Carbon sequestration & regreening by Kenyan smallholder farmers: Methods supplement

Joshua Buxton[1], Guy Lomax[1,2], Tom Powell[1], Rudy Arthur[2], Arwen Nicholson[1,2], Chris Boulton[1,2], Hywel Williams[2], Tim Lenton[1]

[1]Global Systems Institute, University of Exeter

[2]Institute for Data Science and Artificial Intelligence, University of Exeter

Contact: t.powell@exeter.ac.uk

UNIVERSITY OF EXETER | GLOBAL SYSTEMS INSTITUTE | INSTITUTE FOR DATA SCIENCE AND ARTIFICIAL INTELLIGENCE

tist
The International Small Group and Tree Planting Program

The Alan Turing Institute | GCRF | LEVERHULME TRUST

TIST program structure

Farmers join TIST as members of a **small group** of 6-12 individuals, who live close to one another. On joining, farmers establish a tree **grove** set as a recorded GPS track, within which they plant trees of whatever number and species suit them. 30-50 small groups form a **cluster**, at which representatives from each small group meet once per month. Clusters have rotational leadership which alternates between male and female leaders.

Cluster meetings are facilitated by a '**cluster servant**' (CS), who is a farmer trained in facilitation, delivering trainings, and quantifying tree growth. In each country the network is organised and administered by a national **leadership council**. Information is shared across the network via regular newsletters in multiple languages, and by communication between cluster leaders and CSs.

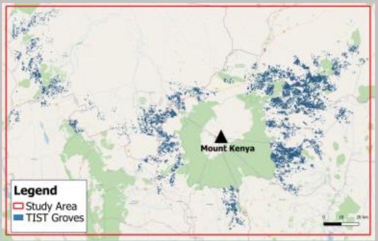
Tree growth monitoring and verification

CSs visit each grove in the clusters they serve at least once every 1.5-3 years. All trees present within the predefined GPS track are counted. Trees are divided into individual age classes for each species, and diameter at breast height (DBH) measurements are recorded for a representative sample of each age and species class. Measurements are uploaded from the field to a central database.

Carbon credits are generated from DBH data using Verified Carbon Standard (VCS) methodologies, and independently verified and audited by Verra.

Study area

The study area was chosen to represent the largest group of TIST farmers in Kenya. This was in the vicinity of Mount Kenya and the Aberdare mountains.



Quantifying carbon sequestration

We analysed 4.7 million individual tree circumference measurements made by Kenyan TIST farmers from 2004 to 2018. These measurements were a sample of the full population of TIST trees.

To estimate sequestration over time, we sampled the dataset at three month intervals and extracted the most recent measurements for each site in each interval.

After data cleaning, we used allometric equations to convert tree circumference to above-ground biomass. We used locally derived equations for the two most common species planted, *Grevillea robusta* and *Eucalyptus grandis*[1] (Kuyah et al., 2013; Owate et al., 2018). For other species, we used a single pantropical equation based on wood density (Chave et al., 2014).

We then used species-specific root-to-shoot ratios to estimate root biomass and converted total biomass to CO_2 storage assuming an average carbon content of 0.482 kg C / kg dry biomass (Thomas et al., 2012) and a CO_2:C ratio of 44/12.

For each age class sampled by TIST, we multiplied the mean biomass of sampled trees in that class to the full population of trees in that class on each TIST farm.

Data analysis was done in R.

[1] *Eucalyptus was widely planted until 2012. TIST has since discouraged its use in favour of other species.*

References

Chave et al., (2014). *Glob. Chang. Biol.* **20**, 3177-3190

Kuyah et al., (2013). *Biomass & Bioenergy.* **55**, 276-284

Owate et al., (2018). *Int. J. For. Res.* **2018**

Thomas et al., (2012). *Forests*. **3**, 332-353.

Measuring greening trends

We used 2000-2019 Landsat 7 data to measure trends in NDVI across agricultural land near Mount Kenya. This data was processed with Google Earth Engine (Gorelich et al., 2017) before it was exported to QGIS and Matlab.

Following the calculation of Landsat 7 NDVI, a monthly maximum value composite was created to minimise cloud, air pollution and aerosol influence (Holben, 1986).

To remove the seasonal cycle, a multi-annual monthly average dataset was subtracted from this monthly composite. A 12-month moving average was then calculated to create a continuous, detrended time series for each pixel.

The Kendall Tau coefficient, a rank correlation measure, was calculated for each of these detrended time series, with positive values representing greening and negative representing browning.

Pixels within agricultural land, as defined by the FAO (2000), were selected and further classified as TIST grove pixels and non-TIST pixels.

Due to the nature of tree planting by TIST members, areas defined as TIST groves usually include a mixture of continuous tree cover, crops interplanted with trees, and continuous crop cover. Observed greening trends thus capture wider impacts than those specifically attributed to increased tree cover

TIST neighbour pixels were determined by whether their centroids fell within a buffer area around TIST groves.

References

FAO (2000) http://www.fao.org/geospatial/projects/detail/en/c/1035404/ (Accessed: 01/12/2019)

Gorelich, N. et al., (2017) *Remote sensing of Environment*, ***202***, pp.18-27.

Holben, B. (1986) *Internatio Journal of Remote Sensing*, **7**, 1417-1434