FUELWOOD EXTRACTION INTENSITY DRIVES COMPENSATORY REGROWTH IN AFRICAN SAVANNA COMMUNAL LANDS

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Supporting Information

Supporting Figure

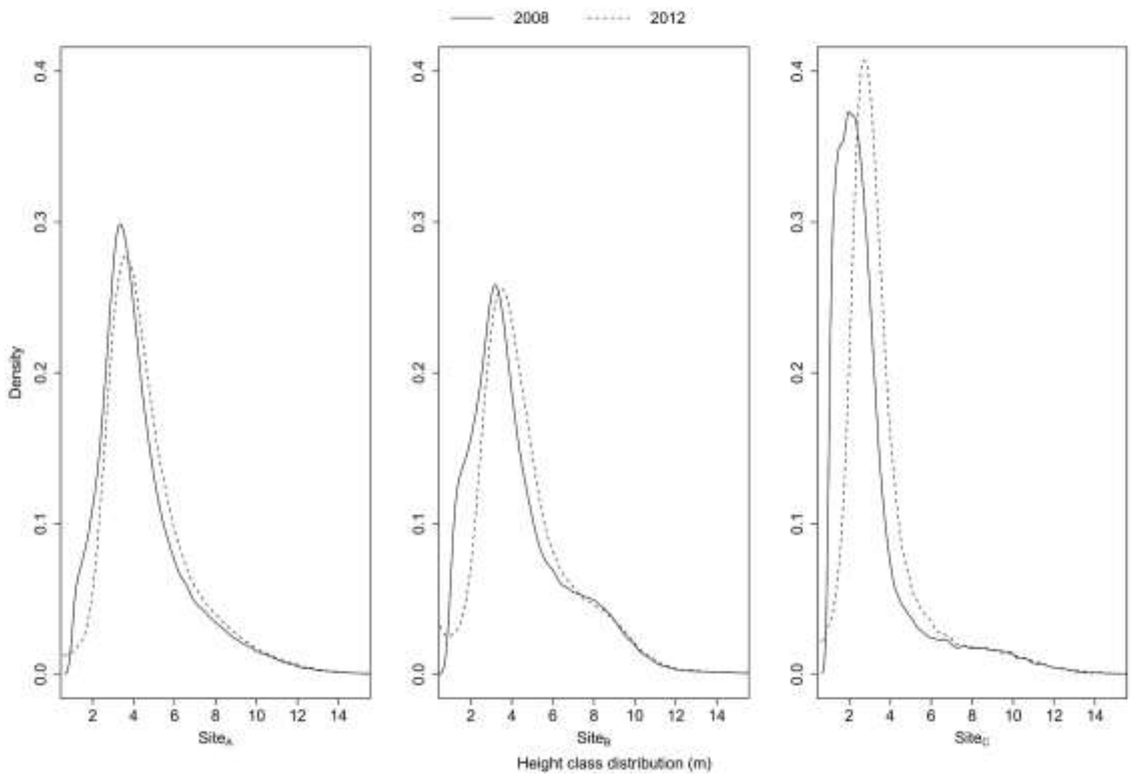

Figure S1. Change in woody height class density distribution in Site$_A$, Site$_B$, and Site$_C$ savanna communal lands in 2008 and 2012. Vegetation entering the >1 m height threshold for identification in 2012 were not included.

Supporting Table

Table S1. Household and population data for Bushbuckridge settlements in 2008 and 2012, including % change since 2008. Select villages from each site were chosen on the basis of data availability ($Site_A$: Xanthia. $Site_B$: Justicia A, and $Site_C$: Ireagh B). Data are from MRC/WITS Rural Public Health and Health Transition Research Unit (Agincourt).

Settlement	Households			Population		
	2008	2012	change (%)	2008	2012	change (%)
Xanthia	760	855	12.5	4180	4532	8.4
Justicia A	1190	1381	16.1	6329	7016	10.9
Ireagh B	386	454	17.6	2411	2622	8.8

