The Forest Degradation Experiment (FODEX)

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1. Introduction

The FODEX (Forest Degradation Experiment) is a 5-year project that aims to shed new light on the status of the world's tropical forests and how they are changing in response to human activities. Tropical forests and woodlands are estimated to contain 300 billion tonnes of carbon (Santoro et al. 2020), however we still don't know with any certainty whether these carbon stocks are increasing, or decreasing over time. This is in part because existing static maps of carbon stocks typically have wide uncertainties (±50 %) (Mitchard et al. 2014), which precludes accurate and precise change detection. Maps of change are therefore rare (McNicol et al. 2018), and often not validated, and when they are, often no relationship is found between field- and remote sensing-estimated changes (Meyer et al. 2013). The project will address this uncertainty by developing new methods for mapping carbon stock change using satellite data, allowing us to accurately assess the balance of regrowth and anthropogenic disturbance across tropical forests and the status and resilience of the land surface carbon sink.

2. Methodology and data

Figure 1 – The contrasting structure of the two sites is a central part of the project. Both images are taken inside our field plots
(top: Gabon, bottom: Peru)

1.1 Approach

This project is based on twin large scale field manipulation experiments located in Peru (Madre de Dios) and Gabon (Ivindo) where we are collecting Terrestrial Laser Scanning (TLS) data alongside traditional forest inventory data before and after controlled logging, meaning the change in aboveground tree volume and biomass (AGB) can be calculated with minimal error and used to train and test models of change. These data will be scaled using LiDAR data collected using a 3.3m wingspan UAV (Delair DT26X UAV) equipped with a Riegl miniVUX, and a 24 MP camera. The UAV has a nominal flight time of 50 - 70 minutes, and can cover 100 – 120 ha in a single flight, and so is capable generating high resolution data that is otherwise unobtainable using ground and/or satellite based platforms. From this, it is possible to derive large scale measurements of several tree biophysical properties such as height, crown dimensions, and vertical structure, while in some areas, the resolution and detail is such that individual trees can segmented (Puliti et al. abstract # 82). Using these data, we aim to generate thousands of hectares of biomass change data, which will then act as a basis for satellite-based methods to generate estimates across the tropics.

1.2 Data

The initial data collection (pre-logging) was conducted in 2019, and early 2020. At each site, four x 1- ha (100 x 100 m) plots were established and all trees >10 cm diameter measured, along with data on x,y position, tree condition, and species. Sites were selected to encompass a range of trees suitable for logging to allow a varying

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intensity of logging between plots. The initial aim was to extract 10– 50% of the initial AGB, however in both areas, the number of trees required to achieve these values greatly exceeded the maximum number of trees permitted under FSC rules, meaning we targeted the extraction of 5 – 25% of the initial plot AGB, as estimated through the forest inventory data. The TLS data were collected concomitantly, with measurements taken at the intersections of a 10 x 10 m grid laid out across the plot. The UAV flights were also conducted during the same measurement campaign over a period of 7 days at each site, with missions performed in perpendicular lines and at a nominal altitude of 100 – 130 m above the ground surface with an average flight speed of 17 m/s (61 km/h). This results in a swath width of 100 – 120 m, with an average flight line spacing of 25 m (based on 70 – 80 % overlap), and a maximum laser beam footprint at ground level of 20 – 30 cm, reducing to 10 – 15 cm at the top of the canopy (40 – 50 m). The final post processed LiDAR point clouds have densities ranging from 250 – 1000 points m^2 in Peru, and 220 – 900 points m^2 in Gabon.

