Monitoring and quantifying the impact of forest degradation associated to charcoal production in sub Saharan Africa through the integration of medium, high and very high-resolution remote sensing data and field-based information

Fernando Sedano[1], Natasha Ribeiro[2], Almeida Sitoe[2], Compton Tucker[3], Ritvik Sahajpal[1], Laura Duncanson[1], and Sa Lisboa[2]

[1]University of Maryland
[2]Eduardo Mondlane University
[3]NASA Goddard Space Flight Cen.

November 21, 2022

Abstract

Urban population in sub Saharan Africa (SSA) is rapidly growing. While only 30% of its population lived in urban centers in 2000, this figure will reach 60% by year 2050. Urban energy demand is closely tied to forest degradation. Charcoal is the main source of cooking fuel for eighty percent of African urban households and its overall consumption is expected to rise by 2040. Charcoal production is already the main driver of forest degradation in SSA. REDD+ guidelines encourage countries to identify and describe individual activities and drivers causing forest degradation as an initial step to define suitable methods for measuring and monitoring and formulate appropriate strategies and policies. Yet, forest degradation associated to charcoal production remains largely under reported. Charcoal production results in partial removals of forest cover that do not necessarily involve significant variations of the spectral signal. As a consequence, efforts to monitor forest degradation associated to charcoal production with medium resolution data has proved elusive. We present initial results of our effort to monitor and quantify carbon emissions from forest degradation due to charcoal production in SSA. Our work combines time series of multi sensor medium (20 – 30m), high (2m) and very high (0.5m) spatial resolution sensors with field data to characterize the spatial and temporal dynamics of charcoal production in charcoal production sites across SSA. The integration of these datasets provides the means to map, monitor and measure charcoal kilns, and subsequently quantify the magnitude and intensity of aboveground biomass removals associated to charcoal production at a level of detail and precision not reported previously. Our initial results reveal that charcoal production accounts for a larger share of greenhouse gas emission than previously reported, highlight its negative impacts on the ecosystem, and question the long-term sustainability of charcoal production under current and future urban energy demands. This work is a first step towards the development of a monitoring, reporting and verification system specific to forest degradation in the SSA context.

Monitoring and quantifying the impact of forest degradation associated to charcoal production in sub Saharan Africa with medium, high-resolution remote sensing data and field-based information.

Fernando Sedano (fsedano@umd.edu)[1], Sa Nogueira Lisboa [2]; Almeida Sitoe [2]; Natasha Ribeiro [2]; Laura Duncanson [1]; Ritvik Sahajpal [1]; Compton Tucker [5].
[1] University of Maryland – Goddard Space Flight Center, MD, USA; [2] Universidade Eduardo Mondlane, Maputo, Mozambique– Maputo, Mozambique; [5] – NASA - Goddard Space Flight Center, MD, USA.

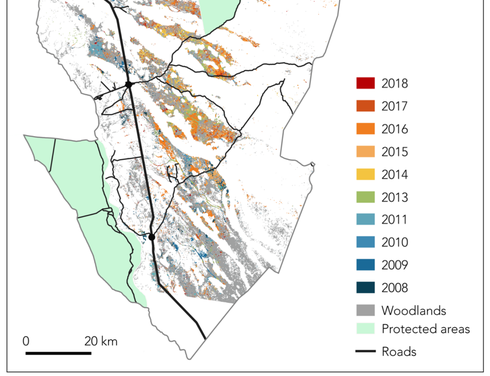
SUMMARY

Urban population in sub Saharan Africa is rapidly growing. While only 30% of its population lived in urban centers in 2000, this figure will reach 60% by year 2050. Charcoal is the main source of cooking fuel for eighty percent of African urban households and its overall consumption is expected to rise by 2040. Thus, urban energy demand is closely tied to forest degradation.

