Above-ground biomass estimates using systematic sampling frameworks integrating LiDAR with other remotely sensed data.

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There is a need for transparent and verifiable biomass estimation at site, project, regional and national scales, and the ability to move up and down through scales for the purposes of calibration, validation, transparency and repeatability. To address these needs a major sampling program was undertaken to estimate biomass in forests and woodlands in a 220,000ha study site near Injune, central Queensland, Australia. A primary aim of the work is to reliably estimate biomass at very fine scales for sample-based assessment and monitoring, as well as calibration of other larger scale wall-to-wall mapping sensors for carbon accounting over large areas. This is achieved through a number of collaborative projects [1], [2], [3], [4], [5].

The multi-phase and multi-stage inventory framework established a systematic sampling scheme on a 4km grid comprised of 150 primary sampling units (PSU), of 7.5 ha which constituted 0.5% of the study area [6]. Airborne scanning lidar was collected within each PSU, with large-scale (1:4000) photography (LSP) collected over 81ha centred on each PSU. Detailed field surveys were undertaken in 35 ¼ ha plots, within 13 PSU's. Landsat TM, radar [3] and hyper-spectral [4] imagery provided wall-to-wall assessments. Core attributes collected by various methods included species, forest structure, growth stage, biomass, disturbance, and 10 year broad land cover change [7].

Ground based biomass estimates used DBH, species, top height, and destructive harvesting of key species, with locally derived and existing allometric equations. Lidar derived biomass was estimated by slicing lidar point data horizontally in 5 metre increments producing foliage density surfaces, then applying a step-wise linear regression between the density surfaces and field based biomass estimates. This resulted in a strong linear relationship with an adjusted r^2 of 0.89 and SE of 11.01tha^{-1}. As field derived biomass estimates are not without error, further analysis found that 69% of the lidar estimates fell within the 95% confidence limits of field data, and a t-test revealed no significant difference between the two estimation methods [6]. Lidar derived biomass estimates were tested against broad forest types derived from LSP and positive trends in median and quartile ranges of biomass were found with increasing forest cover and between broad genii. For example open woodland eucalypts had a median biomass of 60 t/ha (-2t/ha, +8t/ha at 95% confidence), while closed eucalypt forests were 95 t/ha (–2t/ha, +14t/ha at 95% confidence) [8]. Overall median biomass for forests in the study area ranged from 42t/ha through 131t/ha (see Figure 1), which compares well against existing site based [9] and broader continental scale biomass estimates [10], [11].

Using simple, two-phase regression estimation techniques to correct for any biases, lidar can produce fully automated estimates of cover, height and biomass over large, remote, and structurally complex forest areas at a fraction of the cost of doing it in the field. In this study we produced 4,500 0.25 hectare estimates across 220,000 hectares least as accurate and potentially more precise than ground-based methods for approximately AU$120,000 including labour, with no economies of scale. We have also demonstrated that the quality, efficiency and cost effectiveness of many existing satellite-based mapping and monitoring programs could be improved using an integrated framework such as the one presented here.

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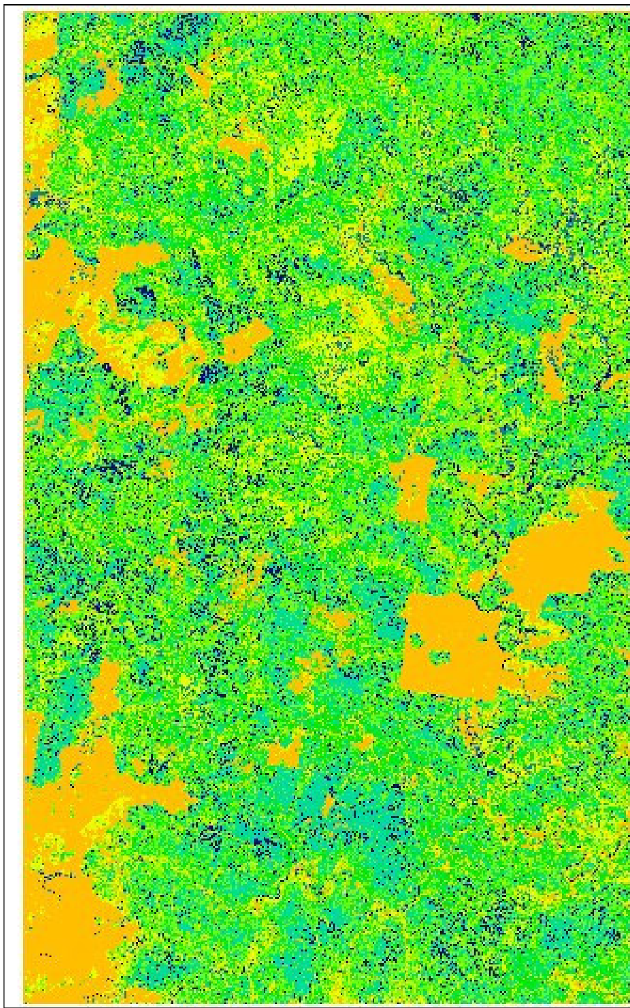

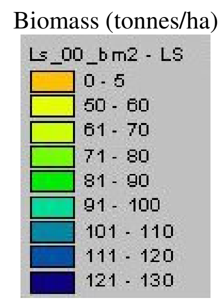

Figure 1. Above ground biomass for the 220,000ha study area, using Landsat TM calibrated with lidar derived biomass and LSP mapped forest types.