

# NERC GEF GNSS Loan 1109 – Scientific Report

## The Tropical Forest Degradation Experiment (FODEX) and CongoPeat

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### 1. Abstract

The purpose of Loan 1109 was to support the deployment of an Unmanned Aerial Vehicle (UAV) collecting LiDAR data and digital aerial photographs (DAP) over remote tropical forests and peatlands in the Republic of Congo, Peru and Gabon. These data were obtained as part of two projects entitled **CongoPeat** and **FODEX (Tropical Forest Degradation Experiment)**, with data collection taking place in February 2019 and June - July 2019, respectively. The aim of the CongoPeat campaign was to measure changes in surface elevation across sections of the world's largest tropical peatland complex in the Congo Basin, providing clues to its formation and functioning. The LiDAR data revealed a clear rise in surface elevation, thus indicating a domed structure, which suggests the peatland is rain-fed. Accurately mapping these subtle changes in elevation was greatly improved using the GNSS receivers. The objective of the FODEX campaigns to Peru and Gabon was to establish forest inventory plots and conduct LiDAR and photogrammetry surveys prior to the sites being logged. These were first of several campaigns that will measure and monitor changes in forest structure and carbon stocks following human disturbance. The data collected under Loan 1109 was used to assess the extent to which 'Structure from Motion' (SfM) techniques can replicate LiDAR data across forests of varying density and structure. Technical problems meant the pre-logging data collection at our second field site in Gabon, scheduled for September 2019, was postponed until January 2020 and thus falls under Loan 1124, although some of the final results are included in this report for completeness. We find that SfM data cannot be considered a reliable substitute for LiDAR, particularly in tall forests with a canopy cover >80%. The results have clear relevance for projects seeking to measure and monitor tropical forest structure and biomass by highlighting the need for LiDAR data.

### 2. Background

**The FODEX (Forest Degradation Experiment)** is a 5-year experiment (July 2018 – July 2023) 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 around 375 billion tonnes of carbon [1], 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 [2] typically have wide uncertainties ( $\pm 50\%$ ) [3]. Maps of change are rare and often not validated [4], and when they are, often no relationship is found between field- and remote sensing-estimated changes [5]. The project will address this uncertainty by developing new methods for mapping carbon stock change using satellites, 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.

This will be achieved using twin large scale field manipulation experiments located in the Peru and Gabon (Figure 1), where we are collecting Terrestrial Laser Scanning (TLS) data alongside traditional forest inventory techniques before and after controlled logging