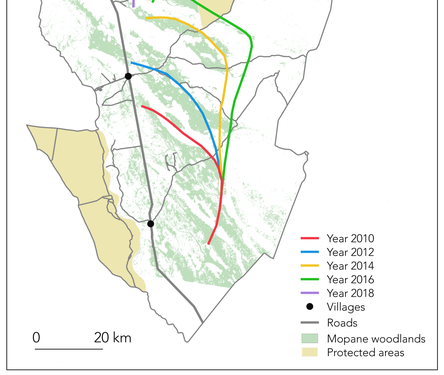
Charcoal production is already the main driver of forest degradation in sub Saharan Africa . REDD+ guidelines encourage countries to identify and describe individual activities and drivers causing forest degradation as an initial step to define suitable methods for measuring and monitoring and formulate appropriate strategies and policies. Yet, forest degradation associated to charcoal production remains largely under reported.

We combine historical Landsat data, multitemporal high resolution imagery and field data to characterize and quantify the spatial and temporal dynamics of forest degradation associated to charcoal production in the main production area for Maputo, Mozambique. This work is a first step towards the development of a monitoring, reporting and verification system specific to forest degradation in a sub Saharan Africa context.

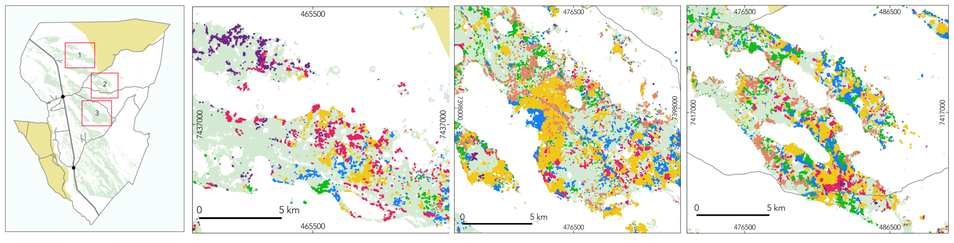
This study is part of the 'Forest degradation driven by charcoal production: characterization, quantification and forecasting to improve carbon monitoring systems in southern Africa' project and it is supported by from NASA Carbon Monitoring System (16-CMS16-0041).



Evolution of forest degradation from charcoal production in the district of Mabalane from historical Landsat imagery during the period 2008 to 2018.



Forest degradation frontier in the district of Mabalane during the period 2008 to 2018.

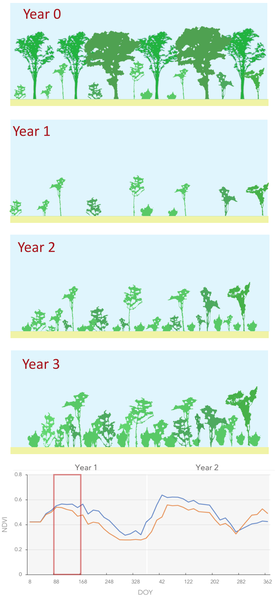


Detail of evolution of forest degradation from charcoal production in three sites of the district of Mabalane during the period 2013 to 2018.

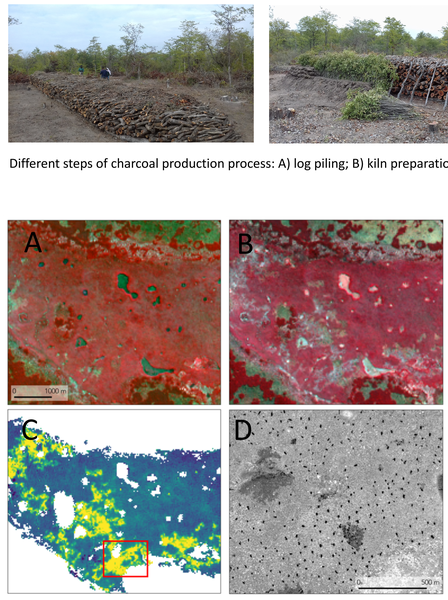
2013 2014 2015 2016 2017 2018 Woodlands Road

METHODOLOGY

Charcoal production involves a selective removal of trees within a certain area that leaves clear-cuts at small spatial scales. This partial removal of trees does not necessarily result in significant variations of the spectral signal at medium spatial resolution. Moreover, the remaining vegetation and the rapid tree regeneration maintain a mostly vegetated surface.
We have analyzed pre and post disturbance spectral signals to identify the most suitable acquisition window to map charcoal production areas. We used historical Landsat imagery to monitor forest degradation from charcoal production during a ten-year period (2008 – 2018)., applying a change analysis approach on cloud free NDVI images from consecutive years from the selected acquisition window.
Simultaneously we combined supervised learning and image processing morphological operations on the multitemporal high resolution dataset (0.5 – 2 m) to identify the location and dimensions of kilns in the charcoal production areas. Together with field information on kiln volumes we quantify the magnitude and intensity of aboveground biomass removals associated to charcoal production at a level of detail and precision not reported previously.

