Impact of Land Change on Aboveground Carbon Stocks in the Taita Hills, Kenya

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Key Concepts

Land use / land cover change (=land change)
Human arrangements / observable properties

Carbon stocks
Terrestrial
Aboveground
~ 50% of woody biomass
In this study: Trees with trunk diameter > 10 cm
Post-industrial carbon cycle

ATMOSPHERE
589 ± 240 ±10 (PgC)

- Oceanic-atmosphere gas exchange
- Gross photosynthesis, Rock weathering
- Net land use change, Total respiration and fire, Volcanism
- Fossil fuels burning (coal, oil, gas) and cement production

OCEAN
40453 +155 ±30

VEGETATION
450-650
-30 ±45

SOILS
1500-2400

FOSSIL FUEL RESERVES
1002 to 1940
-365 ±30

PERMAFROST
~1700

(Modified from Ciais et al. 2013, Fig 6.1.)
Research Questions:

1) What are the aboveground carbon densities for different land cover types in the Taita Hills according to field measurements, airborne laser scanning data and land cover classification?

2) What is the effect of land change on carbon stocks in the Taita Hills based on carbon density data and land cover maps from 1987, 1992, 2003 and 2011?
Indigenous forest

Exotic plantations

Introduction  Background  Material & Methods  Results  Discussion  Conclusion
Background

Introduction  Background  Material & Methods  Results  Discussion  Conclusion

Cropland

Grassland  /  Shrubland  /  Thicket
**Material & Methods**

- **Field measurements**: Jan/Feb 2014
- **LiDAR point cloud**: Feb 2014
- **SPOT 4 Satellite image**: 23 Oct 2011

**Steps**:

1. **Biomass/plot**
2. **LiDAR features**
3. **Regression models**
   - Predict biomass
   - 2013 Sentinel
   - 2014 Lowland Biomass map
4. **Average biomass to carbon**
   - 1987
   - 1992
   - 2003
   - 2011 Carbon density map
5. **Impact of land change on carbon stocks**
6. **Change detection (land cover)**

**Sub-processes**:

- **Preprocessing**
- **Segmentation**
- **Classification**
- **Accuracy assessment**
Material: overview

Field Data
- Sample plots 2013
- Sample plots 2014
- Additional forest plots 2014

ALS data
- Lowland area
- Sentinel site

Land Cover data
- Land cover map extent
Radius 17.84 (0.1ha)

**Field data**

*Trees with dbh > 10cm:*
- Tree species
- Diameter at breast height (dbh)
- Tree height (subsample)
- Land cover class

**Introduction**

**Background**

**Material & Methods**

**Results**

**Discussion**

**Conclusion**
Airborne Laser Scanning (ALS)

Introduction

Background

Material & Methods

Results

Discussion

Conclusion
ALS data

- Field plot 2014
- Canopy height (m)
  - High: 17.84m
  - Low: 0

Plot 2.1

- Introduction
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- Conclusion
Biomass mapping with field data and ALS data

Area based approach

(see for example Næsset 2002, Maltamo et al. 2014)
Plot-level biomass in the lowlands
Linear model for predicting biomass

- Plot-level biomass measurements and statistical features from ALS data was used to construct a linear regression model for predicting biomass.
- The best model had two explanatory variables: SD of Laser Scanning return heights and 60% percentile of height values ($R^2 = 0.90$).
Existing biomass map used for retrieving carbon densities for highlands

Heiskanen et al. (2014)
Biomass map for the lowland site

Aboveground biomass (Mg/ha)
- 18.39 - 204.79
- 10.3 - 18.38
- 2.2 - 10.29
- 0.01 - 2.19
- 0

Introduction  Background  Material & Methods  Results  Discussion  Conclusion
Satellite imagery

Sensor: SPOT 4 HRVIR
Date: 23 Oct 2011
Resolution: 20m x 20 m

4 Spectral bands
Green (0.50 - 0.59 µm)
Red (0.61 - 0.68 µm)
Near Infrared (NIR) (0.78 - 0.89 µm)
Mid-Infrared (MIR) (1.58 – 1.75 µm)

Cloud cover: ~4 %

Clouds filled with SPOT 4 image from Sep 2008 (Itkonen 2012)
Satellite image classification

Introduction | Background | Material & **Methods** | Results | Discussion | Conclusion

- SPOT 4 Satellite image 23 Oct 2011
- Preprocessing
- Segmentation
- Classification
- Fill Clouds
- Accuracy Assessment
- Land cover map 23 Oct 2011
Classification

Object-based classification
Manual editing

Based on:
Spectral properties
Thresholds
Object-relationships
Land Cover map 2011

Overall accuracy 71.1 %
Land Cover change 1987 - 2011

- Burned Area
- Water
- Bare Rock
- Bare Soil & Built up areas
- Grassland
- Broadleaved Forest
- Plantation Forest
- Woodland
- Thicket
- Shrubland
- Cropland

<table>
<thead>
<tr>
<th>Year</th>
<th>Burned Area</th>
<th>Water</th>
<th>Bare Rock</th>
<th>Bare Soil &amp; Built up areas</th>
<th>Grassland</th>
<th>Broadleaved Forest</th>
<th>Plantation Forest</th>
<th>Woodland</th>
<th>Thicket</th>
<th>Shrubland</th>
<th>Cropland</th>
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<td>42.8%</td>
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1987 - 2011

Introduction  Background  Material & Methods  Results  Discussion  Conclusion
### Table 17. Most extensive classes in the change map between 2003 and 2011.

<table>
<thead>
<tr>
<th>Area_ha</th>
<th>Class in 2003</th>
<th>Class in 2011</th>
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<tr>
<td>1103</td>
<td>Woodland</td>
<td>Cropland</td>
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</table>
Impact of land change on carbon stocks

![Graph showing the impact of land change on carbon stocks over different years and land types.](image)

- **Year:** 1987, 1992, 2003, 2011
- **Aboveground carbon (Tg):** 0.000 to 0.160
- **Land types:**
  - Cropland < 1220 m
  - Cropland > 1220 m
  - Shrubland
  - Thicket
  - Woodland
  - Plantation forest
  - Broadleaved forest
Highest carbon densities for broadleaved forests but their coverage is small.

Carbon is stored also outside forests - Small trees are excluded from the results.

Difference between croplands > < 1220 m a.s.l.
Total carbon stocks decreased between 1987, 1992, 2003

Increase in carbon stocks was observed in 2011

More croplands, less thicket and shrublands $\rightarrow$ less carbon

Fluctuations in woodland, plantation forests and broadleaved forests – real change or classification error?
Conclusion

Carbon densities were mapped in the region of the Taita Hills.


Stocks increased in 2011 (?)

Accuracy of changed areas should be further verified.

For a full understanding of the ongoing land change processes and their impacts on carbon stocks, and the consequent effects at different scales, an interdisciplinary approach is needed.