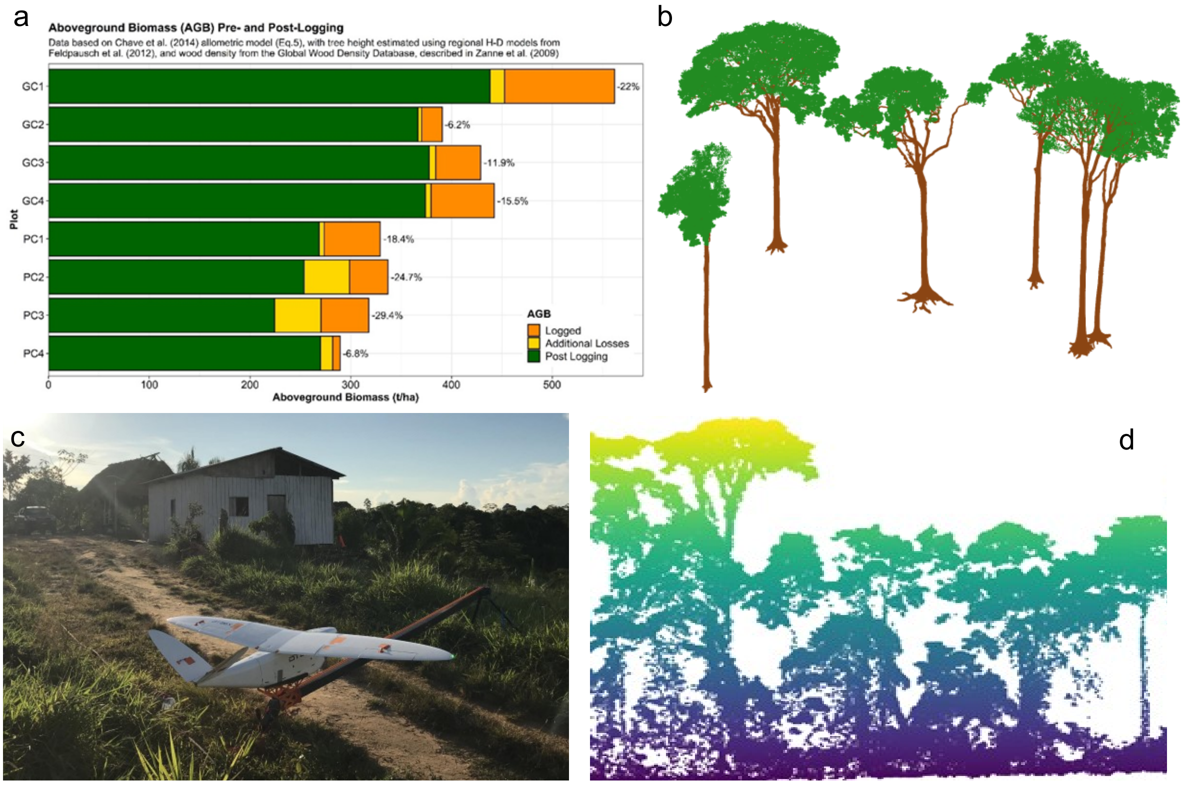
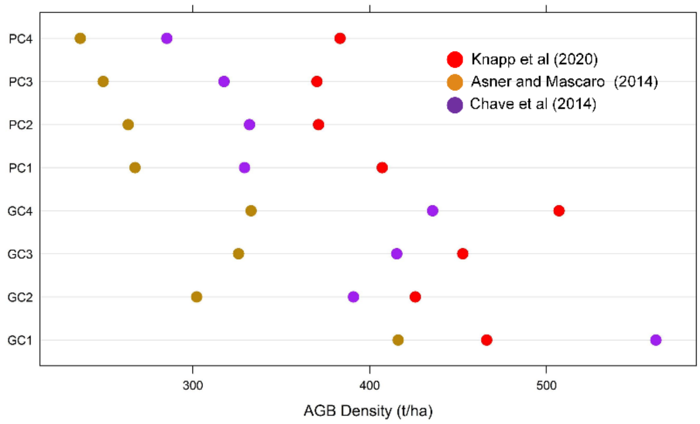


Figure 2 – Aboveground biomass stocks measured before and after logging using traditional inventory data (a). Terrestrial Laser Scanning will provide an improved basis for estimating the change in tree volume/ biomass (b), which will then be scaled using high resolution LiDAR data collected by our fixed wing UAV (c, d). The segmented trees in (b) were derived from TLS data collected in Gabon, and are 5 trees (of 8) that were logged in a single plot The image in (c) was taken before take-off in Peru, and (d) shows a cross section of a forest patch in Gabon.

3. Results

Forest structure varies markedly across, and between our two study regions, with tree canopy heights in Gabon reaching 35 – 50 m in areas with a tree fractional cover > 50%, compared to 25 – 40 m in Peru, based on the UAV-LS data (Figures 1 and 2). Despite their comparatively low stature, the Peruvian forests are structurally more complex, with a clear sub-canopy layer 10 – 15 m in height whereas in Gabon, there is typically a single dominant tree layer varying little in height.

The inventory-based estimates of AGB were broadly consistent between field plots (Figure 2; Figure 3), with the %AGB extracted increasing (5 – 30 %) once collateral damage from tree felling and



removal was accounted for. Using a combination of the UAV-LS data, the forest inventory data, and a variety of published field and LiDAR based models (Asner and Mascaro et al. 2014; Knapp et al. 2020), we find wide range of biomass values for each plot (Figure 3). The TLS data will provide, in due course, accurate and precise estimates of AGB density and loss in each plot, against which changes will be compared, and new + existing methods validated.

Figure 3 - Applying different biomass estimation models yields very different results, which will be compared to the changes derived from the TLS data

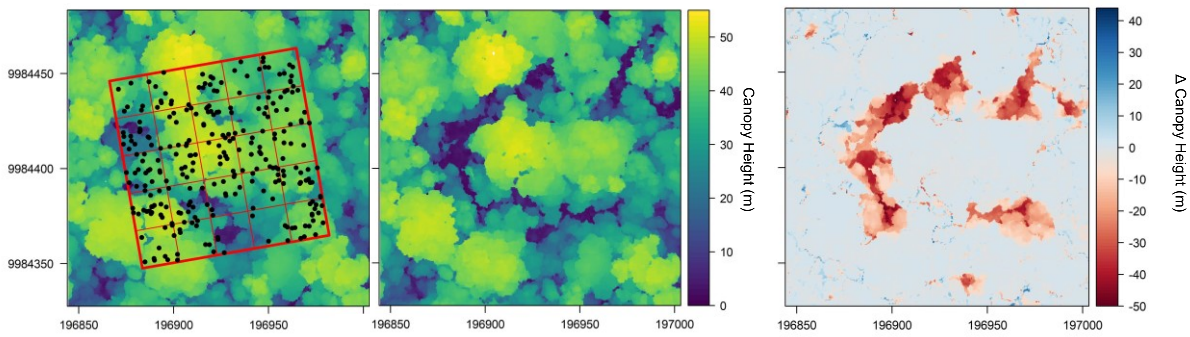


Figure 4 – (a) The change in tree canopy height after logging in and around one of the core 1-ha inventory plots in Gabon (GC4) where 16% of the initial AGB was removed.

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