WOODY VEGETATION DYNAMICS IN AFRICAN SAVANNA COMMUNAL LANDS

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Research Rationale and Questions:

Humans are an ancient part of savanna structure, yet are seldom explicitly considered as determinants of woody cover in savannas. Today savannas are under vast land-use pressure with a third of livestock and crop farming occurring in savannas globally. Millions of people in Africa rely on woody vegetation for energy, extracted from both communal and protected areas. Within southern Africa, South Africa has a high per-capita use of fuelwood as a primary energy supply despite having substantial access to electricity (66% of national population). Within this context, 93% of current fuelwood demands are no longer met by the collection of dead wood. Thus, live wood harvesting occurs around settlements and is a major driving force in woodland degradation in semi-arid ecosystems in southern Africa, particularly in the South African Lowveld savannas. Wood harvesting changes not only biomass, but also vertical stratification of vegetation, affecting ecosystem function and biodiversity. The focus of our research was to explore woody vegetation dynamics in communal lands along a natural resource usage gradient to assess the impacts of humans on savannas. This was done by monitoring changes in woody biomass, subcanopy structure and height-specific tree loss.

Research Highlights

- Using field-based validation and LiDAR canopy-height models (CHM), we derived biomass models which we could generalise across communal lands. The biomass maps were combined with changes in subcanopy information to assess which part of the vertical vegetation structure is contributing to changes in woody biomass.
- We demonstrate considerable aboveground woody biomass increases in communal rangelands despite fuelwood supply-demand model predictions of rapid decreases due to intensive fuelwood extraction. However, this is not necessarily indicative of woodland recovery as three-dimensional subcanopy data shows that the rapid biomass increases are all in the shrub layer (1-3m in height) (Figure A). Subcanopy biomass increases at lower heights are higher in communal rangeland with more wood extraction pressure. It is likely that wood harvesting acts as a 'bush thinning' mechanism, changing the size specific growth rates, particularly in resprouting from stumps with fully-developed root systems. We surmise that thick stands of small-stemmed trees can yield more woody biomass than a few large trees as a result of divergent size-specific growth rates. This work was published in *PLOS ONE* (Mograbi et al. 2015).
- Overall plot-based changes in woody biomass mask changes in individual plants over time. Using an automated object-based image analysis approach we monitored the change in height of >450 000 trees over 7000 ha. If maximum tree height over each canopy decreased by ≥75%, we termed it "treefall". This study was conducted over a variety of land uses, including areas in the presence or absence of two major savanna disturbance agents: humans and African elephants, *Loxodonta africana*. In most of Africa, there is some range overlap between humans and elephants, making drivers of treefall dynamics unclear. However, South Africa contains fenced elephants providing an opportunistic macroscale experimental opportunity to study vegetation dynamics in the presence or absence of humans and elephants.
- Previous exclusion studies on elephant-mediated treefall demonstrated that elephants fell trees at 6 times the background rate. In our study, elephants felled 5 times the background

rate, whilst human-mediated treefall was 2-4 times the background rate, depending on the intensity of natural resource utilisation (Figure B).

- Treefall was best predicted by the presence of humans or elephants, but was also affected by geology and fire frequency. Considering the synergistic relationship between fire and elephants in tree mortality, this was not a surprising finding. Elephant debarking of trees increases tree mortality through subsequent exposure to fire or borer damage. Humans also have an association with fire as they deliberately burn communal lands to increase grazing quality or crop-field clearing, leading to runaway fires. Human-mediated treefall was intensely localised, relative to elephant-mediated treefall, and mostly related to settlement expansion or crop-field clearing. This research is currently in preparation for publication in *Ecography.*
- The combination of gain in subcanopy shrubs and loss of tall trees in communal lands could result in a structurally simple landscape with reduced functional capacity.

Impact of the research on Tree Health

Our research showed, contrary to earlier thought, that woody biomass is increasing in communal lands. However, these increases are all low-height class increases. Whilst coppice regrowth may provide a valuable source of future harvestable biomass, there is little information on regrowth rates and response to continued harvesting, as well as whether the coppice is of appropriate quality for fuelwood. Nevertheless, the repercussions of bush encroachment/thickening in communal lands will have implications for the direct-use values of ecosystem goods and household vulnerability to shocks. Shrubland conversion and loss of tall trees are characteristics of both humans and elephants. Demonstrating that humans act as 'functional megaherbivores' is a useful perspective with which to view vegetation dynamics. We caution that the kind of ecosystem cascades that have been demonstrated with elephant-mediated vegetation research apply equally in human landscapes. Loss of tall trees does not necessarily lead to woodland decline. Elephant-associated shrubland conversion in Chobe, Botswana, facilitated impala population increase, leading to extensive tree seedling mortality through increased impala seedling herbivory. Similar scenarios are possible in human

landscapes where shrubland conversion favours goat keeping over cattle, which could also affect seedling recruitment. This research provides an easily implementable method of unravelling vegetation dynamics in a manner that would allow others in the fields of commons management, sustainable natural resource extraction and bush encroachment trends to relate. Two dimensional remotely-sensed biomass estimates do not capture subcanopy shrub changes or accurate vegetation height measurements, particularly in the context of structurally heterogeneous landscapes and increasing bush encroachment trends in semi-arid environments.

