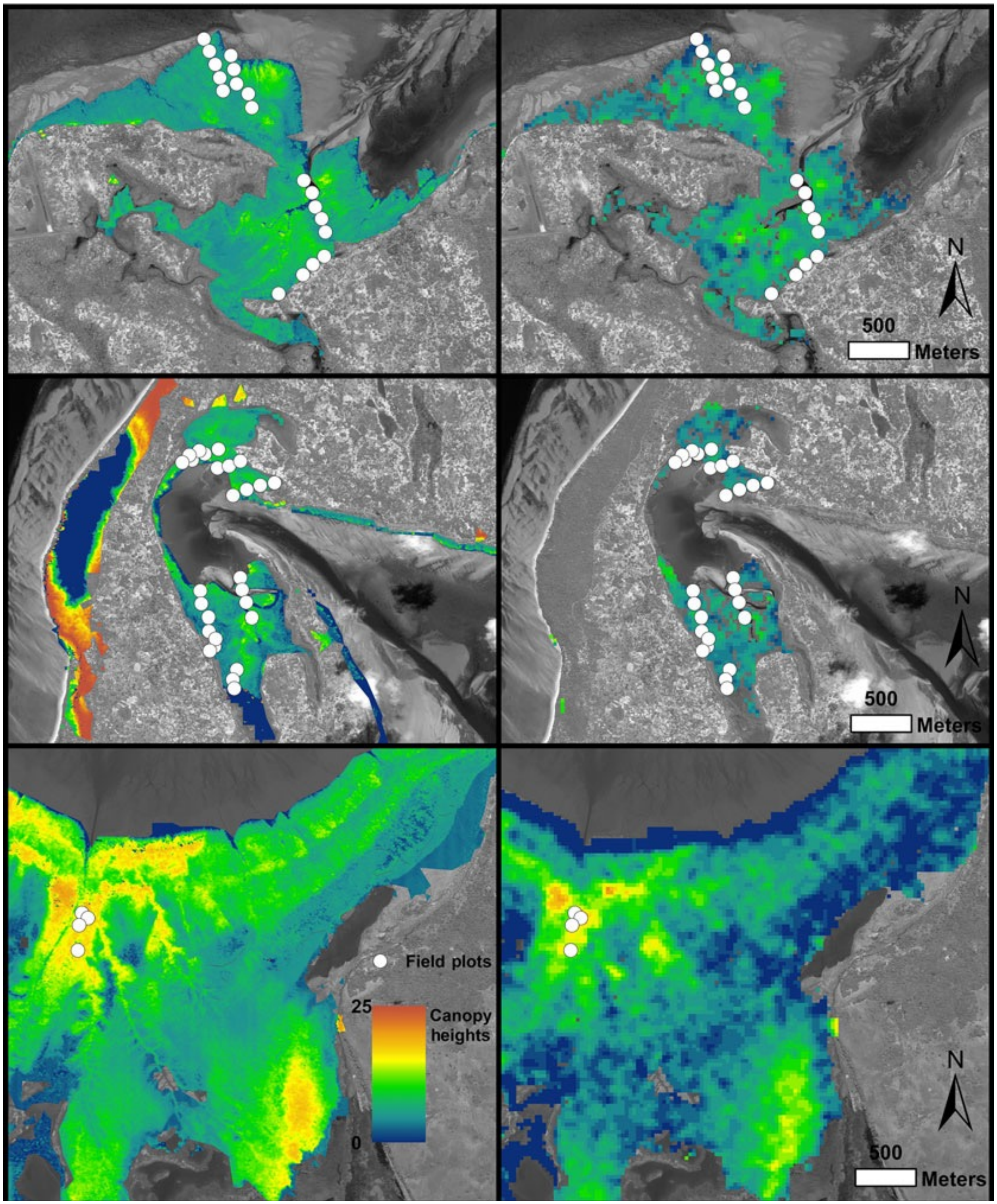
- Remote sensing estimates of aboveground biomass derived from tree height allometry would be improved by HRSI because of the higher accuracy at taller tree canopies.
- HRSI DSMs could serve as supplementary independent comparisons to global surface models and enhance their accuracy and could also be combined with biomass models and species zonation to improve classification cover.



Above: (A) Relationship between high-resolution spaceborne imagery (HRSI) canopy heights and field surveyed canopy heights. (B) Relationship between the HRSI canopy height (H100 and mean) with SRTM30 heights. Field measurements from Fatoyinbo et al. (2008). Black line represents 1:1.



Frequency distributions of high-resolution spaceborne imagery (HRSI) and shuttle radar topography mission (SRTM)30-derived canopy height estimates. Canopy heights were binned into 1 m height intervals. N equals the number of pixels used in the distribution. Despite the difference between the spatial scales and the number of pixels of the HRSI and SRTM data, the frequency distribution of height classes is very similar in both datasets.



Canopy height map comparisons for Inhaca Island (A and B) and Maputo Elephant Reserve (C) between high-resolution spaceborne imagery digital surface models (DSM) (left) and SRTM30 DSM (right). See Figure 1 (in the paper) for site location reference.