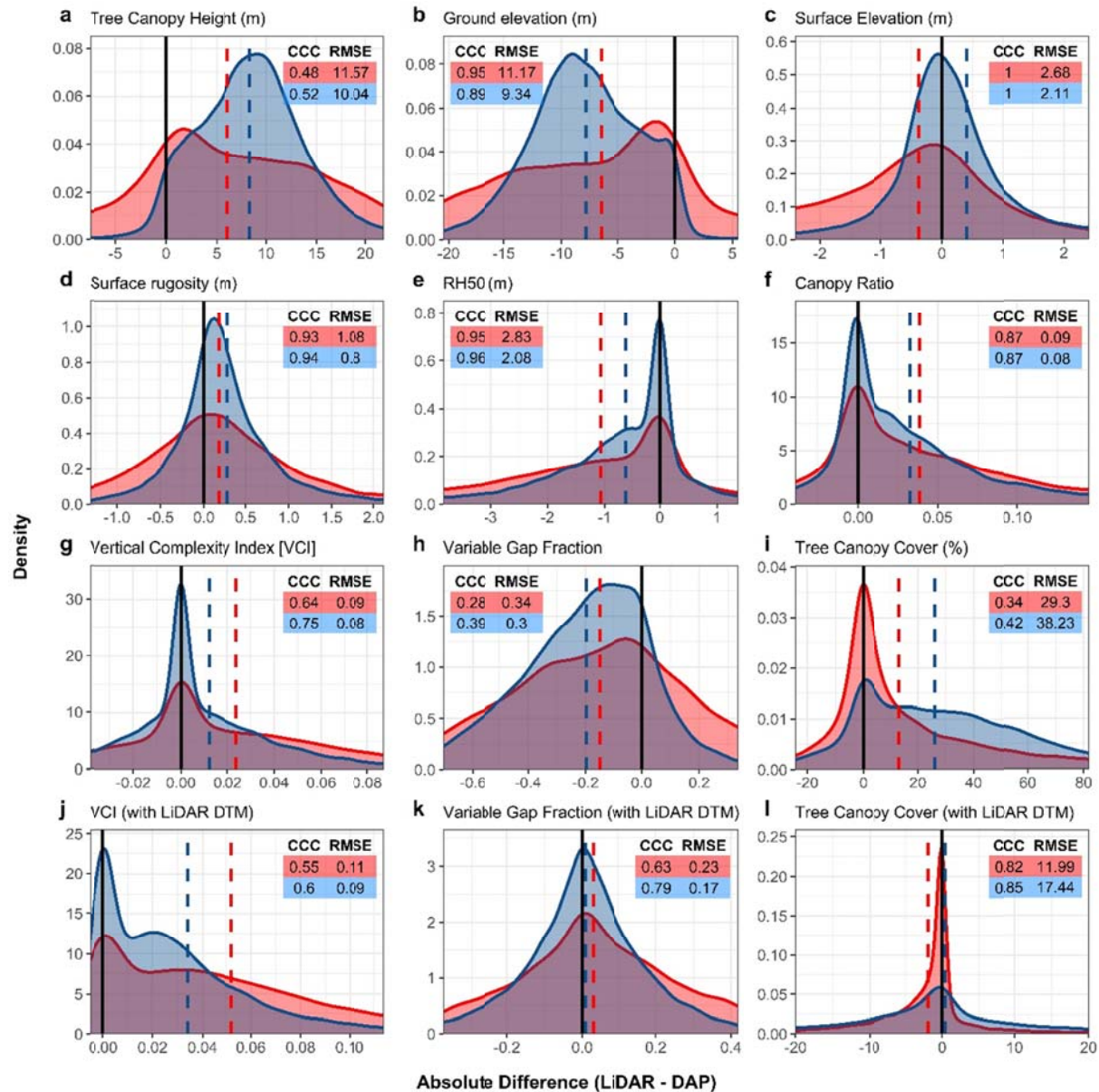








height (DTM), with errors rapidly increasing in areas with a tree canopy cover >80%, and a tree height > 20 m. The measured top-of-canopy surface heights (DSM) showed greater correspondence, particularly when derived at larger resolutions (i.e. > 0.5 ha) suggesting SfM can be used for relatively coarse scale change detection. Other structural metrics considered important for biomass estimation also showed marked variations between methods, with SfM typically underestimating both horizontal and vertical structural complexity. These inconsistencies are likely to have a large impact on the accuracy of biomass estimates derived using these metrics, and the ability of SfM to identify and monitor changes in both canopy and sub-canopy layers.



**Figure 5** – Comparison of UAV LiDAR and SfM derived forest structural metrics in Gabon (Red) and Peru (Blue)

## 7. Data Archive

All of D-GNSS raw data are stored in the NERC GEF facility hard drives in Edinburgh. In addition, geo-referenced and registered UAV-LiDAR data in the .las format, and Digital Area

Photographs are stored on the Mitchard Research Group Datastore, which is located on the University of Edinburgh servers and automatically backed-up. The raw data will also be deposited on the Edinburgh DataShare repository (<https://datashare.is.ed.ac.uk/>) where it will be freely available for sharing. The data will also be stored at the NERC Centre for Environmental Data Analysis (CEDA) [<https://www.ceda.ac.uk/>].

## 8. Conclusions

The work conducted under Loan 1109 was deemed a success, paving the way for future field campaigns on the FODEX project. The GNSS data were critical to this achievement, allowing us to perform the necessary PPK corrections on the UAV flight trajectories, and collect valuable GCPs, which aided the construction of the 3D point clouds. The data collected has already led to one publication [7], with another likely to be submitted in October 2020. Future research efforts on the FODEX will focus on the collection of LiDAR and DAP post logging, with fieldwork provisionally scheduled for January (Gabon) and June (Peru) 2021.

## 9. Publications (including conference presentations)

Davenport, I.J, McNicol, I.M, Mitchard E.T.A and others... (2020) First Evidence of Peat Domes in the Congo Basin using LiDAR from a Fixed-Wing Drone. *Remote Sensing*. 12 (14), 2196

Davenport, I.J, McNicol, I.M, Mitchard E.T.A and others... (2020) Spaceborne LiDAR gives first evidence of peat domes in the Congo Basin. EGU General Assembly Conference Abstracts, 9909

McNicol, I.M., Mitchard, E.T.A. and others ... (in prep) Comparisons of forest structural metrics derived from UAV LiDAR and Structure from Motion Photogrammetry in tropical forests.