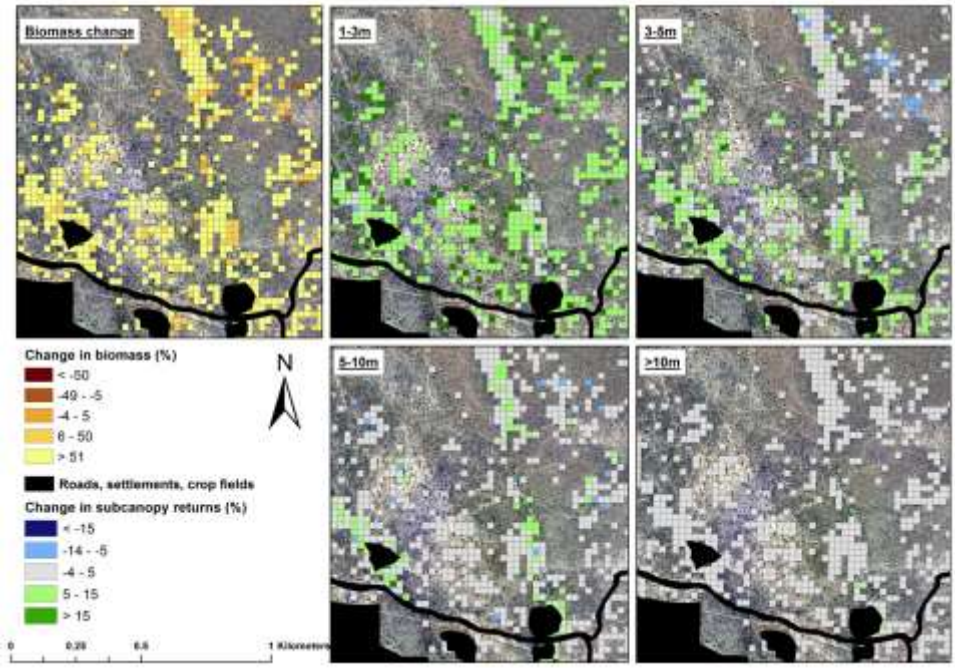

Figure A: Woody biomass changes (%) relative to height-specific change in subcanopy returns (%). Height categories are: 1-3 m, 3-5 m, 5-10 m and >10 m. (doi:10.1371/journal.pone.0127093.s005)

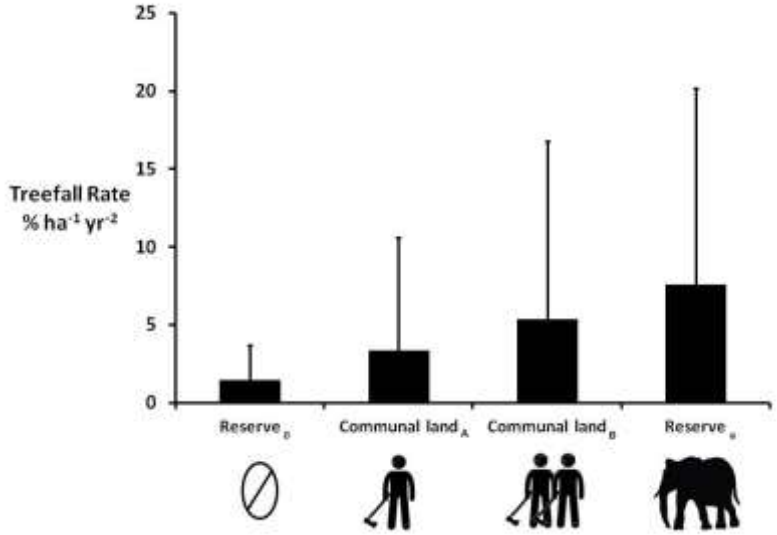

Figure B: Comparing treefall rates (% ha^{-1} yr^{-2}) ± SD over: $Reserve_0$, a nature reserve containing neither elephants nor humans; Communal $land_A$, a moderately utilised communal land; Communal $land_B$, a heavily utilised communal land; and $Reserve_e$, a private reserve containing elephants.

Research Outputs for 2015:

Articles in Peer-Reviewed Journals

Mograbi PJ, Erasmus BFN, Witkowski ETF, Asner GP, Wessels KJ, Mathieu R, Knapp D, Martin R, Main R. 2015. Biomass increases go under cover: Woody vegetation dynamics in South African rangelands. *PLoS ONE* 10(5):e0127093.

Fisher JT, Witkowski ETF, Erasmus BFN, Mograbi PJ, Asner GP, van Aardt JAN, Wessels KJ & Mathieu R. 2015. What lies beneath: Detecting sub-canopy changes in savanna woodlands using a 3D classification method. *Applied Vegetation Science* 18(3):528-540.

National Conference Presentations

Mograbi PJ, Witkowski ETF, Erasmus BFN, Asner GP, Mathieu R, Wessels R. Does size matter? Size-class specific growth rates in communal rangelands. 13th Annual Savanna Science Network Meeting. 8-12 March 2015. Skukuza, South Africa.

Mograbi PJ, Erasmus BFN, Witkowski ETF, Asner GP, Wessels KJ, Mathieu R, Knapp R, Martin R, Main R. Biomass increases go under cover: Woody vegetation dynamics in a communally utilized semi-arid savanna in Bushbuckridge, South Africa. 41st Annual Conference SAAB (South African Association of Botanists). 11-15 January 2015. Tshipise, South Africa.

International Conference Presentations

Mograbi PJ, Erasmus BFN, Witkowski ETF, Asner GP, Wessels KJ, Mathieu R, Knapp R, Martin R, Main R. Biomass increases go under cover: Woody vegetation dynamics in South African rangelands. 27th International Congress for Conservation Biology/4th European Congress for Conservation Biology, Montpellier, France. 2-6 August 2015.