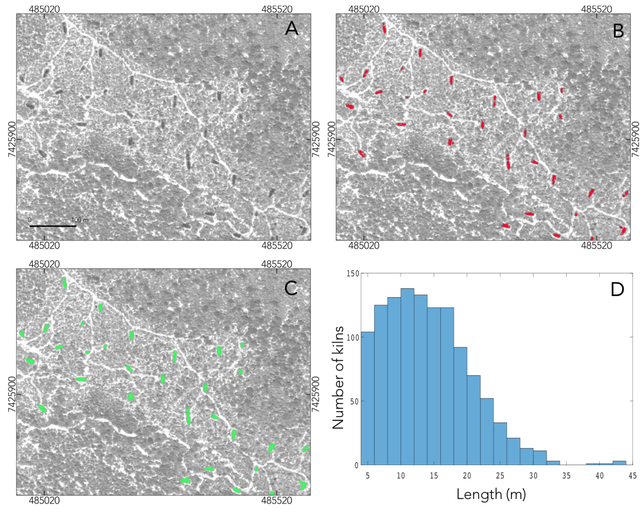


Pre and post charcoal production vegetation sequence in mopane woodlands. Also, NDVI phenological curves for charcoal production site (Orange) and undisturbed mopane woodlands (Blue).

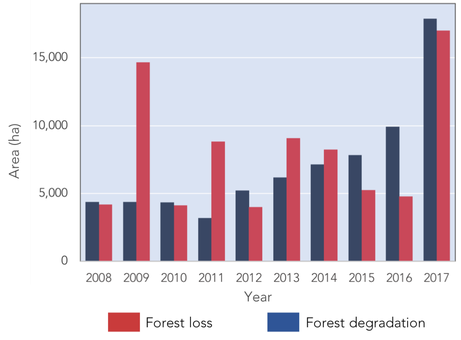


Mapping forest degradation from charcoal production. False color (854) Landsat 8 images for 2013 (A) and 2014 (B); C) NDVI variation associated to charcoal production; D) Panchromatic very high resolution image (0.5 m). © 2014 DigitalGlobe, Inc. Licensed under NextView.

Different steps of charcoal production process: A) log piling; B) kiln preparation; C) kiln burning; D) Charcoal sacks.



Subset of study area: (A) high resolution (2 m) NIR image; (B) kilns detected via supervised learning; C) kiln dimension extraction via morphological analysis of panchromatic very high resolution image (0.5 m); D) distribution of kiln lengths extracted from very high resolution image. © 2014 DigitalGlobe, Inc. Licensed under NextView.



Annual forest loss (Hansen et al., 2013) versus forest degradation from charcoal production extent. The graphic shows that forest degradation in Mabalane district is comparable to annual forest loss in the much larger area of southern Mozambique (provinces of Gaza and Maputo).

CONCLUSIONS

The findings of this work improve our understanding of spatial and temporal dynamics of forest degradation associated to charcoal production, questioning the long-term sustainability of charcoal production in sub-Saharan Africa under current and future urban energy demands.

Forest degradation from charcoal production can become the main driver of forest cover change. While charcoal production may take place at relatively localized areas, its contribution to forest cover change area and carbon emissions are relevant at larger geographical scales. Our initial results reveal that charcoal production accounts for a larger share of greenhouse gas emission than previously reported.

This work highlights the importance of developing charcoal specific monitoring strategies in the context of REDD monitoring, reporting and verification efforts as a first step to reduce carbon emissions uncertainties in sub Saharan Africa.