## 10. References

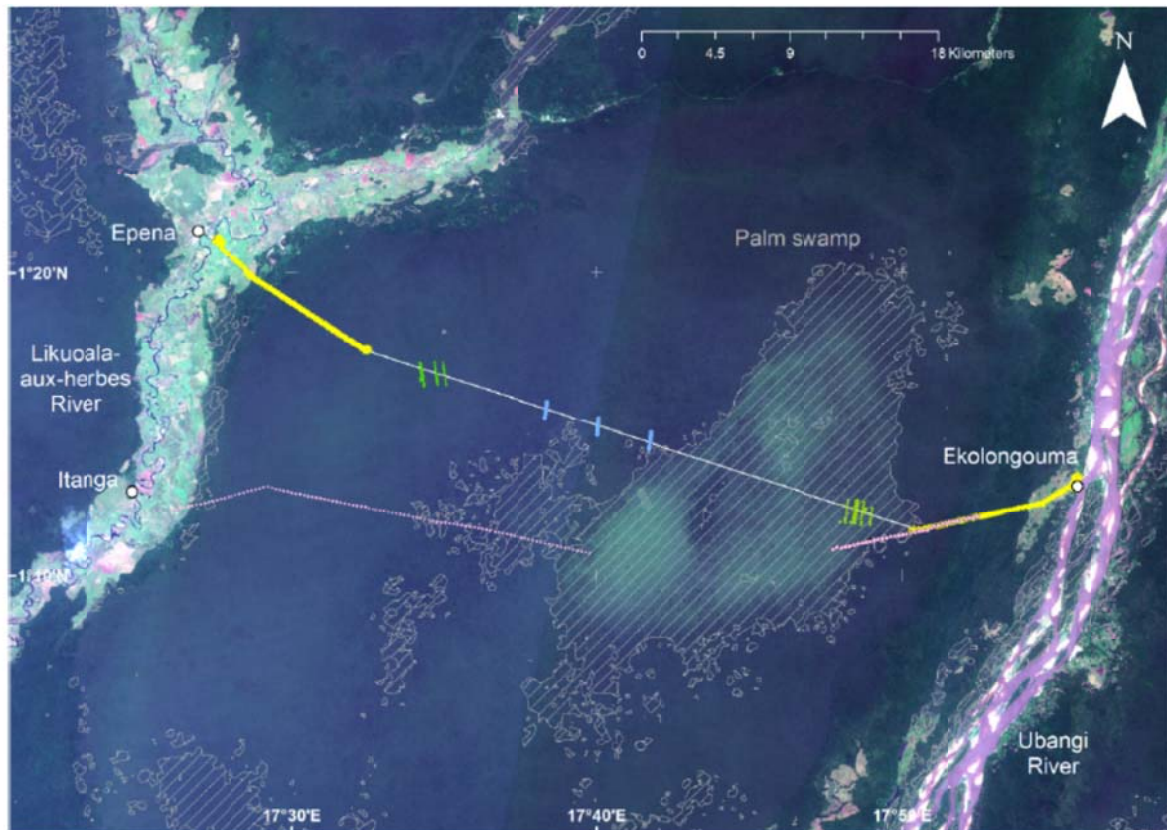
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  7. Davenport, I.J.; McNicol, I.; Mitchard, E.T.; Dargie, G.; Suspense, I.; Milongo, B.; Bocko, Y.E.; Hawthorne, D.; Lawson, I.; Baird, A.J.; et al. First evidence of peat domes in the congo basin using LiDAR from a fixed-wing drone. *Remote Sens.* **2020**, *12*, doi:10.3390/rs12142196.

**Table 1** – GNSS data collected in Peru, including the location of the base station, and the GCPs/ Tie Points (TPs) which fell under the UAV flight paths.