Supporting Methods S1

a) Light Detection and Ranging (LiDAR) data collection

CAO-Alpha and CAO-2 AToMS - flown in 2008 and 2012, respectively - operated on a laser pulse repetition frequency of 50 kHz and 100 kHZ, respectively per mission, with achieved point spacing of 4 hits m^{-2} (for technical details see Asner *et al.* 2007, 2012). Both systems had integrated Global Positioning System-Inertial Measurement Units (GPS-IMU) providing each laser point with accurate locational data, producing a 3-D point cloud of LiDAR data (Asner *et al.* 2007). The LiDAR point cloud was processed to identify first (top-of-canopy) and ground LiDAR returns using the 'lasground' tool in LAStools software (Isenburg 2014). LiDAR uncertainties were <0.20 m vertically and <0.36 m horizontally with crown height validation of <0.7 m error (Asner *et al.* 2009). As errors are not compounded, difference between the surface models was <15cm (Asner & Levick 2012).

b) Justification for height class delineation

The vertical vegetation profile was divided into ecologically-relevant height classes for biomass, voxel and tree object data: 1-3 m shrubs and small trees in the 'fire trap' (e.g. Bond & Keeley 2005), but also form part of the coppice regrowth height class (Mograbi et al. 2015); 3-5 m trees in the 'elephant trap' (e.g. Asner & Levick 2012) but also a height class that is important to rural households (Paumgarten et al.

2009); 5-10 m tall trees which contribute to ecosystem functioning (e.g. Dean et al. 1999) and are valuable to people as non-timber product sources (Shackleton et al. 2003); and very tall trees >10 m acting as ‘keystone structures’ in savannas where their relatively small area occupied contributes disproportionately to ecosystem functions, often filling unique functional roles (Tews et al. 2004; Manning et al. 2006).

c) Data analysis - environmental and anthropogenic variables

The relative elevation model (REM) was the “normalized height” product generated using the “terrain analysis” toolset in SAGA GIS v2.0.6. (Conrad *et al.* 2015) using the LiDAR-derived digital terrain model (DTM) as an input, with 0=lowlands and 1=uplands. Distances from the nearest river, road and settlement were generated using the “Near” tool in ArcGIS v10.2 (ESRI 2012). Fire data were derived from monthly MODIS burned area products (MCD45SA1-V051; 500 m resolution) using R v3.2.1 (R Core Team 2013; packages: ‘sp’ (Pebesma & Bivand 2005), ‘rgdal’ (Bivand *et al.* 2017), ‘raster’ (Hijmans 2017)). Fire data were interpreted as binary burned/unburned and summed (i.e. number of burns) between June 2007 and March 2012. Contour plot interpolations were performed using the ‘akima’ package (Akima & Gebhardt 2016) in R v3.2.1. (R Core Team 2013) to unpack height-specific biomass in relation to sub-canopy structure changes. Contour plots were used to graphically represent vegetation dynamics in relation to distance from the nearest road or settlement. Fuelwood studies have shown that most collection occurs between 1-1.5 km from the settlement as wood is carried in bundles or in wheelbarrows (Shackleton *et al.* 1994, Giannecchini *et al.* 2007). The growing use of vehicles to transport wood to collect and transport (Luoga *et al.* 2000; Twine *et al.* 2003) motivated the inclusion of distance from the nearest road as an anthropogenic variable in this study. The contour plot axes were limited to the maximum distances from roads and settlements that were present in the sites.

d) Data analysis – canonical correspondence analysis (CCA)

The CCA was performed using CANOCO v4.5 (ter Braak and Smilauer 2002) using manual forward selection and 999 Monte-Carlo permutations. Variables were added to the ordination model until at least 95% of the described variation was accounted for by variables’ conditional effects. Variables were also tested for their marginal effect to the data set independently, using a Bonferroni correction to maintain the model’s global type I error at $p < 0.05$ (Rice 1989; Cabin & Mitchell 2000). Variables that were non-significant in marginal effects but contributed substantially to conditional effects were kept in the model but displayed as non-significant variables in graphical outputs (see greyed out arrows in Figure 3). Co-linearity was present between sites and geology as each site was dominated by one type of geology, but both variables were kept in the model as there was still some separation between site and geology (Figure 3a). The exception is the low use communal land where geology as a variable was removed as the site is located solely on granite. To examine separate effects on vegetation structure dynamics between site and geology, models were run with site and geology, only site, and only geology. Models without site had low explanatory power (all sites combined: 10% variance explained). Without geology the models were almost identical in ordination axes display to the site and geology model (Figure 3a), but had lower explanatory power (all sites combined: 19%). Thus, the combination of both site and geology in the models had the best explanatory power, with site as the predominant explanatory variable.

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