| <b>Point</b> | <b>Point Role</b> | <b>Easting</b>  | <b>Northing</b> | <b>Ellip. Height</b> | <b>Geoid Separation</b> |                 |               |
|--------------|-------------------|-----------------|-----------------|----------------------|-------------------------|-----------------|---------------|
| <b>Base</b>  |                   | <b>420079.6</b> | <b>8786861</b>  | <b>273.274</b>       | <b>29.5783</b>          |                 |               |
| <b>Point</b> | <b>Point Role</b> | <b>Easting</b>  | <b>Northing</b> | <b>Height</b>        | <b>Difference</b>       |                 |               |
|              |                   |                 |                 |                      | <b>Easting</b>          | <b>Northing</b> | <b>Height</b> |
| <b>GCP1</b>  | <b>Averaged</b>   | <b>421639.3</b> | <b>8781522</b>  | <b>327.3296</b>      | -0.0183                 | -0.004          | -0.0022       |
|              | 1                 | 421639.3        | 8781522         | 327.3284             |                         |                 |               |
|              | 2                 | 421639.3        | 8781522         | 327.3306             |                         |                 |               |
| <b>GCP2</b>  | <b>Averaged</b>   | <b>421804.7</b> | <b>8781473</b>  | <b>326.8475</b>      | -0.0684                 | 0.016           | 0.6371        |
|              | 1                 | 421804.7        | 8781473         | 326.8475             |                         |                 |               |
|              | 2                 | 421804.8        | 8781473         | 326.2104             |                         |                 |               |
| <b>GCP3</b>  | <b>Averaged</b>   | <b>421381.3</b> | <b>8781155</b>  | <b>325.5215</b>      | -0.0184                 | 0.003           | 0.005         |
|              | 1                 | 421381.3        | 8781155         | 325.5243             |                         |                 |               |
|              | 2                 | 421381.3        | 8781155         | 325.5193             |                         |                 |               |
| <b>GCP4</b>  | <b>Averaged</b>   | <b>421235.8</b> | <b>8780861</b>  | <b>320.1918</b>      | -0.0288                 | -0.019          | -0.0093       |
|              | 1                 | 421235.8        | 8780861         | 320.1883             |                         |                 |               |
|              | 2                 | 421235.8        | 8780861         | 320.1976             |                         |                 |               |
| <b>GCP5</b>  | <b>Averaged</b>   | <b>421044.1</b> | <b>8780535</b>  | <b>332.8154</b>      | -0.0079                 | 0.035           | -0.1253       |
|              | 1                 | 421044.1        | 8780535         | 332.8154             |                         |                 |               |
|              | 2                 | 421044.1        | 8780535         | 332.9407             |                         |                 |               |
| <b>GCP6</b>  | <b>Averaged</b>   | <b>420038.3</b> | <b>8786857</b>  | <b>272.6122</b>      | -0.0004                 | -0.001          | -0.0034       |
|              | 1                 | 420038.3        | 8786857         | 272.6102             |                         |                 |               |
|              | 2                 | 420038.3        | 8786857         | 272.6136             |                         |                 |               |
| <b>GCP7</b>  | <b>Averaged</b>   | <b>421016</b>   | <b>8785132</b>  | <b>314.8272</b>      | -0.0038                 | -0.014          | 0.0024        |
|              | 1                 | 421016          | 8785132         | 314.828              |                         |                 |               |
|              | 2                 | 421016          | 8785132         | 314.8256             |                         |                 |               |
| <b>TP01</b>  | <b>Averaged</b>   | <b>420102.6</b> | <b>8786876</b>  | <b>273.195</b>       | 0.0554                  | 0.025           | 0.0053        |
|              | 1                 | 420102.7        | 8786876         | 273.1964             |                         |                 |               |
|              | 2                 | 420102.6        | 8786876         | 273.1911             |                         |                 |               |
| <b>TP03</b>  | <b>Averaged</b>   | <b>419994.3</b> | <b>8786652</b>  | <b>285.5743</b>      | 0.0023                  | -0.009          | 0.0085        |
|              | 1                 | 419994.3        | 8786652         | 285.5762             |                         |                 |               |
|              | 2                 | 419994.3        | 8786652         | 285.5677             |                         |                 |               |
| <b>TP02</b>  | 1                 | 420061.7        | 8786701         | 276.2394             |                         |                 |               |
| <b>TP04</b>  | 1                 | 419881.7        | 8786687         | 288.4827             |                         |                 |               |
| <b>TP06</b>  | 1                 | 421158.9        | 8784593         | 340.7131             |                         |                 |               |
| <b>GCP8</b>  | 1                 | 420677.3        | 8785719         | 295.7524             |                         |                 |               |
| <b>GCP9</b>  | 1                 | 420667.4        | 8785559         | 288.6213             |                         |                 |               |
| <b>GCP10</b> | 1                 | 420798.8        | 8786036         | 289.0394             |                         |                 |               |



**Figure 6** - The locations of acquired data UAV LiDAR (yellow), IceSat (green), IceSat2 (blue) and the area believed to be palm swamp (white hatched). A white line joins the LiDAR transects forming a path between the peat edges 43.8 km long, compared to 43.3 km direct-line distance. Background image is a Sentinel-2 composite, Copyright European Space Agency. The base station area shown by white dots. Image taken from our own published paper by Davenport et al. [7]